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DOC. 22 311

CURRENT ISSUES IN THE HIGH-LEVEL WASTE PROGRAM

Center for Nuclear Waste Regulatory Analyses

March 9, 1993

Briefers: R. Bernero, NMSS
W. Patrick, CNWRA
B. Sagar, CNWRA

Contact: M. Knapp, NMSS
Phone: 504-3324

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STAFFING

- Planned Staff of 52
- Current Staff 49 Plus
  2 Limited Term
- Ultimate Staff of 54

SPENDING

- Current Underrun of 35%
  of CNWRA Funding

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- Analysis of Issues
  - Statement of Issues
  - Progress on Addressing
  - Outlook for Resolution

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- Iterative Performance Assessment
- Development of Analytical Capabilities
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- Prelicensing Interactions

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- Submodel and Model Validation
- Use of Early Site Characterization Data
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- Complete Rulemakings
- Performance Assessments

Samuel J. Chilk
October 29, 1981
Page 2

Thank you for the opportunity to comment on these proposed regulations.

Sincerely,

Nicholas D. Lewis
Chairman and
State Liaison Officer to the NRC

NDL:lm

cc: G. Wayne Kerr, Director, State Programs, NRC
Steven Excell, Office of the Governor
David Stevens, Office of the Governor
Alan J. Gibbs, Secretary, Department of Social and Health Services
John A. Beare, M.D., Director, Division of Health, DSHS
Richard Watson, Acting Director, State Energy Office

DOCKETED
USNRC

'81 NOV -3 P2:40

OFFICE OF SECRETARY
DOCKETING & SERVICE

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Engineers – Constructors

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October 27, 1981

37

PROPOSED RULE PR-60
(46 FR 35280)

Secretary of the Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch
Room 1121
1717 H Street, N.W.

Subject: Comments on 10 CFR Part 60, Proposed Rule for Technical Criteria: Disposal of High-Level Radioactive Wastes in Geologic Repositories

Gentlemen:

We appreciate the opportunity to provide comments on the proposed technical criteria for regulating geologic disposal of high-level radioactive waste. In general, we are pleased that the NRC is developing such licensing criteria; however, we continue to be disappointed that the proposed rule has not changed appreciably from an earlier version. As expressed previously, the EPA concept of a single, overall repository performance standard is preferred over the NRC's basic approach of applying several specific, subsystem performance standards. We firmly believe that reasonable assurance can be realized for complying with a single, overall performance standard for the total repository system through the use of current and proven engineering practices. Further, such a single standard will provide the basis for allowing flexibility in design for differing waste package and site specific characteristics, while protecting the public health and safety and the environment.

It is strongly recommended that the Commission substantially revise the proposed Part 60. As partial fulfillment of such revision, the specific numerical values proposed for subsystem performance standards should be withdrawn and a single, overall repository performance standard substituted in their place. With the preceding in mind, we would urge the Commission not to finalize this proposed rule until the EPA standard for geologic disposal of high-level radioactive waste, or a similar standard by some other regulatory authority, is promulgated.

Acknowledged by card 11/4/81 ramp

NUREG-0804
Part 3

Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories"

NUREG--0804

DE84 900591

Manuscript Completed: July 1983
Date Published: December 1983

Division of Health, Siting and Waste Management
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Secretary of the Nuclear Regulatory Commission
October 2[illegible], 1981
Page two

Attached are our general comments in response to several areas identified by the NRC for which further public comment was solicited, as well as our detailed comments on specific sections of the proposed Part 60.

We would be pleased to respond to any questions you may have concerning this submittal.

Sincerely,

Ashton J. O'Donnell

Ashton J. O'Donnell
Vice President

Attachments
cc: N. J. Palladino, Chairman
J. F. Ahearne
P. A. Bradford
V. [illegible]
T. M. Roberts

GENERAL COMMENTS
IN
RESPONSE TO THE AREAS IDENTIFIED
BY NRC FOR FURTHER PUBLIC COMMENT

The following perspectives address five of the six general areas which the NRC identified as subjects where particular comments are being sought. The perspectives presented herein are based on Bechtel's extensive engineering and construction experience in related activities that are applicable to geologic disposal of high-level radioactive waste. The following general comments are also based, in part, on the attached Detailed Comments on specific sections of the proposed Part 60.

1. The Commission seeks comments on alternative approaches to performance criteria:

   (a) The Commission seeks comments on the use of Alternative 1 which prescribes a single, overall system performance standard that must be met.

      We are of the firm view that Alternative 1 is the most appropriate of the three presented in the proposed technical criteria of 10 CFR Part 60. The fundamental reason for the selection of Alternative 1 is that this is a more realistic approach for utilizing the compensating benefits of both the engineered barriers and those provided by the geologic medium. Additionally, the application of Alternative 1 could realize important trade offs in the design of the repository components and subsystems for differing site specific characteristics. Further, Alternative 1 would be compatible with the approach of EPA and its application could prevent regulatory conflict. Thus, the application of Alternative 1 or a single overall performance standard for the repository will allow flexibility in design, while protecting the public health and safety and the environment.

   (b) If commentors favor Alternative 1, address ways in which NRC might find reasonable assurance that the ultimate standards are met without prescribing standards for the major elements of a repository.

      One can apply current and proven engineering practices -- coupled with a single, overall repository performance standard -- in providing reasonable assurance that after repository decommissioning, radioactive waste would be isolated for the protection of the public health and safety. The careful application of site investigation techniques can determine the characteristics of the geological setting as the first step in identifying potential and significant performance uncertainties that may reside in the geologic medium. These and other potential performance uncertainties can be reduced in importance and made inconsequential by conservative analysis and design that incorporates compensating design margins in the engineered and geologic medium barriers for differing site specific characteristics. Thus, the ultimate or single repository performance standard could be satisfied in a more flexible, practical and optimized manner — rather than the needlessly stringent approach of depending on one set of overly conservative standards for the subsystems or engineered barriers.

2. The Commission seeks comments on the degree to which 110-year requirement for retrieval will govern thermal and mechanical design of the repository and on whether some shorter period would be adequate or whether there are other ways than an overall retrievability requirement to preserve options before permanent closure.

   While the concept of retrievability may have merit for some geological settings and waste form descriptions, it is not necessary to specify a retrievability time period. Instead, a retrievability time period for a given set of circumstances should be based upon the time needed to verify repository performance, which will be site and design specific.

3. The Commission seeks comments on whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases.

   We believe the ALARA principle should not be applied to these requirements and that the discussion of ALARA should be removed from the Supplementary Information.

4. The Commission seeks comments on whether a population-related siting requirement should be included in the final rule and how they might be implemented.

   It is not necessary to include a population-related siting requirement in the final rule for 10 CFR Part 60. The relative risk to the public health and safety during the repository operational and decommissioning phases and beyond is likely to be substantially less than that for most types of nuclear facilities.

5. The Commission seeks comments on formulations for the design and construction criteria in the rule.

   There should be few, if any, components designated as "important to safety" related to the design and construction of the repository. Consequently, any formulations of such design and construction criteria should deal with safety principles and criteria to be incorporated in the design as opposed to design details that are more appropriately the subject of regulatory guides.

DETAILED COMMENTS

Section 60.2 - Definitions

1. The definition of "important to safety" uses the words "without undue risk to the health and safety of the public". Due to lack of specificity, this qualitative definition can cause considerable difficulty during the licensing review process.

   It is recommended that the definition be quantified to specifically apply to items essential to the prevention or mitigation of the consequences of operational accidents that could result in exceeding some defined radiological release or exposure limit. Utilizing 1/10 of the "accident dose limit" stipulated in 10 CFR 72, 0.5 rem to the whole body at the site boundary may be appropriate for such a limit for a geologic repository.

   In addition, the definition of "important to safety" should include engineered items and site characterization activities which are important for assuring the long term isolation of the waste from the human environment, e.g., the waste package and activities that are necessary to verify certain characteristics of the geologic setting.

2. The definition of "TRU waste" should be more specific since if spent fuel was defined as a waste form, it could be classified either HLW or TRU waste in these proposed regulations. In addition, the activity level defined for TRU waste (10 nanocuries per gram of alpha radiation) is extremely low to require its disposal in the same manner as HLW (see e.g. 60.111) and, in fact, is a factor of 10 below the specific activity defined for TRU by the EPA in Draft 19 of 40 CFR 191. We recommend, therefore, that the TRU definition be reconsidered in view of the stringent requirements imposed by this rule. As an alternative, TRU disposal could be removed from the consideration by this rule and subsequently treated by future regulations.

Section 60.21 - Content of Application

3. 60.21 (c) (3) - This paragraph requires the Safety Analysis Report to include "a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation". Comparative evaluations of this type are not appropriate for safety analyses which should be directed at the specific design being proposed and the safety requirements it must satisfy. Furthermore, on what basis would such an evaluation be assessed by the NRC — cost, safety, reliability, environmental impact? We recommend this requirement be deleted.

4. 60.21 (c) (13) - This paragraph requires an evaluation of resources, including "undiscovered deposits", for the disturbed zone and for areas of a similar size in the geologic setting. The determination and specificity of "undiscovered deposits" is a complex and highly variable process for different prospective sites, and estimates by "reasonable inference based on geological and geophysical evidence" present an argumentative situation at best. What is the purpose of considering "areas of a similar size", how many should be considered, and at what depths? We recommend this paragraph, 60.21 (c)(13), be removed.

Section 60.111 - Performance Objectives

5. 60.111 (a) (1) - This section specifies exposure or release limits during normal operation but does not specify limits for operational accidents. To be consistent with 10 CFR 72, the following "accident dose limit" is suggested for inclusion in this section:

   "The dose to any individual located at or beyond the site boundary during the facility operations period shall not be greater than 5 rem to the whole body, or to any organ, from any design basis accident."

6. 60.111 (a) (2) - This performance objective requires that the repository be designed so that the entire inventory of waste can be retrieved starting at any time up to 50 years after waste emplacement operations are complete. Enclosure (J) to SECY-81-767 makes it clear that this requirement does not preclude backfilling or sealing the mined openings during the retrievability period; however, this is not made clear by the body of the proposed rule. This clarification should be added.

   Furthermore, we believe it is preferable to delete the retrievability time period since this period should be based upon the time needed to verify repository performance, which will be site and design specific. In this regard, we support the NWTS position on retrievability as described by W. A. Carbiener at the ANS Topical Meeting, Waste Management '81, in Tucson, Arizona, February 23-26, 1981.

7. 60.111 (b) - The EPA draft regulations contained in 40 CFR 191 and the assessments on which they are based are limited to releases of radionuclides to the accessible environment for a period of 10,000 years after disposal. During deliberations on 10 CFR 60 prior to its release for public comment, the Commissioners indicated that this same limitation should apply to the performance requirements of 10 CFR 60. This limitation should be stated explicitly within the

body of the final rule. Furthermore, if consequence analyses are to be performed for periods beyond 10,000 years, this requirement should also be stated and the time frame for such analyses should be indicated.

8. 60.111 (b) (2) - In a footnote to this paragraph, the Commission requests comments on whether an ALARA principle should be applied to the performance requirements dealing with containment and the control of releases. We believe the ALARA principle should not be applied to these requirements and that the discussion of ALARA should be removed from the Supplementary Information for the following reasons:

   (a) It is not evident that improving upon the stated performance requirements for waste-package containment and control of releases would have any significant effect on further enhancing overall system performance,

   (b) If the currently proposed overall system performance requirements are met, the risks to public health and safety will be so low as to be inconsequential, and thus, expenditure of additional effort to further reduce the risk would be unwarranted, and

   (c) There is no basis for determining whether ALARA has been achieved, consequently, individual judgment would have to apply which could lead to endless and futile debate between the parties concerned.

9. 60.111 (b) (2) - The engineered system performance requirements of this section are applied in an almost equal manner to TRU wastes as they are to HLW. This does not seem appropriate based upon the very large difference in hazard potential between these two waste forms. We recommend, therefore, that TRU be removed from consideration in this proposed rule, and handled separately by future regulations.

10. 60.111 (b) (2) - Based upon the detailed ONWI studies of engineered barriers reported in PNL-3356 and PNL-SA-9926, it is not evident that the subsystem performance objectives specified in this paragraph do much, if anything, to enhance overall repository performance. These studies show that, even in view of the uncertainties inherent in the analyses,

   (a) There is, in effect, no change in repository performance when the waste package release rate is reduced from 10^{-3}/yr to 10^{-5}/yr,

   (b) A containment period of 1000 years has no significant effect on dose reduction; rather, a containment period of greater than 100,000 years would be required to accomplish this, and

   (c) For a properly chosen deep repository site, any radionuclide release to man's environment is expected to take in excess of 10,000 years.

As pointed out by the authors of PNL-3356, these results should be viewed with the "realization that the analysis tends to maximize both the incentive for, and the resultant effectiveness of, the engineered barriers in the context of the overall repository system".

In addition, the NRC does not provide a valid justification for these subsystem performance objectives with the arguments presented in Enclosure (J) to SECY-81-287. For example, the NRC states that the 1000-year containment requirement is necessary to protect against the possibility of an accelerated release from the disturbed zone into the far field due to elevated temperatures in proximity to the waste package during the first 1000 years after waste emplacement. However, no analyses are provided to show that a zero release from the waste package during this time period is necessary, or even beneficial, to meeting the overall system performance objectives. Furthermore, the NRC does not appear to recognize that temperature effects, should they be important, will be a function of waste emplacement density, repository design, and host rock characteristics, and thus, are site and design specific.

For these reasons, we believe the numerical subsystem performance objectives given in this section of the proposed rule should be deleted.

<u>Section 60.112 - Required Characteristics of the Geologic Setting</u>

11. 60.112(c) - The acceptability of the requirement for a 1000-year groundwater travel time is strongly dependent upon the definition of "accessible environment". If the definition in 60.2 is interpreted to have the same meaning as the definition currently under consideration by the EPA in Draft 19 of 40 CFR 191 (which could locate the accessible environment at a potential well location 1 mile from the repository), then the 1000-year requirement is overly restrictive and could rule out many excellent sites. On the other hand, if "accessible environment" applies to only aboveground land or water surface areas and "large", "readily accessible" underground sources of drinking or irrigation water, then the 1000-year requirement may be appropriate, though this can only be determined by evaluation of

the overall repository system. We recommend deletion of this requirement since, again, it represents a subsystem characteristic which needs to be considered in view of total system performance on a design and site specific basis. However, if this requirement is retained, a more precise definition for "accessible environment" is needed than is given in paragraph 60.2, and a justification for the 1000-year duration should be provided.

Sections 60.130 through 60.134 - Design and Construction Requirements

During repository operations, there are expected to be few, if any, credible accidents that can result in significant radiological exposure to off-site personnel. Consequently, there should be few, if any, components designated as "important to safety". For this reason, it should not be necessary for Sections 60.130 through 60.134 to deal so extensively with design and construction requirements for items "important to safety" that will not be present or functional after the operations period has passed.

Furthermore, many of the proposed requirements for these sections tend to prejudge the final repository design and are presented at a level of detail that goes far beyond that which is normally included in Title 10 regulations. Some examples of requirements that fall into this category are contained in 60.130 (b)(4)(iii) and (iv), 60.130 (b)(5)(vi), 60.130 (b)(6)(iii) and (iv), 60.131 (a), 60.132 (c)(2), 60.132 (d)(1), 60.132 (d)(3)(v), 60.132 (f), 60.132 (g), 60.132 (h)(2) and (4), 60.132 (j)(1), and 60.133 (c).

For the reasons expressed above, we recommend that the design and construction requirements be considerably shortened and simplified. They should deal with safety principles and criteria to be incorporated in the design as opposed to design details that are more appropriately the subject of regulatory guides.

DOCKETED
USNRC

'81 NOV -3 P2:

emf

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

B. R. McElmurry
6000 Moongate Drive
Rancho Palos Verdes, California 90274

October 28, 1981

(58)

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

USNRC
Secretary of the Nuclear Regulatory
Commission, Washington, D.C. 20555

Attention: Docketing and Service Branch

Gentlemen:

As a professional chemical engineer in the state of California, I offer the following comments regarding the proposed 10 CFR 60 rule as published in the Federal Register for Wednesday, July 8, 1981:

This proposed regulation is flawed in several ways. Basically, it does not recognize the existence in nature of numerous naturally radioactive soils and regions in which there is a history of unlimited human use for many generations. Such areas include China, India, France, South America, and several districts within the United States. There is not, and can never be, a sound basis for requiring repositories to perform better than nature. I know of no instances where people have been required to evacuate an area because the natural background is too high.

Specifically,

1. The requirement for retrievability beyond the filling of the repository is superfluous. The containers and the geology are designed to immobilize the waste, and it can always be recovered by mining techniques. In the interest of security the repositories should be sealed as soon as possible.

2. In all cases, the setting of a single overall performance standard for waste confinement is the preferred approach because it allows for future technological improvement (page 35283, alt. 1). Specifying criteria for each component will rule out any system with different and perhaps superior components.

Acknowledged by card. 11/4/81 emf

3 Population siting requirements [illegible] are entirely superfluous. Geologic criteria should govern site selection, because no one knows what the population situation will be in 500 or 1000 years.

4 I cannot find any logic to support a 10 nanocurie/gram limit for the definition of TRU waste. As I understand it natural uranium or thorium ore may be 60-600, so that a limit of 100 might be reasonable. The limit maybe should be higher yet, because no one is restricted from entry into natural regions where soil activity is still higher. Furthermore, NUREG/CR-1005 suggests that shallow land burial of up to 22500 nanocuries per gram of Pu239 is acceptable for shallow land burial. Severe restrictions of this sort must be based on toxicological data, not supposition. (Section 60.1)

5 The regulation subordinates the use of reason to the use of mathematical modelling, and the validation of models. The real selection criteria should be the positive identification of formations which are geologically stable and hydrologically isolated from the surroundings. No amount of effort at modelling can ever determine the future. (60.21).

6 The resource evaluations called for in 60.21.13 are not justified to the extent called for. Any resources discovered in the extensive testing should be reported, but it is futile to burden such a program with requirements for developing acceptable methodology for projecting the presence of unknown resources and unknown uses. Since repositories will occupy such an incredibly small portion of the land area of the United States, we should accept the small risk associated with the simpler approach.

7 The requirements of 60.51 relative to providing permanent markers are unnecessary, especially the part about providing foreign governments (Russia, No. Viet Nam?) detailed records. After 500 years or so, the waste is essentially harmless, so that should suggest the design life of a suitable marker.

8 In section 60.111, the retrievability requirement is undesirable. See paragraph 1 above.
Specification of performance requirement, beyond 1000 years is unwarranted, and probably unfeasible. Much data already shows the waste toxicity to be below that of natural ore somewhere around 500 years. Therefore, we should not be concerned if the waste is dispersed hundreds of meters below ground after 500-1000 years.

9 The discussion of "backfill" in Paragraph 60.132 appears superfluous, since no requirements for backfilling are stated. Further the most available and compatible backfill will be the material mined out to form the repository, and for environmental reasons this material should be returned to the repository to the maximum extent feasible.

I sincerely hope you can incorporate these suggestions into a revised regulation which will actually make it possible to proceed with the development of a repository. The ultimate effect of an overly restrictive regulation will be to assure that none of this waste is ever immobilized or buried. While it will always be impossible to set repository criteria sufficient to guarantee 100.0% containment forever, we are in far greater jeopardy of contaminating the biosphere thru our prolonged inaction than by any reasonable repository design that has so far been proposed.

B. R. McElmurry

B. R. McElmurry

BRM:bg

DOCKETED

'81 NOV -3 P2:53

-60
(46 FR 35280)

Secretary, U.S. Nuclear Regulatory Commission
Attention: Docketing and Services Branch
Washington, D.C 20555

Sir:

After reviewing your "Proposed Rule" published in the July 8, 1981 Federal Register on "Disposal of High-Level Radioactive Waste in Geologic Repositories", I have a few suggestions. The suggestions deal principally with theissues of site integrity since this was the greatest problem encountered by your predecessor, the Atomic Energy Commission. I had great difficulty understanding your proposed technical criteria since they appeared to be poorly organized and illogically developed. The development should have been written in a narrative sense i.e. based on a time scale or on a spatial hierachy. Therefore, I respectfully submit these few suggestions;

1. Provide an illustrative time scale and spatial diagrams in your "Concepts" section.

2. Place more emphasis on site investigations and assessments and less on modeling.

3. In your "Supplementary Information: Background" you state that "additional or alternative criteria may be needed to be developed for regulating disposal in the unsaturated or vadose". What do you mean by this? I would think that during construction and operation of the repository, the waste package would be "unsaturated" and for a long period of time following closure. The question of "resaturation" and possible movement of the chemically leached or diffused radioactive and/or toxic material I think should be addressed. For example the method by which the water gets from the surface to the "saturated" area and how the water moves back into the tunnels and shafts is very important.

4. I most strongly disagree with your multiple barrier philosophy. Didn't Lyons, Kansas teach you a lesson? From a pratical standpoint, it may sound good, but for the time spans and depths your are concerned with, the site is the most important issue. If DOE can do a good investigation of the site including all the critical parameters and processes, then the

4 (continued) repository's performance can be conservatively determined.

5. The section entitled " Role of the Site" illustrates your lack of confidence in the site by not mentioning the "systems approach" you and DOE had discussed in the IPG report.

6. The section on "Major Features of the Proposed Rule", 3. Siting Requirements, page 35284, discusses minimum groundwater travel times. From where to where? Does this have anything to do with the "accessible environment"? Why does the definition of "accessible environment", not mention groundwater and groundwater users?

7. Again in the same section, the question of siting requirements for population density or proximity to population centers has been opted for resource considerations. This appear to be a wise choice, however the "Proposed Rule" does not provide water resource siting criteria in enough detail to allow evaluation of acceptable versus nonacceptable site conditions. For example, sole source aquifers such as the one designated by the EPA for the Spokane, Washington area and projected water withdrawls for irrigation purposes should be discussed.

8. Provide a better definition of stability since it appears to be unenforceable in a licensing environment.

9. I recommend the following definition for "accessible environment" means that portion of the earth and its atmoshpere with which humans have routine contact, and includes the atomsphere, soil, mineral and water resources actively being developed, and surface water bodies.

10. Paragraph 60.112 requires "the geologic repository shall be located so that pre-emplacement ground-water travel times through the far field to the accessible environment are at least 1,000 years". What does this mean? I would recommend changing pre-emplacement to ambient conditions and require DOE to analysis how their construction, testing, and waste emplacement has affected the ambient conditions.

11. In your paragraph "60.122 Favorable Conditions", you fail to mention geomechanical stability in the host rock to allow for long periods of open shafts and boreholes. The confining pressures at that depth must be analysed before workers are sent down. Also very low water flow conditions and capability modest water flow conditions are necessary to prevent rock collapse and flooding in the shafts and tunnels.

12. The section on monitoring does not mention long-term monitoring and assessment for site conditions. Monitoring should include water and confining rock pressures. Rock tension, and release, moisture content, and release of gases from the fluid and rock are also necessary. Most important is monitoring to make sure DOE's early data and analyses are not a function of the conditions and the short time under which they were done.

13. I further recommend requiring DOE to collect monitoring data and analyzing it for 10 years prior to waste emplacement to be sure.

11. Finally, I highly suggest that NRC require DOE to complete all site investigations to include rock and water properties and conditions for all material between the surface and the host rock and laterally out for 1/4 mile prior to waste emplacement since retrieval may be compromised by naturally induced accidents i.e. flooding, roof collapse, and buckling of support pipes and supports.

Thank you for the opportunity to respond to your "Proposed Rule". I hope my suggestions can improve your licensing program.

Respectfully submitted,

M J Keeler

(40)

29 October 1981

DOCKETED

FROM: William J. Bryan III
2420 Lantern Lane
College Park, Georgia 30349 '81 NOV -3 P2:53

DOCKET FILE PR-60
(46 FR 3528)

TO: Secretary, U. S. N. R. C.
ATTN: Docketing & Service Branch
Washington, D. C. 20555

OFFICE OF SECRETARY DOCKETING & SERVICE BRANCH

SUBJECT: Storage and Usage of High Level, Radioactive, Short Life Wastes.

SOLUTION: #1. These products can be an asset! How? Heat! There is more than enough heat to produce electricity on a macro scale. The ideal situation for this would be to store these products in large, air-tight tanks with heat exchange coils in the soup. The heat produced will create steam, the steam will move turbines, and the turbines will power generators. This is a very broad outline; but, simplistic though it is, it will work.

REASONS FOR SOLUTION #1: The USSR found out what could happen if these type wastes were not properly cooled and contained; their underground storage areas suffered a disastrous BLEVE. (Boiling Liquid Expanding Vapor Explosion)

Geothermal power plants touted as a safe method of power production by 'environmentalists', use the heat from decaying radioactive isotopes in the earth's crust to heat water--latent heat in the earth's crust comes from radioactivity.

SOLUTION: #2. This solution ties in with Solution #1. Out of sight, out of mind can be translated to: invisible, crazy. These radioactive wastes have to be monitored! These radioactive wastes are radioactive! Redundant? Answer: Didactic. I do not have a college degree; but, I am continually appalled at the ignorance of scientists regarding radioactivity. Radioactive chemicals put out hydrogen gas, radon, helium, etc and change chemically as they transmute to other elements. Storage in stainless steel barrels is a waste of steel as this type of radioactive soup creates tremendous internal pressures, creates an extremely acid enviroment and the combination makes for a very short container life. (Twenty years ago I wrote a letter to the old AEC protesting stainless steel containment and the dumping of same into the ocean. Events since then have borne out my predictions when some of those old drums were dredged from the ocean and found to be leaking; some were leaking after only ten years.) Vitrification is better; but, flawed by the same problem, the nature of radioactive decay.

I could be very precise in this letter; but, the concept I have presented--radioactive wastes as an asset--is too alien for serious consideration. Eventually, the USSR, France or China will discover radioactive wastes. Can be a resource

Acknowledged by card 11/4/81 emp

William J. Bryan

Oct 31 – 81

PA

Docketing Service Branch
NRC
Wash, DC 20555

Re: 10 CFR PART 60
Disposal of HLW

(41)
[illegible] 60
(46 FR 35280)

Sirs –

Three comments:

1 – At least four areas of the country are now heavily contaminated with waste sites. Instead of opening more dumps, why not repair, improve and reinforce dumps already in existence?

2 – Would it be safe and/or feasible to use the sites of underground atomic tests as dumps?

3– Re: the proposed ALARA standard ("as low – or as long – as is reasonably achievable"). This sounds very much like a semantic cop-out.
What's "reasonable" in situations like this? Only near-perfection!
uncompromising
We propose/[illegible] – To highest/scientific standards.

Very truly

S Nemethy, Sec'y

DOCKETED
USNRC
'81 NOV -3 P2:53
amp
OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

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BRANCH

Rural Rt. 1
Box 17-2
Trinity, New Mexico 88003
November 1, 1981

Secretary
U.S. Nuclear Regulatory Commission
Washington, D C 20555

Attention: Docketing and Service Branch

Re: 10 CFR Part 60

(42)
[illegible] 60
(46FR 35280)

Gentlemen:

As industry spokesman I want to take issue with one part of the Federal Register Notice on 10 CFR Part 60: 60.130 (b) (8) "Criticality Control".

NRC has it backwards. The geologic repository should be designed so that criticality is reached as soon as possible. Let the heat of the waste melt the rocks. As it cools it will form an impenetrable glass. Your human intrusion problem will go away and you will be sure to meet the performance objectives for release rates and duration of the waste package (60.111).

Adam Baum
Industry Spokesman

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(43)

-60
(46 FR 35280)

452 Clermont Ave.
Brooklyn, N. Y. 11238
November 1, 1981

'81 NOV -3 P2:53

The Secretary of the Nuclear Regulatory Commission
Attention Docketing and Service Branch
Washington, D. C. 20555

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

SUBJECT: COMMENTS ON DRAFT PART 60

As requested, I am offering my comments on Draft Part 60. First, I would like to commend those members of your staff for their effort on this project. Given the monumental importance of the subject and the diversity of factors that must be considered, the development of regulatory guidelines in this area is, perhaps, one of the most difficult tasks the Commission has ever tackled. From my position as a reviewer and the contents of the draft, I can appreciate the effort. However, I cannot say that at this point we have hit the mark or even come close in any respect with providing adequate regulatory guidelines useful for licensing a high level waste repository or any other HLW disposal option. I have difficulty with just about every aspect of the regulation -- the format, the language used, the use of terms, the requirements, the information it provides both technical and procedural, and even with its utility. General and more detailed comments follow.

<u>General Comments</u>

1. I first must express my own personal view as to the utility of having a regulation for high level waste disposal, particularly a regulation which casts HLW disposal in the conventional review process. Given the uniqueness of the project (i.e., in terms of the few (if more than one) disposal options which in all practicality will be realized given political, social, environmental, scientific (especially geological) restraints; federal government ownership and operation; the monumental urgency in establishing long term HWL disposal solutions; and its impact on the nuclear option, and even defense), I must call to question the decision which has seemingly been made, as reflected by the draft regulation, that we will proceed to handle HLW disposal in the same manner as we have licensed conventional facilities. In my view, this is nothing short of ludicrous, of wasting government and public resources, of over-reaction on the part of government regulators to show the public we are doing our job in an open atmosphere. The project deserves more, much more, from us.

   Similarly, it must be realized that those agencies (e.g., NRC, EPA, USGS) which will be involved in the safety and environmental review are now working with DOE and DOE laboratories in coming to grips, in developing rational solutions, to the waste disposal problem. I believe this is the way it should be done. This combined concern--this combined tapping of a broad spectrum of government expertise--is essential. The Energy Reorganization Act states the NRC will participate in assisting ERDA (DOE) in resolving the waste disposal problem.

Acknowledged by card 11/4/81 emp

It is also somewhat ambiguous in that it states we will license ERDA (DOE) HLW waste. Thus, the Act although it split the functions of the AEC, still maintained a tie between agencies in dealing with HLW. Yet, this tie is not clearly expressed in the regulation. How will this be viewed by the public if we follow the usual review scheme as promulgated by this regulation, where we are supposedly conducting an objective review (when in fact we are involved with DOE now)? How will our credibility be viewed? It is a certainty cries will ring out that we are "all in bed together," that the licensing process is a sham.

Irrespective of my expressed view, I have tried to review the draft regulation as I review all documents presented to me for comment. In this case, I assume such regulations are a given and will be established.

2. As a whole, I find the language of the regulation difficult to comprehend; as such, I appreciate the statement that only the interpretation of the General Counsel is binding. The subject matter in the regulation touches upon a variety of disciplines, lawyers, administrators, engineers, scientists, hearing boards, etc. Surely, the language of the regulation can be simplified and "de-bureaucratized".

3. Because of the diversity of subjects included, I suggest a flow chart be developed highlighting the procedures and requirements and be incorporated as part of the regulation.

4. Throughout the regulation the term DOE is used. In the event of the imminent demise of DOE I suggest such words be striken and replaced with "responsible federal agency".

5. As I interpret the regulation, the body is applicable to any HLW disposal concept and Subpart E to the Deep Geologic repository option. The <u>Supplemental Information</u> statement should include some discussion of this and the development of additional regulations if other options become available.

6. From the title of Subpart E, it would seem that it would mostly concern itself with describing the physical parameters and requirements of establishing a geologic repository. I find it limited in this respect. Rather, it appears to mostly concern itself with matters which are applicable to any option for disposal, e.g., systems, components and structures; accounting for radioactive waste; ownership and control; quality assurance. All these factors could be incorporated (and appear to already be) in the main body of the regulation. I would limit the Subpart to <u>only</u> the factors unique to deep geologic repositories.

7. As I read the regulation, it would imply decommissioning is the state where the repository is filled in, and is thus in an irretrievable mode. It seems to imply that nothing further is required. Shouldn't we have requirements for long term observation (i.e., on the order of decades)?

8. I can appreciate the general nature of a regulation and the desire to develop details in regulatory guides, i.e., acceptable means of implementation and the like. Given the lack or incomplete nature of available information, can we produce meaningful regulatory guides to supplement this regulation? In the time frame called for?

Given the few repositories that will be developed and the individualized treatment they will require and deserve, what purpose will regulatory guides serve? Will we write regulatory guides for each potential repository? If detailed information presently exists applicable to all potential repositories, then I believe it should be included in this regulation. As it now stands, detailed technical information is surely lacking.

9. The staff paper does not contain a viable Value/Impact Statement. Has one been prepared, or is one being prepared? The decision-making process that went into the decision to develop regulations placing the review of HLW repositories in the usual review scheme is essential and should be made public.

10. The staff paper does not contain a Report Justification Analysis. Has one been prepared or is one being prepared?

11. The Supplementary Information statement does not contain a NEPA declaration. If an environmental report is being prepared, the SI should state this; if not, the SI should contain a negative declaration.

12. It is my opinion that if the Appendix goes out for public comment as is, without a more detailed explanation as to its scope, the geologic community will be up in arms as to its deficiency. I would suggest either we say more, or we say less. What is stated now is neither sufficient nor broad enough in scope. If our intent is to be broad, we should just state, "all relevant geologic and seismologic factors will be considered." If our intent is to provide a more limited approach we should expand the technical requirements now given. As they stand, they say little if anything beyond an elementary textbook.

Thank you for this opportunity to offer my comments on Part 60. This is a tremendous undertaking on your part and you are to be commended for what you have achieved so far. However you still have a long way to go.

Sincerely,

David M Petefish

David M. Petefish
Consultant

UNWMG

Utility Nuclear Waste Management Group
1111 19th Street, N.W. • Washington, D.C. 20036 • (202) 828-7009

November 2, 1981

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DOCKET NUMBER PR-60
PROPOSED RULE (46 FR 35280)

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Docketing and Service Branch

Re: Notice of Proposed Rulemaking: 10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories (Technical Criteria) 46 Fed. Reg. 35,280

Dear Sir:

These comments are submitted on behalf of the Utility Nuclear Waste Management Group (UNWMG) in connection with the above-referenced matter.

The UNWMG has maintained a continuing interest in the development of 10 CFR Part 60 over a number of years. In particular, with respect to the establishment of technical criteria for regulating the geologic disposal of high-level radioactive waste, the UNWMG provided, on July 31, 1980, detailed comments in response to the Commission's advance notice of proposed rulemaking (45 Fed. Reg. 31,393).

The current rule, as proposed, incorporates a number of improvements over earlier versions, and the UNWMG wishes to commend the NRC on its continuing effort toward further improvement. However, the UNWMG continues to have a fundamental concern over the specific, quantitative performance objectives for separate components of the repository system still contained in the rule. We also believe that other provisions of the proposed rule can be improved.

The UNWMG comments on the proposed rule are presented in two separate parts. First, the remainder of this letter addresses the specific areas identified in the notice of proposed rulemaking as being of special interest to the Commission. In particular, the matter of

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"Alternative 1" (the "systems approach") versus "Alternative 2" (the "barrier performance objectives approach") is discussed in some detail, and -- because of its overriding significance and importance -- is addressed first.

In addition to the responses contained in the body of this letter, the Attachment presents specific, detailed comments on the wording of the rule as proposed in the notice of rulemaking. As discussed more fully below, the UNWMG believes that regulations based on a systems approach would be both more technically sound and workable than those currently proposed by the Commission, which are keyed to the performance of specific nuclide barriers. However, should the NRC choose to retain the current barrier performance objectives approach, we believe the comments in the Attachment will aid in the development of a supportable, practical rule governing the design, construction and operation of geologic repositories.

<u>Alternative approaches: systems approach v. barrier performance objectives (46 Fed. Reg. 35,283-84)</u>

While it is generally agreed that the use of separate nuclide barriers and other features -- such as a reasonably long-lived waste package, a stable waste form and a favorable geologic setting (exemplified, in part, by significant water travel times to the accessible environment) -- is appropriate for a repository system, the fundamental, basic consideration is assurance that such barriers and features operate in a way so as to preclude the excessive release of radioactive materials to the accessible environment. From this perspective the NRC barrier performance objectives approach, as embodied in the current proposed regulations, can only be viewed as the arbitrary imposition, on individual system components, of specific-value standards that are without scientific or other technical support. Moreover, it is intrinsically at odds with an important aspect of sound repository design and operation; i.e., the interaction of individual components to achieve, on a combined basis, the required level of repository system performance. Further, we cannot agree that the inclusion of such component requirements will increase the ability to show compliance with an overall system performance requirement (e.g., EPA protection standards), since such a showing will necessarily involve the use of mathematical models independent of specific component performance requirements.

UNWMG is firmly of the view that overall repository performance should be addressed directly by means of the systems approach. Utilization of an overall performance standard would correctly serve to focus attention on total repository performance. In addition, it would provide for appropriate design flexibility: something which is important in order to both be able to take advantage of new developments, as this new undertaking proceeds, and to accommodate and effectively utilize the specific characteristics of individual sites.

In particular, use of the EPA environmental standards in 10 CFR Part 191 -- which are currently in draft form and, when adopted, will have to be met anyway -- would provide a unified, supportable basis for regulation and, at the same time, preclude the possibility of conflicting regulatory requirements. Utilization of a systems approach, based on such overall system performance standards, would have the additional advantage of being universally applicable to all geologic repositories. Thus, special criteria pertinent to disposal in, for example, the vadose zone, would be unnecessary.

UNWMG notes that the Commission could, consistent with a systems approach, specifically require the utilization of certain components (a waste package, stable site geology, etc.) in any and all repositories. However, the prescription of separate numerical barrier performance objectives should be avoided. This, of course, could be accomplished either by eliminating individual numerical requirements, or by specifying that variations and departures from them would be equally acceptable as long as the overall performance requirements for the repository system were met.

Whether or not the Commission decides to require the use of specific components, however, UNWMG urges that the NRC adopt a rule which properly implements the systems approach by prescribing performance standards for the entire repository system, rather than imposing numerical requirements for individual components.

<u>Retrievability (46 Fed. Reg. 35,282)</u>

UNWMG is of the view that requiring, as a parameter of repository design, the ability to maintain retrievability for a period of up to 110 years is excessive and without adequate supporting rationale. In addition, a design allowing for retrieval over a 50 year period following waste emplacement could, in and of itself, motivate extended and unnecessary delay in final repository closure, i.e., shaft sealing.

A more reasonable and appropriate approach might be to base design requirements for retrievability, if any, on the period of repository operation. Assuming the first waste packages to be loaded into the repository could be in place for about 30 years before all emplacement was complete, and allowing another 30 years (the same time as for original construction and emplacement) for retrieval, would lead to a retrievability design requirement for a total of 60 years. Such a period would be reasonable since any difficulties which are likely to be apparent at any time in the near future will probably manifest themselves quickly. In addition, it would tie retrievability to the period of the waste package monitoring program, which must extend as long as practical up to the time of permanent repository closure.

In any event, the rule, itself, should make clear that the requirement for retrievability does not preclude the back-filling of emplacement rooms and drifts when the operator deems it appropriate. From the discussion at page 35,282 of the Federal Register it is clear that, as the rule is now written, it is not the intent of the Commission to preclude such back-filling. However, to avoid any possible misunderstanding, the wording of the rule, itself, should be clarified.

Human intrusion (46 Fed. Reg. 35,283)

The treatment of this subject is proper and should be preserved in the final rule. In this same general connection, however, UWMG believes that the importance of avoiding natural resources, in the siting of a repository, is overemphasized. This point is considered in additional detail in the Attachment to this letter.

Population (46 Fed. Reg. 35,284)

UWMG supports the approach taken in the proposed rule which does not include any siting requirements dealing directly with population density or proximity to population centers. Over the periods of time involved, such requirements would be virtually meaningless since, among other things, population projections into the far future would be completely speculative. Further, since overall system performance requirements will, presumably, be stated in terms of radioactive material release limitations, population-related siting requirements are unnecessary from a purely regulatory viewpoint.

Design and construction criteria (46 Fed. Reg. 35,285)

UWMG believes that the level of detail required under the rule, as proposed, is excessive and should be greatly abbreviated. This comment is based upon what the UWMG views of the basic desirability of maintaining flexibility with respect to design and construction wherever possible and minimizing unnecessary cost. It is difficult to identify any repository structure, system or component important to safety in terms of limiting accident doses to the public to levels such as the 0.5 rem prescribed in 10 CFR § 20.105(a) pertaining to allowable levels of exposure in unrestricted areas. Accordingly, the need to specify design and construction requirements, if any, is small.

This matter is considered in additional detail in the Attachment to this letter.

ALARA (46 Fed. Reg. 35,289)

UWMG is of the view that, with respect to high-level waste repositories, the application of an ALARA principle is superfluous. Projected doses are a small fraction of those resulting from variations in natural background radiation. Further reductions cannot be justified. In addition, the inclusion of an ALARA principle would add nothing to the certainty of performance of any individual component or the overall repository system. Thus, application of ALARA would make no sense and, indeed, could lead to confusion. Accordingly, its use should be avoided.

In concluding this letter we would like to note that, as in the past, the UWMG would be pleased to discuss these comments -- as well as those in the Attachment -- with the NRC in additional detail, if so desired.

Sincerely,

R. E. L. Stanford
Program Manager

Enclosure

ATTACHMENT

Secretary, U.S. Nuclear Regulatory
  Commission
November 3, 1981
Re: Notice of Proposed Rulemaking
    10 CFR Part 60 (46 Fed. Reg. 35,280)

Presented below are specific, detailed comments on the wording of 10 C.F.R. Part 60 as proposed in the above-referenced rulemaking. As discussed in the letter to which this Attachment is appended, the Utility Nuclear Waste Management Group (UNWMG) favors recasting of the currently proposed rule so as to adopt "Alternative 1" (the systems approach). However, the detailed comments presented below are offered in the event that the NRC should choose to retain the current barrier performance objectives approach. It is hoped that, in such a case, the comments will aid the development of a sound, workable rule governing the design, construction and operation of geologic repositories.

pp. 35, 285-86, col. 3 & 1-2 respectively

Definitions contained in § 60.2 should be modified as follows:

- The definition of "disturbed zone" should specifically refer to the properties of the geologic setting which are of interest insofar as disruption is concerned. In particular, "disturbed zone" would be better defined as "that portion of the geologic setting the physical and/or chemical properties of which is significantly affected by construction of the

subsurface facility or by the heat generated by the emplacement of radioactive waste."

- In the definition of the term "floodplain," the words "including flood prone areas of offshore islands" should be deleted as they are redundant.
- "HWL facility" should be corrected to "HLW facility."
- The phrase "important to safety" is significant primarily to the extent that it serves to identify structures, systems and components subject to the design, construction and quality assurance requirements specified in §§ 60.130, 60.133 and 60.150. The definition in the proposed rule, however, is overly vague. To cure this, the meaning of "undue risk to the health and safety of the public," as used in the definition, should be specified in terms of a particular dose to a member of the public. In this regard, the UNWMG believes that use of a

dose of 0.5 rem to the whole body, or any organ, similar to that utilized in 10 C.F.R. § 20.105(a) in connection with allowable, annual whole body doses to persons in unrestricted areas, would be appropriate.

- Definition of "stability," without reference to a particular type of stability (e.g., structural stability, tectonic stability, hydrogeologic stability, geomorphic stability, etc.) is somewhat confusing. Accordingly, the term should be defined with reference to particular modifiers.

- p. 35,286, col. 3

- As presented in the proposed rule, the definition of "transuranic wastes" or "TRU wastes" is unduly restrictive. There is no technical justification for a 10 nanocurie per gram limitation. Further -- from a practical standpoint -- such a level is at the extreme low end of detectability. A limitation of 100 nanocuries per gram, as contained in the draft EPA standards for 40 C.F.R. Part 191, would result in a more workable and technically sound definition.

- p. 35,287, col. 1-3

In any event, as discussed below in connection with § 60.102(b)(4), the UNWMG is of the view that regulations pertaining to TRU should be developed in a separate document. Such an approach would, among other things, provide an opportunity for directing needed attention to the unique aspects of TRU waste disposal. In this connection, the UNWMG will be providing additional analysis of TRU waste disposal in its comments on the regulations currently being proposed for 10 C.F.R. Part 61.

As currently worded the requirement contained in § 60.10(d)(2) is confusing. To the extent that the intent is to require that the number of exploratory boreholes and shafts be minimized, the section should be reworded to directly so state.

The use of the term "bulk" with respect to geomechanical, hydrogeologic and geochemical conditions and properties in §§ 60.21(c)(1)(i)(C)-(F) differs from normal technical usage. The apparent reference is to the average of such properties and conditions over the disturbed zone. The language should be modified to so state.

With respect to § 60.21(c)(1)(ii)(E), it may be impossible to literally "confirm" models used to perform the required assessments. Rather, it would be more appropriate to require that assessments be <u>supported</u> by tests, data or studies. Further, it is not clear what would constitute "field-verified laboratory tests." Depending on the definition, field-verification may not be possible in some situations. A preferable approach would be to reference and require "appropriate laboratory and field tests."

Under § 60.21(c)(3), "a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation" is required. For the reasons discussed in the letter to which this Attachment is appended, however, such an open-ended, ALARA-type analysis is unnecessary. Simply stated, where projected doses are a small fraction of those which already result from variations in natural background radiation, further reductions cannot be justified. Accordingly, the requirement should be deleted.

- p. 35,288;
col. 1-2

In addition, the use of the expression "undiscovered deposits of natural resources" in § 60.21(c)(13) appears to be intended as a term of art (such as used by McKelvey in U.S.G.S. Professional Paper 820), meaning speculative resources, or those suspected but not actually found. If this is, indeed, the case, appropriate references or clarification should be provided to avoid any possible misinterpretations.

More basically, however, whatever the intended meaning of the expression, a prospective site would be explored in such detail during the characterization process that, as a matter of course, the presence or absence of resources should become well enough understood to accommodate the site selection process. Accordingly, § 60.21(c)(13) should be eliminated from the final rule as superfluous.

Finally, the word "sits" in § 60.21(c)(1)(ii)(A) should be "site."

Section 60.101 presents the purpose and nature of findings relevant to technical criteria. Pursuit of the barrier performance objectives approach, however, has resulted in a lack of flexibility. Proposed numerical standards do not accommodate the wide range of variations available for allocating safety functions among separate system components when designing to meet overall performance criteria for repositories in various geologic media. In short, single-value criteria that attempt to cover all options are appropriate for none of them. The use of such criteria, as currently prescribed in [illegible], would bias site selection and design, quite possibly to the extent that achieving required performance would be both more difficult and costly.

In addition, the [illegible] cannot agree with what appears to be the major NRC motivation for the inclusion of such criteria (see page 35,284) that the inclusion of individual component requirements facilitates a showing of compliance with overall system performance requirements (EPA standards). Such a showing will necessitate the use of numerical models, independent of specific, individual component requirements.

To provide an efficient, practical regulatory framework for repository licensing the Commission should assure that the regulations afford sufficient flexibility to both take advantage of new developments, and effectively utilize the specific characteristics of individual sites. Such flexibility could be provided through the addition of a new paragraph (e) to § 60.101 as follows:

(e) Sections 60.111 and 60.112 contain performance objectives concerning the containment of waste in the waste packages; the control of releases from the engineered system; and pre-waste emplacement groundwater travel times through the far field to the accessible environment. The ability to meet specific performance objectives, however, will vary from site to site, particularly as a function of the host rock involved. Accordingly, variations from and/or alternatives to the specific performance objectives are equally acceptable, provided that there is reasonable assurance that the overall system performance objective embodied in the environmental radiation protection standards referenced in § 60.111(b)(1) will be met.

- p. 35,299, col. 3

Section 60.102(b)(4) addresses waste form requirements for TRU. Because of the special factors relevant to transuranic waste disposal, however, we believe that regulations pertaining to the management of such material should be developed in a separate document, and that this section of the regulations should so note. If this approach were followed, some of the complexity of the currently proposed rule would be eliminated. This approach would also provide an opportunity for directing needed attention to the unique aspects of TRU waste disposal.

- p. 35,299, col. 1-3

As stated in the letter to which this Attachment is appended, the UMRG is of the view that the provision of § 60.111(a)(2) requiring, as a basis for repository design, the ability to maintain retrievability for a period of up to 110 years is excessive and without substantial

rationale. In addition, a design allowing for retrieval over a 50 year period following waste emplacement could, in and of itself, motivate extended and unnecessary delay in final repository closure.

A more reasonable and appropriate approach might be to base design requirements for retrievability, if any, on the period of active repository operation. Assuming the first waste packages to be loaded into the repository could be in place for about 30 years before all emplacement was complete, and allowing another 30 years (the same time as for original construction and emplacement) for retrieval, would lead to a retrievability design requirement of 60 years, total. Such a period would be reasonable because retrievability, if it is to be designed for at all, should be tied to a concept of performance confirmation, and any difficulties which are likely to be apparent at any time in the near future will probably manifest themselves quickly. Further, such an approach would tie retrievability to the period of the waste package monitoring program, which must extend as long as practical up to the time of permanent repository closure.

In any event, the rule, itself, should make it clear that the requirement for retrievability does not preclude backfilling of the emplacement room and drifts when the operator deems it appropriate.

In addition, § 60.111(b)(2) imposes, as design objectives: (1) that the waste packages contain all radionuclides for at least the first 1,000 years after permanent closure, and (2) that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting -- assuming anticipated processes and events -- is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. It is obvious that literal proof of compliance with these objectives is neither intended nor

possible. To avoid any potential confusion in either the licensing review or hearing process however, these provisions should be redrafted to emphasize that the specifications are only <u>design</u> objectives; <u>i.e.</u>, that the intent is to provide for the application of pertinent field, laboratory and analytical information in accordance with good engineering practice.

In particular, with respect to the 1,000 year containment requirement, the rule should specifically provide for a determination based on <u>reasonable</u> input parameters, *derived from* acceptable field and laboratory data and analyses, for a <u>nominal</u> (not first-to-fail) waste package. *Similarly, the one part in 10^5 release rate* requirement should be prescribed in terms of being demonstrable by means of analysis based upon reasonable input parameters. This portion of the rule, too, should specifically provide for analysis based upon typical waste package performance, and reasonable inputs with respect to the underground facility. A period of consideration, <u>i.e.</u>, out to 10,000 years as is being utilized by EPA in the case of its draft radiation protection standards, should also be specified.

In addition, § 60.111(b)(2)(i) imposes an assumption of "all or partial separation of the underground facility." Under certain circumstances, however, (e.g., disposal in salt) such an assumption may not be reasonable. Accordingly, the rule should provide that the waste package design basis may reflect site specific [illegible].

Finally, the specific requirements pertaining to TRU waste should be removed from § 60.111(b)(2) for the reasons discussed above in connection with § 60.1?2(b)(4).

p. 35,289, col. 3

Section 60.112 specifies certain required characteristics of the geologic setting having to do with stability and groundwater travel times. As discussed above in connection with § 60.111, however, it is important that the rule note that a reasonable demonstration of the required characteristics is sufficient, and that a higher level of proof is not required.

Further, the requirement prescribed in § 60.112(e), which limits repositories to locations

exhibiting pre-waste emplacement groundwater travel times through the far field to the accessible environment of 1,000 years or more, could be confusing insofar as disposal in media such as salt is concerned. To avoid possible uncertainty, the 1,000 year groundwater travel time requirement should be worded as follows:

> The geologic repository shall be located [illegible] water flowing between the outermost waste container location and the accessible environment is at least 1,000 years.

p. 35,290, col. 1-2

In § 60.122 the proposed regulations require specified favorable conditions "so that, together with the engineered system, the favorable conditions present are such to provide reasonable assurance that . . . performance objectives will be met." In accordance with the discussion above in connection with §§ 60.111 and 60.112, however, the rule should specify that the indicated "favorable conditions" may be determined on the basis of a reasonable demonstration, and that additional certainty is not necessary.

In addition, §§ 60.122(a)-(e) involve the projection of past tectonic, structural, hydrogeological, geochemical and geomorphic processes into the future. Such projections, however, should not be left open-ended, and should be specifically limited to the period of analytical consideration; i.e., the 10,000 year period suggested above in the discussion of § 60.111(b)(2).

In this same general connection, UNWMG believes that the absence of groundwater travel times from the geologic setting to the accessible environment of less than 1,000 years should also be indicated as a favorable condition in this section. The 1,000 year flow time from the outermost waste container to the accessible environment, discussed above in connection with § 60.112(c) as a performance objective, is, of course, more significant. However, UNWMG believes that the lack of groundwater communication from anywhere in the entire geologic setting to the accessible environment within 1,000 years would offer an additional advantage sufficient for its identification as a "favorable condition."

Finally, in the tenth line of § 60.122, the word "engimeered" should be "engineered."

p. 35,290-91, col. 2-3 & 1, respectively

Again, the rule should specifically provide for a determination of the existence or non-existence of the potentially adverse conditions identified in § 60.123 on the basis of a reasonable analysis. In this regard, § 60.123(b) requires geologic investigation to a distance 500 meters below the repository. This appears excessive and, under some circumstances, could be counterproductive (as when a deeper aquifer is penetrated by an exploratory borehole). If a numerical value is deemed necessary, 100 meters would seem both more realistic and reasonable.

In addition, § 60.123(b)(14) identifies as potentially adverse "[g]roundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could affect the solubility and chemical reactivity of the engineered systems." Any groundwater, however, will "affect" solubility and chemical reactivity. Accordingly, the proper issue is whether or not there will be a significantly adverse effect. The regulation should be revised to correctly reflect this concern, perhaps by adding

"adversely, in a significant
way."

after the word "affect" in the proposed text.

- pp. [illegible].201-04, beginning with col. 2 on the first page to col. 2 on the last page

Sections 60.130 to 60.134, inclusive, specify numerous requirements for the design of, and construction specifications for, the geologic repository operations area. As discussed in the letter to which this Attachment is appended, UNWMG believes that the level of detail prescribed is excessive and should be greatly abbreviated. This comment is based upon what the UNWMG views as the basic desirability of maintaining appropriate flexibility with respect to repository design and construction. Nevertheless, UNWMG is of the view that the rule will at least be generally practical if the suggested modification to the definition of "important to safety," discussed above in connection with § 60.2, is adopted. There are, however, several areas which are in need of particular attention.

First, § 60.132(g)(4) states that "Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained." This requirement is overly vague. It should be recast in terms of controlling and containing unexpected inrushes of water or flooding that can <u>reasonably</u> be hypothesized.

Second, § 60.132(j)(2) requires that handling systems be designed "to minimize the potential for operator error." The design of a handling system, however, is a function of a number of considerations (such as space availability, reliability, maintainability, <u>etc.</u>), and cannot have as a sole goal minimizing the potential for operator error. This section should be revised to reflect this fact.

Third, § 60.133(b)(1) should be deleted. The decision to seal shafts and boreholes is an operational one. Accordingly, it should be made by the operator on the basis of operational considerations.

Finally, § 60.133(b)(2) is unduly restrictive and, in fact, would discriminate against favorable media such as salt. The first sentence should be deleted. A design aim for such seals would be more realistically and soundly based on a performance objective tied to overall system performance, e.g., if it prescribed that shaft and borehole seals be so designed and constructed as not to compromise the overall system performance objective.

p. 35,295, col. 1

Section 60.140(a) requires a performance confirmation program to "ascertain" whether or not certain conditions exist. In some cases, however, it may be impossible to confirm completely certain conditions. Accordingly, § 60.140(a) should be modified to reflect that confirmation is required only to a reasonable extent.

Section 60.140(d)(1) requires that the confirmation program be implemented so as not to

"adversely affect the natural and engineered elements of the repository." Almost any confirmation program, however, will have some adverse effects. Accordingly, the regulation should be reworded to require that the confirmation program not adversely affect the natural and engineered elements of the repository to a significant degree.

- p. 35,295, col. 3

Section 60.150(a) defines quality assurance as "all those planned and systematic actions necessary to provide adequate confidence that the repository and its subsystems or components will perform satisfactorily in service." UNWMG assumes that "adequate confidence" is equivalent to reasonable assurance, and the rule should be modified to so reflect.

- p. 35,296, col. 1

As in § 60.150(a), reference is made to "adequate confidence" in § 60.153, with respect to assuring that emplaced wastes will remain isolated from the accessible environment. As suggested with respect to § 60.150(a), the content of § 60.153 should be modified to indicate that reasonable assurance constitutes "adequate confidence."

NATIONAL RESEARCH COUNCIL

COMMISSION ON NATURAL RESOURCES

[illegible] Washington, D.C. [illegible]

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OFFICE OF THE CHAIRMAN
[illegible]
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Washington, DC [illegible]

October 30, 1981

45

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

The Honorable Nunzio J. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Palladino:

Enclosed is a letter report by the Board on Radioactive Waste Management (BRWM) of the National Research Council's Commission on Natural Resources responding to the U.S. Nuclear Regulatory Commission's invitation to comment on proposed rule 10 CFR 60 on disposal of high-level radioactive waste in geologic repositories. The report has been reviewed internally by the Commission on Natural Resources and the Academy's Report Review Committee.

Nine of the thirteen members of the Board on Radioactive Waste Management participated on one or both days of the Board's deliberations. Participating members were Albert Carnesale, Roger Kasperson, Konrad Krauskopf (Vice Chairman; Chairman since 10/1/81), Philip LaMoreaux, Todd LaPorte, Frank Parker, Thomas Pigford, E. Bright Wilson (Chairman through 9/30/81), and Herbert Wright. Members not participating were Merril Eisenbud, Nicholas Grant, Harold James, and Colin Mawson.

Dr. Frank Parker participated only on Thursday, September 17, and wishes it noted that he is not in agreement with some of the Board's comments. He will submit additional comments to you directly as an individual contribution. Dr. Thomas Pigford prepared a working paper as background for the Board's deliberations, and he will also submit it directly to you.

Sincerely yours,

Robert M. White

Robert M. White

RMW:rh
enclosure

Acknowledged by card. 11/4/81 [illegible]

NATIONAL RESEARCH COUNCIL

COMMISSION ON NATURAL RESOURCES

2101 Constitution Avenue Washington, D.C. 20418

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COMMITTEE ON RADIOACTIVE WASTE MANAGEMENT

October 30, 1981

The Honorable Nunzio J. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Comments on Proposed Rule 10 CFR 60 on Disposal of High-level Radioactive Waste in Geologic Repositories

Dear Dr. Palladino:

During its September 17-18, 1981, meeting, the Board on Radioactive Waste Management (BRWM) of the National Research Council's Commission on Natural Resources discussed the proposed rule and supplementary information on disposal of high-level radioactive waste in geologic repositories, as published in the Federal Register on July 8, 1981, and the explanatory document "Rationale for Performance Objectives and Required Characteristics of the Geologic Setting: Technical Criteria for Regulating Geologic Disposal of High-level Radioactive Waste," dated June 1981, provided by the Nuclear Regulatory Commission (NRC).

The BRWM recognizes the difficulty of formulating an NRC rule for disposal of high-level radioactive waste in geologic repositories before the establishment by the Environmental Protection Agency (EPA) of generally applicable standards for radiation exposure from such repositories. The BRWM also recognizes that the NRC rule may be more, but not less, demanding than would be required by the EPA standards. The difficulty is exacerbated by the great disparity to be expected between a standard based on dose to individuals and one based on dose to populations, an important question that must be addressed before any standard can be set. In any event, neither the EPA standard nor the type of dose to which the standard will be keyed has yet been determined by EPA. The Board believes it is not good practice, in the absence of compelling reasons, to base a rule on tentative standards. If compelling reasons exist in this case, they should be explained.

Although a generally applicable standard has not been established, NRC found it necessary to assume a standard in formulating the proposed rule. We were informed by an NRC representative that the provisional standard adopted, but not explicitly stated in the rule, was a set of curie release limits of radionuclides to the environment that appears in an unpublished internal draft regulation by EPA, but seems not to be available to the general public. In our comments on the rule we assume that this is the "EPA standard" frequently referred to in supplementary material accompanying the rule and that it is the standard on which the rule itself is based.

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

NRC proposes to achieve adherence to this "EPA standard" by requiring minimum performance standards for each of the major elements in the geologic isolation system, including the following numerical criteria: 1000-year containment by the waste package; a fractional release rate of 10^{-5}/year or less of radionuclides from the engineered system after the first 1000 years; and a minimum time of 1000 years for travel of water from the repository to the accessible environment. NRC states four purposes for these criteria, the first purpose appearing in the proposed rule and the other three in the accompanying Supplementary Information:

1. To specify site and design criteria which, if satisfied, will support a finding of no unreasonable risk to the health and safety of the public.
2. To enhance NRC's confidence that the EPA standard will be met.
3. To simplify NRC's review of DOE's application to construct a licensed repository.
4. To guide DOE in siting, designing, and constructing a repository in such a manner that public health and safety will be protected.

The BRWM questions the adequacy of the proposed numerical criteria to accomplish these purposes. We appreciate the difficulty of devising numerical criteria and we commend NRC on its attempt to arrive at a reasonable set of numbers. In our view, however, it is premature to formulate a rule at this time, especially a rule containing such numerical criteria. Specifically, our conclusions regarding the proposed numbers are as follows:

1. NRC has not presented adequate evidence that these numerical criteria can "support a finding of no unreasonable risk to the health and safety of the public." To provide such evidence, NRC would have to identify a safety standard of "no unreasonable risk" and show that the numerical criteria would contribute significantly to compliance with this standard.
2. NRC has not shown that these numerical criteria are either necessary or sufficient to meet the "EPA standard." Such a showing would require an analysis, including the effect of uncertainty, to demonstrate that meeting these criteria would satisfy the "EPA standard" and that failure to meet the criteria would make compliance with the standard doubtful.
3. It has not been shown that adoption of the numerical criteria will simplify the licensing process; the opposite may well be true. Unless the numerical criteria are shown to be adequately founded, verifiable, and related to an overall performance goal, a licensing review based on them would be at least as difficult to carry out and as subject to challenge as a review focused simply on the long-term radiation safety of the waste isolation system.

4. No attempt has been made to demonstrate the technical validity of the proposed criteria. To show that a criterion is technically valid requires critical analysis of the current state of knowledge and of the problem of extrapolation to the long periods needed for waste isolation.
5. NRC has not shown how the proposed numerical criteria for the waste package can be verified. Such criteria serve little purpose unless a method can be described for demonstrating compliance or noncompliance.
6. The criterion of water transport time may not be verifiable and is probably not verifiable in some geologic media. Because flow of water in some media is complex and poorly understood, transport time may be verifiable only within broad limits. Difficulties in verification should be discussed and acceptable limits should be specified.
7. These numerical criteria are not appropriate as a guide for DOE. Attempting to satisfy particular technological constraints may deflect DOE's attention from the more important goal of complying with an overall performance standard for the safety of the waste disposal system.
8. Adopting such criteria risks steering research and development by DOE and other agencies in unproductive directions. For example, if these criteria prove to be invalid and unnecessarily restrictive, much time and money may be wasted in attempting needless refinements of waste packages and repository designs.

On the basis of these conclusions, the BRWM considers the proposed NRC rule premature at this time. We recognize, however, that there may be compelling reasons for NRC to issue a rule in the near future. In this case we recommend that the rule state that it is based on an assumed single overall performance standard (alternative 1 of the three listed in the rule) with the understanding that this standard will be the EPA standard, yet to be promulgated; and we recommend that precise numerical criteria for major elements of the repository system be eliminated. A critical qualitative analysis of the goals to be sought in long-term containment of radionuclides, in low leach rates, and in slow ground-water movement, including other methods of attaining these goals and trade-offs among them, will provide adequate guidance for DOE's current investigations as well as for NRC's activities in a licensing procedure. The difficulty of establishing technically valid and verifiable numerical criteria on the basis of current knowledge should be stressed in the analysis, as should the unavoidable uncertainty in such standards even at a later time when actual numbers may have some significance. When and if numerical criteria are used in the future, we strongly recommend that they appear in regulatory guides rather than as

Dr. Nunzio J. Palladino
October 30, 1981
Page 4

part of the rule itself, so that they can be more readily adjusted to the results of continuing research and to the specific conditions of particular repository sites. NRC has used such guidelines to promulgate most of the vast body of its technical requirements in other licensing procedures.

Finally, NRC proposes to require that the engineered system be designed so that waste can be retrieved, if necessary, for up to 50 years after the last waste is emplaced. The BRWM believes that any inclusion of a retrievability requirement must be studied further because the need to provide for any type of retrievability after emplacement may preclude the use of some otherwise desirable repository designs and some otherwise desirable geologic media.

It is important to recognize that the BRWM has limited its review to the need for and adequacy of the proposed NRC rule and its accompanying rationale document. In commenting on the technical criteria and the lack, as presented, of demonstration by NRC of technical validity for its stated purposes, we do not here imply any evaluation of the state of technology or of scientific understanding for implementing the geologic waste isolation system. We wish to compliment the NRC staff for their obvious dedication to making progress in an important area of radioactive waste management, and we hope that these comments will aid their endeavor.

Sincerely,

E. Bright Wilson

E. Bright Wilson
Chairman through 9-30-81

Konrad Krauskopf

Konrad Krauskopf
Chairman since 10-1-81

EBW:KK/md

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AMERICAN INSTITUTE
OF CHEMICAL ENGINEERS

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DOCKETING & SERVICE
BRANCH

November 3 1981

46

The Secretary
Nuclear Regulatory Commission
Washington, D.C. 20555

DOCKET NUMBER PR-60
PROPOSED RULE (46 FR 35280)

Attention: Docketing and Service Branch

Dear Sir:

The Nuclear Engineering Division of the American Institute of Chemical Engineers submits the following response to your request for comments on the proposed technical criteria for disposal of high-level radioactive wastes in geologic repositories under 10 CFR Part 60.

The American Institute of Chemical Engineers is a professional organization representing over 50,000 chemical engineers, many of whom are members of the Nuclear Engineering Division. Members of this division have been involved in virtually all facets of the nuclear industry.

Technical criteria are, of course, needed for the Department of Energy to move forward with construction and operation of a geologic repository. However, in our view, these specific proposed criteria go so far beyond those required to protect the environment and the public that they constitute a basis for needless and costly delay in moving forward with the repository. In fact, we believe that these criteria, however well intentioned, provide a prime example of the type of overregulation being addressed by the President's Task Force on Regulatory Relief, chaired by Vice President Bush. Consequently, a copy of this letter is being sent to the Vice President.

At 46 FR 35281, the Commission's supplemental information notes that the Environmental Protection Agency has the authority and responsibility for setting radiation standards but has not yet done so for high level waste. In this supposed regulatory vacuum, the Commission's proposed criteria would establish a requirement for zero release for a period of at least 2,000 years, as demonstrated below.

11/9/81 emp

We feel that this is not only totally unrealistic in itself, but also is in marked contrast to the EPA's published standard of 25 millirem per year to the public from most nuclear activities (40 CFR Part 190).

Section 60.111 (b) (2) (i) of the proposed regulation would require that the nuclear waste be in such form and so packaged that, "even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure." After this initial 1,000 years, Section 60.111 (b) (2) (ii) would limit releases from the package to not more than one part in 100,000. Moreover, pursuant to Section 60.112 (c), the repository must be such that water travel time to the accessible environment is longer than 1,000 years. Thus, overall, the zero release requirement from the repository is not only for the required 1,000-year package containment time, but also for the 1,000-year travel time— a total of 2,000 years of zero release.

The following factors should lead to the conclusion that the proposed 2,000-year zero release criterion is not only unnecessary but also contrary to rational protection of the health and safety of the public:

(1) No scientific basis related to radiological protection (the domain of the NRC) is presented in the proposed regulation. Indeed, in related documents (Draft NUREG-0805 and Draft NUREG-0804), the radiological exposure to the public resulting from the waste disposal operation is not quantified, but only addressed in general terms.

(2) The proposed regulation seems to make a mockery of the principle of "as low as reasonably achievable" (ALARA). For quite some time, we have understood that the implementation of ALARA involved the weighing of costs and benefits of reducing radiation exposures below a well-defined exposure guideline or limit. For the NRC to query commenters as to the appropriateness of applying such a principle to a mandated 2,000-year zero release would seem to be a moot question. This is even more the case when, taking into account 2,000 years of radioactive decay, natural retardation of nuclides, and dilution (especially if the release is from a body of salt), the potential exposure to the population or any individual resulting from escape from a reasonably selected, designed, and constructed repository would be but a small fraction of normal background exposure as well as being far below the 40 CFR Part 190 standard of 25 mrem/year.

(3) We believe that although compliance with the requirements of the proposed regulation can be accomplished, it would be at a cost increase which would be shown to be unwarranted if NRC had done the usual cost/benefit analysis.

(4) Licensing under these proposed criteria would require that DOE prove absolutely zero release — not one atom. This is virtually an impossible task, and would lead inevitably to lengthy licensing delays.

(5) Adoption of the proposed regulation would increase the misconception of many who incorrectly perceive nuclear waste to be much more hazardous than a number of frequently encountered and accepted non-radioactive toxic materials.

There are several other facets of the proposed regulations which warrant comment:

- Retrievability should be made possible only to the extent that it does not, in any way, compromise the integrity of the repository or the ability to monitor the repository. Every opening to the environment left for retrievability is a potential pathway for escape of radionuclides as well as for ingress of water. Most importantly, open shafts and tunnels will significantly distort the heat transfer pathway which will exist after complete closure. This will cause thermo-mechanical monitoring during the period before complete closure to have a reduced value related to the long-term life of the repository.

- Regardless of what is done with it, spent fuel is not a "waste" by any generally accepted definition. In our opinion, spent fuel should be reprocessed not only for its energy value, but also through removal of plutonium to reduce the duration of hazard and the volume of high level waste.

- In Section 60.123 (b) (3), the gross value of resources should be omitted. There are many bodies of mineral resources so dilute that recovery is quite uneconomic, yet the total (gross) value of the contained resource could be considerable. Net value or commercial potential should be the only factors of consideration.

The Secretary
November 3, 1981
Page 4

- Section 60.130 (b) (8) (iv) requires that "all systems important to safety shall be designed to permit them to be maintained at all times in a functional mode." This is contrary to NRC requirements in other facilities where redundant systems are required to permit one of two or more systems to be removed from service—in other words, be not "in a functional mode"—for maintenance while the other systems provide the required capability for safety.

- We continue our strong objection to the unduly low transuranic content level in the definition of TRU wastes which we believe is in no way technically supportable for appropriate protection of the health and safety of the public. However, as the "justification" for this definition is published by the NRC in support of its proposed 10 CFR Part 61, we will provide further comments on TRU when we comment on Part 61 after reviewing the voluminous environmental impact statement.

Finally, a concern we have which relates to all the above comments is that, while the proposed regulation is labeled as "technical criteria," it really provides detailed "design bases." Realistic criteria should allow specific, acceptable exposure of the public in short and long time periods. This would permit DOE to explore alternative means to accomplish such a goal. The design bases go far beyond the usual concept of "defense in depth" in that they require virtually absolute, 100 percent assurance of performance at each of several consecutive barriers.

We have read, fully concur with, and endorse the comments and position of the American Nuclear Society on this subject submitted to you on October 14, 1981.

We would be pleased to expand on any of the above comments in writing or in personal discussion with members of your staff. Please let us know if you desire follow-up.

Sincerely,

R D. Newman

R.T. Newman
Chairman
Nuclear Engineering Division

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U.S. NUCLEAR REGULATORY COMMISSION

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DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

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PMS SECRETARY OF COMMISSION US NUCLEAR REGULATORY COMMISSION RPT DLY
MGM, DLR IN A.M., D.R
WASHINGTON DC 20555
RE: PROPOSED RULE 10 CFR PART 60, DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

DEAR SIR,
NEW ENGLAND COALITION ON NUCLEAR POLLUTION INC COMMENTS ON PROPOSED RULE INCORPORATE BY REFERENCE IN TOTO COMMENTS BY SIERRA CLUB NUCLEAR SUBCOMMITTEE OF THE NATIONAL ENERGY COMMITTEE. WE EMPHASIZE PARTICULAR CONCERNS THAT MAXIMUM PROTECTION OF PUBLIC HEALTH AND SAFETY MUST BE PRINCIPAL GOAL NOW AND FOR FULL PERIOD OF TOXICITY OF WASTES. THEREFORE URGE,
A. MOST EXACTING CRITERIA FOR DETERMINING ENVIRONMENTAL IMPACT BEFORE STORAGE OF TEST RAD WASTE.
B. GOAL OF ZERO RELEASES OF RADIO NUCLIDES
C. THOROUGH ASSESMENT OF MINERAL RESOURCES IN CANDIDATE REGIONS AND HUMAN INTRUSION PAST, PRESENT AND FUTURE
D. CHOICE OF SITES WHICH ASSURE PUBLIC SAFETY DESPITE POSSIBLE FAILURE OF LONG TERM CONTROLS (IE FAR FROM POPULATION CENTERS PRESENT OR FUTURE)
E. PRIMARY AND SEPARATE CONSIDERATION OF HUMAN HEALTH EFFECTS SEPARATE FROM DOLLAR VALUE IN EVALUATING SITES
F. FULL STATEMENT BY NRC OF CONDITION OF WASTE RETRIEVAL BEFORE DEPOSITION EVEN FOR TEST PURPOSES
G. STRICT LIMITATION OF AMOUNT OF WASTE IN TEST SITES TO AVOID DEFACTO UNLICENSED REPOSITORIES

NECNP REITERATES PROTECTION OF PUBLIC HEALTH AND SAFETY MUST BE OVERRIDING CONSIDERATION IN EVERY DECISION. RESPECTFULLY SUBMITTED
DIANA P SIDEBOTHAM, PRESIDENT
RD 2 BOX 223
PUTNEY VT 05346
1451 EST

1707 EST

NRC BHDA

Acknowledged by card 11/9/81 emp

Department of Energy
Washington, D.C. 20585

(48)

DOCKET NUMBER PR-60
(46 FR 35280)

DOCKETED USNRC NOV 5 1981 Office of the Secretary Docketing & Service Branch

NOV 5 1981

MEMORANDUM FOR Mr. Samuel Chilk
Secretary, Nuclear Regulatory Commission
Attention: Docketing and Service Branch
Washington, D.C. 20555

The Department of Energy is pleased to respond to the request of the Nuclear Regulatory Commission (NRC) for comments on the proposed amendments to 10 CFR 60, published on July 8, 1981 (46 Fed. Reg. 35280). This submission continues the Department's involvement in the development of a rule by which the disposal of high-level radioactive wastes (HLW) will be governed. Our involvement has included letters commenting on the Advanced Notice of Proposed Rulemaking (ANPR), and meetings with NRC staff. Because of the length of this submission, our comments are contained in two enclosures to this cover letter: the first is a commentary on major issues, including six for which the Commission requested comment; the second is a section-by-section analysis with recommended alternative language where appropriate.

The Commission is to be commended for its considerable efforts and determination to move forward with this most important rule. Many Department concerns with specifics of the rule, some of them major, have already been resolved by the Commission staff. The statement added since the ANPR on the concept of "reasonable assurance" is a major contribution toward a credible regulation. I might note here that we generally support the Commission's position on siting requirements and human intrusion, and we agree that ALARA (as-low-as-reasonably-achievable) principals should not be applied. However, we still have differences of opinion on the proposed rule and have proposed alternative language for parts of the rule which will mitigate those differences.

Specific Comments

Our major concern with the proposed rule is related to the fundamental philosophy used in its preparation. The Department feels that the primary emphasis should be placed upon meeting an overall system performance objective. The final determination concerning levels of performance required of individual subsystems should be made during the preparation of an overall system analysis for a specific site and design. We have long recognized the need for a multibarrier approach and the objectives which the Commission is seeking to achieve. However, as mentioned above, the Department considers that a more appropriate way of accomplishing the objectives expressed by the Commission would be to propose specific subsystem performance goals which are clearly distinguished from requirements by providing the flexibility to select numerical subsystem criteria on a case-by-case basis. As currently written, the performance objectives provide no such flexibility and preclude maximum utilization of engineering ingenuity in meeting the goal of assuring the public's health and safety. Essentially, we believe that: 1) the regulation should be based on achieving an overall system performance requirement, in the manner of the EPA standard; 2) a multiple-barrier system should be proposed by the Department; 3) the performance of intermediate subsystems

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(barriers) of the system should be proposed by the Department and should support the overall system performance criterion; 4) the numerical criteria should be justified by engineering principles and proven site specific data; and 5) the methods by which compliance is to be demonstrated should be clearly defined.

The Department agrees that the Commission must establish the philosophy in developing this regulation from among alternatives such as those posed in the Federal Register notice. We would find a position closer to alternative 1, as proposed by the Commission in the Supplementary Information Section, to be more appropriate. We are concerned that the imposition of inflexible intermediate component performance requirements as now proposed in the Federal Register notice would distract both the NRC staff and our own from the central issue of the licensing process, which is that of demonstrating that the public health and safety will be protected. The alternative language we have proposed in the enclosure would allow the Department, as a license applicant, to propose performance objectives for the several subsystems on a site-specific basis. These detailed objectives would then reflect the results of site-specific investigations and an improved understanding of the required performance of each individual component.

A second concern is with the treatment of transuranic (TRU) wastes in the proposed rule without appropriate consideration of the comparative hazard of these wastes, relative to high level wastes. We suggest that TRU wastes be eliminated from the rule with provision that they would be considered on a case-by-case basis, with reasonable assurance that the functional performance of the repository system would not be significantly compromised by emplacing TRU wastes in a repository.

We have provided revisions that we believe are needed in the requirement for extending retrievability beyond the operational life. The requirement for a long retrievability period could compromise the primary objective of isolation. Furthermore, we expect a high degree of confidence to result from performance confirmation data taken over 50 or more years of operation. This plan for performance confirmation testing should be available as part of the license application and should provide sufficient basis for an early decision by the Commission on backfilling and decommissioning. Also, it is desirable to have some portions of the repository available for low-heat wastes and to allow an early decision on non-retrievable emplacement of such wastes, without waiting for the decision on high level wastes. We have not been able to quantify the cost impact of maintaining the capability to defer a retrieval decision for 50 years after operation ceases, since a design is highly site-specific, but we believe additional costs will occur in the area of shaft and tunnel maintenance and from provisions for operator safety.

The requirements placed on the sealing of boreholes and shafts appear to be excessive and undemonstrable. We have suggested that rather than requiring seals to match the performance of the native rock and not become preferential pathways for water flow that the requirement be stated in terms that would relate seal performance to the overall performance of the repository.

In various meetings on this rule, the Commission has discussed with the staff the proposed cutoff of the draft EPA regulation (draft 19, 40 CFR 191) at 10,000 years. We concur with the Commission's judgment that a 10,000 year cutoff is appropriate and request that the Commission's position be made a matter of record in the rule.

Given the sum of these comments, we urge a restructuring of the rule, first and foremost to emphasize the overall system performance objective and to provide flexibility in meeting individual barrier design objectives. Compliance with the regulation should be demonstrated by systems analysis techniques and the use of mutually-agreed-upon modeling and testing methods developed into Regulatory Guides. Finally, the rule should be clarified and simplified to permit the maximum utilization of engineering ingenuity in meeting the goal of assuring the public's health and safety.

The Department is deeply concerned with the content of this rule and is ready to provide the services of both Departmental staff and contractors to meet and work further with the NRC staff. The revised language which we have proposed would go a long way toward resolving these concerns. In addition, although we have proposed several alternative definitions, we believe that through continued dialogue between our staffs we will be able to develop a series of definitions that will be consistent and mutually useful.

Sincerely,

Sheldon Meyers

Sheldon Meyers
Acting Deputy Assistant Secretary
for Nuclear Waste Management
and Fuel Cycle Programs
Office of Nuclear Energy

Enclosures

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COMMENTARY ON MAJOR ISSUES

The Commission requested specific comments on six issues, namely: (1) the requirement to maintain the retrievability of the waste, (2) the question of human intrusion, (3) the use of an alternative approach in placing criteria on the repository's performance, (4) the definition of a siting requirement related to population density, (5) the nature and quantity of design and construction criteria, and (6) the application of ALARA principles to the performance requirements. This enclosure contains our detailed comments on each of these questions.

The Department has identified three additional issues of a major nature that merit special consideration. These are: (1) the appropriateness of considering TRU waste in this rule, (2) requirements for sealing of boreholes and shafts, and (3) credit for site-specific factors. These issues are also addressed in this enclosure.

RETRIEVABILITY

Issue

The requirement proposed by the NRC in section 60.111(a)(2) that DOE design for a retrievability capability that extends for 50 years beyond completion of waste emplacement appears excessive in view of the site-specific considerations involved, as well as the extensive performance confirmation program to be conducted throughout the period of repository operations.

DOE Position

The duration of the period during which retrieval capability should be maintained should, as the Commission correctly states, be linked to "the expected time needed to execute the performance confirmation program." Studies conducted by DOE[1] have indicated that performance confirmation programs similar to that suggested in 10 CFR 60.137-141 are:

a. Achievable in substantially less time than the period suggested by the Commission

b. Definable only on a site-specific basis.

Having an upper bound number in the rule, as proposed, will very likely compel the Commission to wait that full period before deciding to decommission the repository, even if there would be no objective technical basis for delay beyond the completion of waste emplacement. Further, the Commission may be excessively pessimistic in its statement that "neither the specific nature nor the period needed for execution of the performance confirmation program will be certain until construction of the repository is substantially complete". The scope and timing of such a program can and should be defined as part of the license application process for specific repositories, while maintaining reasonable options for decision-making prerogatives subsequent to the completion of waste emplacement. Moving towards non-retrievability should occur with the Commission on a step-by-step basis including possible early decisions to backfill, to decommission part or

RETRIEVABILITY (continued)

all of the repository, and to determine that the retrievability period is over. Closure of portions of the repository should be permissible prior to closure of the entire repository.

Discussion

Our position on retrievability is derived from several considerations:

- <u>It is unlikely that emplaced wastes will need to be retrieved.</u> A conservative step-wise site selection program should provide reasonable assurance that the repository will function to provide long-term isolation. We presume that NRC will authorize construction and waste receipt only if this premise is substantiated. Nonetheless, it is prudent and necessary to plan for the retrieval contingency.
- <u>Confidence in the as-designed, as-constructed disposal system increases with time.</u> As repository development and operations proceed, understanding of the host rock and the natural system, as well as the waste package and near-field performance, will improve. It should also be recognized, however, that the cost and hazards associated with retrieval operations may also increase with time.
- <u>An initial period of time will be required after waste emplacement is initiated</u> to verify the performance of the specific site and the design for isolation of the wastes. During this period, performance confirmation can be achieved by direct measurement of critical parameters and phenomena. Parameters and phenomena whose effects are measurable generally reach their critical values early in the process, e.g., peak rock temperatures occur fairly early, and the actual values can be accurately extrapolated once the initial gradients and rock response are determined.

- Parameters and phenomena to be measured in a performance confirmation program will vary from site to site. For example, creep closure response may be an issue in salt but not in crystalline rock. Conversely, fracture permeability phenomena may be of little concern in salt.
- The results from the performance confirmation program should support a decision to backfill storage rooms, with such a decision acknowledging the intent to truly dispose of the waste. Backfilling and sealing of storage rooms makes retrieval more difficult but does not rule out retrieval as a future option. As backfilling represents a true disposal condition, monitoring of a representative backfilled area is appropriate as part of performance confirmation.
- The capability to retrieve does in fact exist as long as access to the repository horizon is maintained. Thus, retrieval can be accomplished at any time up until authorization for full decommissioning and sealing of the repository.

This basic approach to retrievability seems compatible with the approach taken by the NRC in the regulation. Both regard retrievability as a planned contingency. Both acknowledge the value of a performance confirmation program yielding the earliest possible results.

However, the proposed regulation deviates from this approach by stipulating that the repository must be designed so that retrieval capability is maintained for an additional period of 50 years following the last emplacement of wastes. To this the NRC suggests adding 30-year allowances for both emplacement and retrieval operations, for a total of 110 years. (This latter figure presumably would increase if emplacement activities extended for longer than 30 years.)

The staff's rationale for the 50-year increment has been presented in the Supplementary Information. It is based on an anticipation that little will be known about specifics of the performance confirmation program before

operations commence and seeks to compensate by preserving flexibility in decisionmaking options regarding repository closure. We note that within the body of the regulation, no linkage is made between the 50-year period and the performance confirmation program.

We have several concerns relative to the 50 year period and believe the supporting rationale to be unduly pessimistic, since the NRC proposed rule includes a requirement that a performance confirmation program be underway during early stages of construction (sections 60.141 and 60.142). We have always assumed that the performance confirmation program, specifically as provided in Subpart F, would be the subject of much of the NRC review of the license application.

Second, the type of information required in Subpart F can be obtained during the period of waste emplacement. Table 2, which provides summary results from one DOE study[1], is an example of how one could establish a time frame for performance confirmation. The bases for the time periods are contained in reference (1). Most of the required data can be obtained in less than one decade of repository operation. We recognize that while the time required will vary from site to site, it is highly improbable that measurements would be needed beyond the waste emplacement phase. Sufficient data will be available from the ongoing verification studies to support the closure decision at that time.

The basis for this position on the time required for performance confirmation stems from analyses of phenomena and conditions that, if developed, would warrant retrieval. Such conditions, leading to a decision to retrieve, can be categorized as follows:[1]

- Natural Events and Processes. The occurrence of totally new, unknown, and unexpected natural phenomena in the environment of an operating repository which could render it unusable.
- Geologic and Hydrologic Response to Excavation and Waste Emplacement. The design of the repository will be based on data obtained from sampling and testing and on accepted thermal, mechanical,

RETRIEVABILITY (continued)

and hydrologic models. Designs will incorporate margins of safety to accommodate reasonable assumptions of inaccuracies in such design bases. Nevertheless, abandonment of the repository, or a portion of the repository, could conceivably be dictated if performance characteristics indicate that the required degree of confidence in the predicted performance could, for some reason, no longer be provided.

- Predicted Waste Package Performance. Post-emplacement evaluations could indicate that an excessive number of waste packages have defects or that the engineered barrier design is not performing as predicted. Retrieval of some defective waste packages or of all emplaced waste could be dictated in this event.
- Repository System Operation. The repository system could be judged not operable due to either an uncorrectable inadequacy of the design basis or small but chronic inadequacies that, with time, would build to an intolerable level.
- Malicious or Inadvertent Human Intrusion and Repository Disruption.

Performance confirmation programs should address these conditions wherever feasible. However, direct measurements and observations that can be made during repository construction and operation can only contribute to assessments of performance by one of the following approaches:

- Direct observation or measurement of unacceptable phenomena.
- Observation or measurement of precursors to unacceptable phenomena; that is, observation of environments or repository system responses that could cause unacceptable phenomena sometime in the future.
- Observation or measurement of repository environments and responses to define more representative input values for predictive models, thereby improving confidence in performance predictions.

RETRIEVABILITY (continued)

These measurements and observations, and the resulting confirmation of performance (and the time required for this confirmation) will vary from site to site. However, many phenomena and conditions may not be amenable to direct measurement or observation. The following criteria should be used to exclude phenomena from performance confirmation programs following the emplacement of waste:

- The phenomenon has a very low probability of occurrence, e.g., volcanism, or glaciation, during the operational period.
- The phenomenon has very little or no significance on repository long-term performance; e.g., small movements of canisters in salt.
- The phenomenon is of such a nature that its behavior can be satisfactorily evaluated prior to the beginning of waste emplacement. This is the case for the effects of mining on rock integrity.
- There is a very high degree of confidence that the phenomenon can be eliminated through active institutional controls during the period prior to decommissioning or that decommissioning will substantially reduce the probability of impact, e.g., human intrusion or alteration of surface or near-surface utilization.

Using this approach, DOE will identify, as part of the license application, phenomena that should be addressed in a performance confirmation program.

A final argument for requiring a decision on closure of the repository much earlier than the proposed 50-year time period is to put the decision in the hands of those directly involved with the regulation and operation of a specific repository. We propose that those concerned with the initial licensing and operation of the repository are the best qualified to judge its suitability, and permitting delays for the 50-year observation period may in effect preclude these individuals from making such a decision.

RETRIEVABILITY (continued)

However, NRC correctly notes in the Supplementary Information that DOE is now, and will be making, critical decisions regarding the design of repositories which will have a direct effect upon how long the option to retrieve wastes can be reasonably maintained. We recognize the need to maintain these options on behalf of the NRC in their decisionmaking role regarding final repository closure. Therefore, we agree that fixing an upper limit on the retrievability period sufficient to provide some degree of flexibility in closure decisions is a reasonable approach at this time and this limit should be considered on a case-by-case basis during the license application review process.

Recommended changes to sections 60.2 and 60.111 to reflect these comments are included in the detailed section by section comments on the proposed rule (enclosure B, pages 12 and 21).

References

1. ONWI-203, Retrievability: Technical Considerations, Science Applications, Inc. September, 1980.
2. DOE/NE-0007, Statement of Position of the U.S. DOE (Waste Confidence Rulemaking).
3. Draft 40 CFR 191.
4. U.S. Nuclear Regulatory Commission, Proposed Goals for Radioactive Waste Management, NUREG-0300, 1978.

HUMAN INTRUSION

Issue

Deliberate and Inadvertent Intrusion.

DOE Position

The Commission's discussion of deliberate intrusion and inadvertent intrusion in the Supplementary Information of the proposed rule is well-reasoned. The Department supports the Commission's position on this issue.

We endorse the Commissions position and feel the general approach to human intrusion set forth in the Supplementary Information, e.g., avoiding resources to diminish the likelihood of inadvertent intrusion and using long-term communication and identification measures, is reasonable. The potential for exploiting mineral, energy, water, and subsurface land-use resources both now and in the future will be assessed throughout the site-selection process (i.e., via site selection criteria for the National Waste Terminal Storage Program). Beyond site selection factors, additional protective measures will be used to communicate knowledge of the existence and location of repositories to future generations.

Discussion

We endorse the position of the Commission as stated in the Supplementary Information but have a concern with respect to the Commission's consideration of resources presented under "Potentially adverse conditions," section 60.123(b)(3). Our concern is explained in the section-by-section comments on section 60.123.

A Licensing Topical Report to be issued by DOE will elaborate on long-term communication measures the Department could use to forewarn future societies of the existence of repositories, e.g., monuments.

ALTERNATIVE APPROACHES

Issue

Definition of the most effective approach for specifying the performance objectives for the geologic repository

DOE Position

The NRC should establish a level of performance for the total system and provide that multiple barriers be used for containment and control of release. DOE should be given the responsibility to analyze each site-specific system, define the boundaries of the accessible environment, and propose the barriers and the contribution of each in achieving the level of performance of the total system. In this approach, DOE should be required to show how the specific level of performance for each component contributes to the total performance requirement and the site. It will be necessary to show how the analysis of the system is internally consistent. Alternative language to achieve this approach is provided for section 60.111 among the section-by-section comments attached to this response.

Discussion

In 10 CFR 60, NRC establishes four specific performance objectives for the waste isolation system and its components. The performance objectives include the following:

1. Containment of the radionuclides in the waste package for a specified time (1,000 years).
2. Control of release of the radionuclides from the engineered system (one part in 100,000 of the inventory).
3. Minimum groundwater travel time (1,000 years) between the engineered system and the accessible environment.
4. Maximum quantities of radionuclides that can enter the accessible environment throughout the isolation period. (EPA Standard)

Sections 60.111 and 60.112 of the rule appear to give the greatest emphasis to the first three performance objectives thereby placing greater reliance on individual components than on the total waste isolation system.

ALTERNATIVE APPROACHES (continued)

We believe that this emphasis is unintentional and believe that the alternative language proposed will more properly reflect the desired intent.

The performance of the total waste isolation system will depend on the performance of each of the components that comprise the system. However, if the desired level of performance of the total system is known initially, then the required level of performance of the components must be derived from the total system performance, based on the physical conditions of any portion of the system that is already in place and cannot be changed. Independently establishing generic performance requirements for the total system and its major subsystems without recognition that they are interdependent may severely limit the flexibility of DOE and NRC to design and license the most effective waste isolation system.

We support the requirement to establish a set of regulations that will provide a basis for licensing a waste repository. However, we believe that the current version of the rule contains basic impediments that may make it difficult or impossible to reach closure in the licensing process. The potential difficulties result from the following three factors:

1. Internal inconsistencies in the proposed rule.
2. Failure to consider analysis of the contribution of various barriers, and limits the DOE's flexibility to engineer the total system.
3. Lack of clarity regarding basis for demonstration of compliance.

Internal Inconsistencies in the Proposal Rule

In the introduction to the rule, NRC states that its goal in developing the barrier performance objectives is to ensure that compliance with the draft EPA release limits can be shown. It appears that the selection of the numerical objectives were estimates based on judgment rather than quantitative models, demonstrable engineering considerations or site-specific data. However, it is not clear how the individual performance objectives are related to the EPA release limits using the techniques of performance analysis and an understanding of the geologic and hydrologic environments. The relationship needs to be based on the realities of physics and chemistry that

ALTERNATIVE APPROACHES (continued)

govern the release and movement of radionuclides. Because the proposed numerical performance objectives have no clearly defined technical basis, they appear arbitrary. They become inflexible since there can be no basis for changing them. Should they happen to be insufficient within the context of a specific application, the regulation will be criticized; and should they be too restrictive, cost will exceed what is warranted by radiological safety considerations.

An important factor in establishing the containment period was the time during which the thermal pulse is dominated by the decay heat from the fission products. An indication of the length of this period is the point when the peak temperature is reached. In the NRC Rationale document it is stated on page 28 "The maximum temperature of the repository as a whole is reached during the period of 100 to 500 years after emplacement...". On page 49 it is stated that "...maximum rock temperatures in the underground facility occur at approximately 35 years after emplacement for reprocessed waste and at 75 years after emplacement for disposal of spent fuel. By 100 years after emplacement, near-field rock temperatures have started to slowly decrease for both waste types in all four media...". The length of the containment period should be reexamined in view of these results presented by the NRC staff. Such a review might indicate that the containment period could be on the order of 300 years since the power output of the waste decreases two orders of magnitude over the first 300 years and only half an order of magnitude over the next 700 years.

In support of the 1,000 year containment period, it is argued in the NRC Rationale document that "Containment for 1,000 years also requires only extrapolation by a small factor beyond what the Department has already been considering for bedded salt...". Further, on page 31-32 it states that "Containment for 300 years...appears to be achievable at reasonable cost...". It is argued that the NRC requirement is only a modest extension of technology that is already established. In contrast, the work that is used as the basis for the NRC position is in the early R&D stages and has "the goal of estimating

ALTERNATIVE APPROACHES (continued)

the potential of a material to survive 300 years" (Magnani and Braithwaite, 19[illegible]). The cost quoted in this study ($3,[illegible]) is for the material for a canister of 304-L stainless steel surrounded by TiCode-12 and not for design, fabrication, testing, QA, and other factors to be included in determination of waste package cost. The study concludes "This material may well survive 300 years or more. However, further study is still necessary to qualify the material for such an extended lifetime." The conclusion drawn by NRC that containment for 300 years appears to be achievable at reasonable cost on the basis of this study is unjustified. The implication that extrapolation from 300 year life-time is essentially trivial is purely unsupported conjecture. The qualification of any package and its material will be based upon extrapolation of short-term tests. Extrapolation to 300 years involves significant uncertainties and extrapolation to 1,000 years can only serve to make these uncertainties greater.

Failure to Consider Analysis of the Contribution of Various Barriers

The NRC has proposed performance objectives for container lifetime, release rate and groundwater travel time for the three major waste isolation subsystems. A preliminary study of the sensitivity of the total waste isolation system to these parameters has been completed.(1). The mathematical models used to study the system included transport processes and the probabilities of important failure events. The model computed the maximum total 70-year whole body dose to the average individual in the local population and expressed the results as a fraction of the equivalent natural background dose. These three subsystem parameters for which performance objectives have been proposed were varied as a basis for evaluating the barriers for three different geologic environments.

(1) [illegible] Kuhlman, Engineered Components for High-Level Radioactive Waste Isolation Systems--Are They Technically Justified?, ONWI-[illegible], Office of Nuclear Waste Isolation, Battelle Memorial Institute (Draft Report)

ALTERNATIVE APPROACHES (continued)

The results of these calculations are compared with proposed 10 CFR 60 criteria in Figures 1, 2, and 3. Although this study used spent fuel as a source term solidified HLW from reprocessing should give qualitatively similar results. Doses resulting from human intrusion are not included in this analysis.

The effect of varying the delay time for water to penetrate the containment over a range of five orders of magnitude is shown in Figure 1. For all three geologic environments, the analysis shows that the effect of a 1,000 year lifetime package is not significantly different from that of a 100 year lifetime package. In all cases the analysis indicates that the maximum exposure is below background.

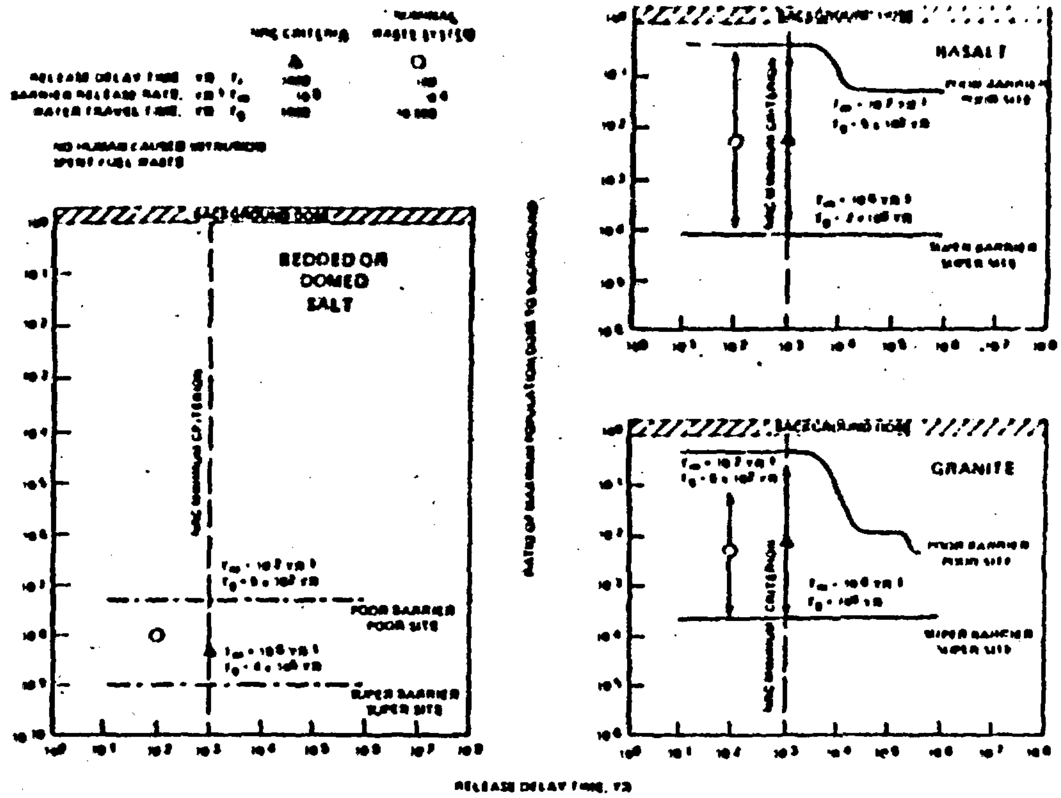
Once containment has been breached, the effect of varying the release rate over a range of four orders of magnitude is shown in Figure 2. There is no significant change in calculated population dose as the waste release rate is increased from the proposed maximum criterion of 10^{-5} fraction per year to a rate of 10^{-4} per year for a nominal repository. Of course, further reductions of release rate toward the theoretical zero release would marginally reduce computed release to the accessible environment, but it is very doubtful that the additional reduction in the maximum exposure below the already extremely low level would be justified.

The effect of varying the groundwater travel time from the waste to the biosphere over a 3,000-fold range is shown in Figure 3. The population dose decreases as the travel time is increased over the entire range for both extremes. Thus, it can be seen that the isolation system is by far more sensitive to groundwater travel time than to the performance of the engineered barriers.

(2) H.D. Hill, "The Effect of Variations in Parameter Values on the Predicted Radiological Consequences of Geologial Disposal of High-Level Waste," Scientific Basis for Nuclear Waste Management, 2, 753 (19[illegible]0).

101-V

COMPARISON OF SYSTEMATIC PARAMETERS WITH NRC CRITERIA
EFFECT OF DELAY TIME OF WATER REACHING WASTE



COMPARISON OF SYSTEMATIC PARAMETERS WITH NRC CRITERIA
EFFECT OF MAN MADE BARRIER

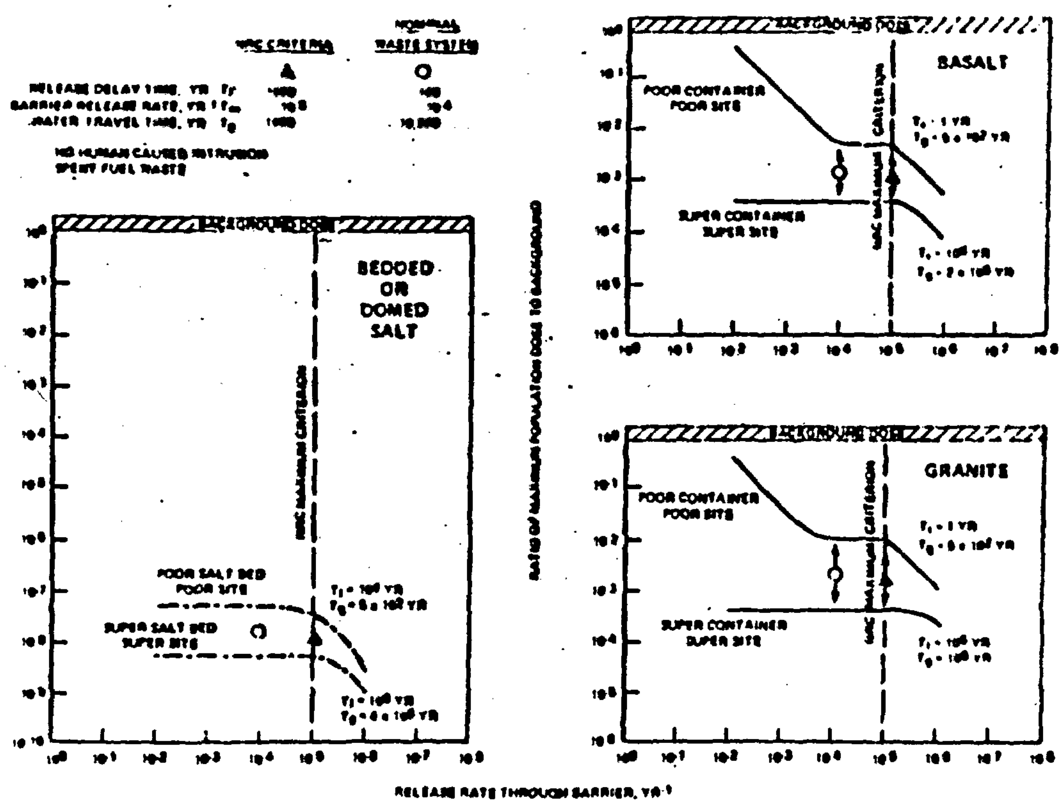
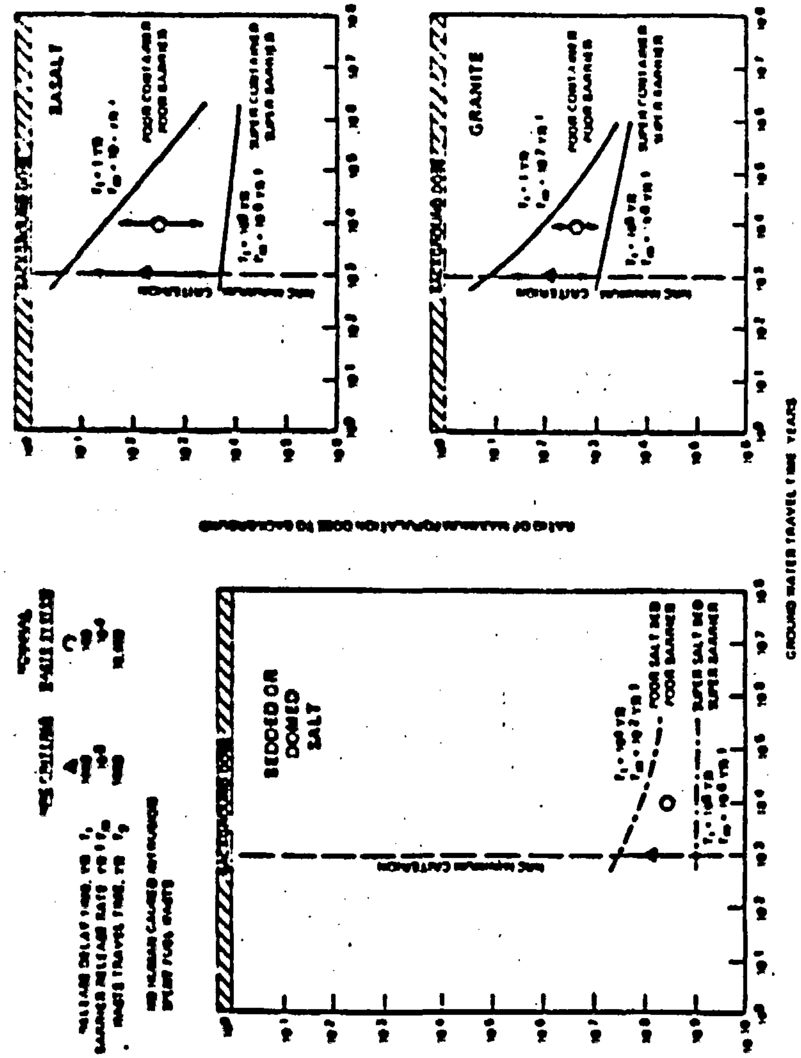


Figure 3



COMPARISON OF SYSTEMATIC PARAMETERS WITH NRC CRITERIA
EFFECT OF SITE ISOLATION

ALTERNATIVE APPROACHES (continued)

Because detailed site-specific modeling has not yet been done, these calculations were conducted to compare effects. Conclusions from these figures should not be extended to doses at real sites. However, this study does indicate the relative difference each of the barriers make in the isolation of the waste.

Another study performed by Hill (1980)[2] on high-level waste in a non-salt repository indicated that delay of initiation of waste transport could only affect maximum dose if delay time was large compared to the groundwater travel time, the time for complete dissolution of the waste form, and the half-life of the major nuclides contribution to dose.

A study performed by Sutcliff, et al. (1981)[3] which considered sensitivities and uncertainties of system performance showed that maximum discharged rates were insensitive to container lifetime.

The above mentioned studies used differing assumptions in their analyses, and yet resulted in similar conclusions. No study performed to date has shown otherwise.

In view of the results of these studies, we are concerned about the significance these specific numerical values will have on the outcome of the licensing review and recommend restructuring section 60.111 as noted in the section-by-section comments attached.

Lack of Clarity Regarding Basis for Demonstrating Compliance

The NRC explains that the engineered system is a means to deal with uncertainty in the performance of the site. However, in establishing the engineered system NRC has created additional engineering uncertainties since several of the critical concepts will lack the definitions that are necessary to facilitate design. For example, the boundary of the engineered system over

(3) W.G. Sutcliff, et al. Uncertainties and Sensitivities in the Performance of Geologic Nuclear Waste Isolation Systems, UCRL-53142, University of California, Lawrence Livermore National Laboratory, Livermore, CA (1981).

ALTERNATIVE APPROACHES (continued)

which the release rate of one part in 10^5 must be evaluated is inadequately defined. It is not clear whether the engineered system includes any of the geologic formation or whether it is limited to the waste package and the tunnel backfill.

With regard to the 1,000 years for containment, when considering a population of 50,000 waste packages, the total significance of the 1,000 years is unclear. Does it represent a mean value or a minimum value? If it is a minimum value, no waste package failure could be allowed in 1,000 years. Allowing for probabilistic variations, it must be concluded in any design that some chance of failure exists.

Another detailed issue concerns the identification of the actual failure mode leading to loss of containment. There are numerous degradation mechanisms that could lead to failure and one or two may be dominant. We have considered the issue of the elimination of the non-important failure modes that may be active over 1,000 years based on, say, 5 years experience. The data needed to allow confident selection between the important and unimportant failure modes must be carefully developed. This decision on the required data will be important for establishing a rational design basis for the waste package.

The NRC requirements state that "The engineered system shall be designed so that....the waste packages will contain all radionuclides for at least 1,000 years...." This requirement is stated in absolute terms, implying that any release before the 1,000 year period ends would constitute noncompliance.

Even extraordinarily high reliability factors and safety margins for the waste package will not meet the absolute wording of the performance objectives in the proposed rule. To achieve a single-package reliability of 0.9999 that the minimum lifetime is 1,000 years would require a median design lifetime between 10,000 years and several million years. Achieving this level of reliability even for systems that operate in the short term under relatively well-defined conditions is unprecedented. Proving that

ALTERNATIVE APPROACHES (continued)

this reliability can be achieved for a system that is to operate for 1,000 years under less well-defined conditions will be a requirement well beyond any previous engineered system. Therefore, rather than achieving the objective of reducing uncertainty and simplifying the licensing process, the use of such a waste package quantitative performance objective could, instead, complicate the licensing process with additional uncertainties. In view of the incomplete understanding of the demonstration of compliance, we recommend caution regarding the premature commitment to numerical values without fully defining their meaning and without providing flexibility to adjust the requirements for each component for specific sites in order to collectively perform to meet the overall system criteria.

POPULATION DENSITY AND SITING

The Commission has invited comment on whether population-related siting requirements should be included in the final rule, and how any requirement might be implemented. The request did not distinguish between operational and postclosure population proximity considerations. These considerations for the operational phase surface facilities are distinctly different than for postclosure.

Because air pathways are the predominant mechanism for radioactive release from surface facilities during the operational phase, the objective should be to consider release mechanisms (and the consequences of release) to the same extent they are considered in licensing other fuel cycle facilities. The regulation requires DOE to meet 10 CFR 20 requirements and EPA standards for radiological exposures or releases, thereby accomplishing this objective. DOE believes no further requirement is needed, especially given the practical considerations that:

- Low population density and distance from population centers would normally be viewed as favorable conditions.
- NRC will review each application on a case-by-case basis, and would critically analyze the proposed use of any site in close proximity to a large population or within a zone of high population density.

For the postclosure phase, population considerations do not provide a valid basis for regulation. After a repository is filled and sealed, the most likely mechanism for the escape of radionuclides to the biosphere is by dissolution and transport in groundwater. Such action is likely to occur only after the long-term decomposition of engineered barriers, thus permitting a slow rate of release into the host rock and surrounding geologic environment (the "far-field") over periods of thousands of years. There, in the far-field, natural geochemical mechanisms of sorption and precipitation would work in concert with long groundwater travel time and radioactive decay to delay and reduce any releases to the accessible environment. Because potential future release points may be distant from the repository, and future population

POPULATION DENSITY AND SITING (continued)

trends over hundreds or thousands of years also cannot be predicted, current population density near a repository has very little safety significance during the post-closure period. Release rates, or dose to a maximum individual, provide a more meaningful basis for judging the suitability of a proposed isolation system. While reference-sized populations may be useful for comparing sites or establishing limits on release, site-specific population factors should not be used as the critical basis for licensing a site.

We believe, therefore, the treatment of population in the proposed 10 CFR 60 is appropriate.

DESIGN/CONSTRUCTION REQUIREMENTS

The DOE comments on the Advanced Notice of Proposed Rulemaking (ANPR), contained in a letter dated July 15, 1980, noted that in many cases design solutions to perceived problems were incorporated into the rule rather than technical criteria or performance objectives. We note that the proposed rule is substantially improved from the ANPR in this area. We believe that sections 60.130 through 60.134 are generally at an appropriate level of detail to allow the NRC to regulate design and construction while still giving DOE the necessary flexibility to provide the appropriate design. There are still a few areas where the level of specificity is unwarranted or the rule may otherwise deviate from past practice. These are presented in the detailed comments in enclosure B.

ALARA

We agree with NRC's position not to apply ALARA to performance requirements dealing with containment and control of releases. Calculated releases of radionuclides from a repository are made far into the future. Good estimates of regional populations in the distant future cannot be made, and thus population doses cannot be calculated and the benefit of making changes to the engineered system cannot be quantitatively evaluated. Also, the natural features of a site, the geologic setting, cannot be modified once a site is chosen. Therefore, we agree with NRC's position that ALARA requirements should not be applied to repository performance requirements.

INCLUSION OF TRU WASTES IN THE RULE

Issue

Inclusion of TRU wastes in the rule.

DOE Position

We believe that it is inappropriate to issue specific requirements for commercial TRU waste disposal in this rule.

Discussion

Transuranic (TRU) waste consists of a diverse mixture of materials and equipment that have been contaminated by association with transuranics. Generally, fission product levels are very low and heat generation rates average a few hundredths of a watt per container. The physical and chemical properties of this waste inventory can be highly variable and quite unlike high-level waste (HLW).

In many cases it will be impractical to process such waste to the extent that may be required to meet the 1×10^{-5} annual fractional release rate, and in some cases, it may be impossible. A considerable body of knowledge on migration of transuranics in geologic media exists and shows that such restrictive package release rates are not necessary to protect the environment and maintain public health and safety.

Because of the variability of TRU waste it is difficult to assess the reasonableness of the NRC requirements as they are presently formulated. It is not clear that in light of the relative hazard of TRU waste as compared to HLW that the requirements in 10 CFR 60 are justifiable. Knowledge (of commercial TRU waste) that needs to be gained to determine the impact of these requirements (and in our opinion, to develop appropriate requirements) includes: 1) the quantities and radionuclide composition of TRU waste; 2) lifetime of TRU waste packages; 3) the release rate from various TRU waste

INCLUSION OF TRU WASTES IN THE RULE (continued)

forms as a function of temperature; 4) potential effects of TRU wastes on the repository performance; 5) cost of processing and packaging TRU waste; 6) hazard index for TRU as compared to HLW; 7) and the cost/benefit trade-offs of the options for disposing of TRU wastes in a repository.

Defining TRU waste in this rule as any material containing over 10 nCi/gm of activity from transuranics suggests that any such material must be disposed of by geologic isolation. The draft rule on low-level waste, 10 CFR 61, states that waste exceeding 10 nCi/gm is unsuitable for shallow land burial disposal but that other modes of land disposal giving greater confinement are possible for these higher-activity wastes and that detailed technical criteria for such disposal are to follow at a later date. We believe that separate guidance or case by case handling would be the proper way to address TRU waste and it is suggested that direct references to TRU waste be dropped entirely from the 10 CFR 60.

Such guidance should recognize the unique nature of the waste type and the hazards associated with it. It should not be merely a duplication of the high-level waste rule but based on available information on the behavior of TRU waste elements in the disposal environments including any temperature constraints, containment requirements, etc. This approach could fully consider all aspects of TRU disposal and result in requirements that provide totally adequate protection and are also practical to implement.

Finally, we are unaware of any statutory authority for Commission exercise of regulatory control over the disposal of TRU waste by DOE.

BOREHOLE AND SHAFT SEALING

Issue

How to specify requirements for borehole and shaft seals.

DOE Position

Setting criteria on the individual components of the system defeats the full utilization of the "systems approach" as discussed in the "Alternative Approaches" section beginning on page A-11. However, if NRC decides to set component criteria, it is inappropriate to allow minimum repository seal performance to vary as a function of the site's isolation capabilities (10 CFR 60.133(b)(2)).

Stating minimum performance of seals in terms of site isolation capabilities is attractive because it does not allow a good site to be compromised by inferior seals. However, if a site's permeability is so low that the best state-of-the-art seals cannot match it, then it would seem that an otherwise excellent site might have to be rejected from further consideration. That does not seem to be reasonable and probably is not the intent of the proposed rule.

Discussion

The proposed rule states: "Shaft and borehole seals shall be designed so that ... sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts and boreholes pass." This is interpreted as meaning that the radionuclide migration through a vertical column of rock containing a shaft or borehole shall not exceed the radionuclide migration through a vertical column of undisturbed rock of the same size. Thus the rule, in effect, requires that the ratio of radionuclide releases through boreholes and shafts to releases from the repository as a whole shall not exceed the ratio of the total cross-sectional area of boreholes and shafts to the horizontal areal extent of the repository.

BOREHOLE AND SHAFT SEALING (continued)

A practical application of section 60.133, with negative results, can be illustrated with a simple example comparing two potential sites. If we assume a repository of 1,500 acres (65 million square feet) and 5 shafts at 30 feet diameter each, or 3,600 square feet, the fraction of total releases that could be attributed to the shafts is 5.4×10^{-5}.

If we further assume that the best possible design for shaft and borehole seals has a total release rate of 50 arbitrary units (in terms of either dose or quantity), then, if a site is found that has a total release rate of one million arbitrary units, and if the one million units met the EPA standard, the repository would be acceptable. However, if another site could be found where the total radionuclide release was 500,000 arbitrary units, it could be disqualified because the best possible design for shaft and borehole seals could not meet section 60.133--even though this is the better site in terms of total release.

This example illustrates why the performance of sealed shafts and boreholes should not be keyed to site isolation capabilities.

Alternative Criterion

The actual quantitative specification should be developed on a site-by-site basis to suit the actual repository design and seal design conditions.

Recommended changes to section 60.133 to reflect [illegible] comments are included in the detailed section-by-section comments on [illegible] proposed rule, enclosure B, beginning on page B-40. Quantitative limits can be incorporated into Regulatory Guides as additional design information and as EPA standards become available to both the DOE and the NRC.

Finally, the term "shafts" in the sealing context includes both the vertical shaft and the access tunnel through the shaft pillar. Seals for this combination of penetrations will be designed as a system. This condition is reflected in the suggested alternative language to section 60.133(b)(1), (2), and (3).

CREDIT FOR SITE-SPECIFIC FACTORS

Issue

The NRC proposed rule does not specify credit for site-specific factors.

DOE Position

DOE feels credit for site-specific factors should be specified.

In a DOE letter to NRC, dated May 29, 1981, concern was expressed that the DOE would be required to calculate exposures from radionuclide transport, with no assurance from NRC or the draft regulation regarding what assumptions and site-specific mitigating factors might be applied in the calculations. Consequently, DOE expressed concern that the licensing process may be unnecessarily protracted by debate over the related systems-safety objective, and how it might be achieved.

Section 60.21 adequately specifies what site conditions and assessments the DOE safety-analysis report should contain, and therefore largely alleviates DOE's concern. However, as in the case of nuclear-reactor facilities, DOE suggests that NRC develop, as part of its Regulatory Guide Series, guides for implementation of 10 CFR 60. The DOE would be pleased to assist NRC staff in the development of such guides.

SECTION BY SECTION COMMENTS

This portion of our comment on the proposed rule presents comments on individual sections of the rule. To assist the reader for each section addressed we have provided (1) the NRC proposed language, (2) the DOE recommended revision, and (3) our rationale for the recommended change.

In some cases the recommended revisions reflect our positions as presented in the previous sections where we discussed several issues raised by either the Commission or ourselves. In other cases the change reflects our intent to obtain consistency, simplification, and maximized opportunity to use engineering initiative.

Discussion of the Supplementary Information Section of 10 CFR 60

This section provides much needed insight into the staff's intent and thought processes and has proved to be very helpful. We do have certain specific comments on portions of this section.

Specifically, we noted the staff's comment on earlier DOE program plans that emphasized fully saturated geologic formations. Since opportunities may arise for exploratory studies in unsaturated structures, we request that the NRC staff reexamine the rule and make whatever changes (i.e., rewording, insertion or deletions) they deem necessary to ensure that the rule will apply to all geologic media.

We wish to reemphasize our support for the development of a multi-barrier repository system. This concept is basic to our waste isolation program, as is the development of a high-integrity long-lived waste package. However, we believe that inflexible numerical criteria for individual components should not be established at this time but instead specifications should be derived from an overall system performance standard and supported by technical justification for a specific site.

SECTION BY SECTION COMMENTS (Continued)

We have noted the Commission's discussion with the NRC staff relative to the cutoff of the EPA's regulation at 10,000 years. We concur with those expressed opinions and suggest that it would be appropriate to make the Commission's position a matter of record in the rule.

In its discussion of the role of the site the staff has indicated their desire to have the Safety Analysis Report contain a projection of the expected performance of the repository, giving the rates and quantities of the expected releases as a function of time. Given this additional requirement we question the necessity of precisely specifying the performance of subsystems of the waste disposal system.

Within the discussion on the major features of the rule we note that the repository depth was required to be 300 m below the surface. This appears inconsistent with the intent of section 60.122 - Favorable Conditions and, if an editorial oversight, we trust it will be rectified.

10 CFR 60.2:

General Comments:

The comments below pertain to the definitions of terms given in the proposed section 60.2--Definitions, as well as related terms discussed under section 60.102 - Concepts; the NRC should strive to obtain consistency between these two sections and eliminate any redundancies.

The objectives of our comments are to obtain clear, consistent usage of terms within 10 CFR 60 and to strive for a consistency, or at least an understanding of the differences, of terms used by the NRC, DOE, EPA, and other interested parties. Unnecessary terms should be deleted to improve the readability of the regulation. It is proposed that the Commission consider the following recommended revision of definitions. For those revisions adopted by NRC we suggest you provide an appropriate discussion under section 60.102 based on the concepts expressed in the attached comments and rationale statements.

We are eager to work closely with the NRC staff to develop a consensus on a common set of definitions. It is proposed that discussions be held between representatives of the NRC, DOE, and, where necessary, the EPA, to reach agreement on such definitions before the rule is finalized. The attached comments would provide a useful starting point for these discussions.

10 CFR 60.2 "Accessible Environment"

NRC Proposed Wording:

"Accessible Environment" - those portions of the environment directly in contact with or readily available for use by human beings.

10 CFR 60.2 "Accessible Environment" (continued)

Recommended Revision:

Reword to be consistent with EPA definition.

Rationale:

The definition of "accessible environment" in 10 CFR 60 should be consistent with the EPA definition of the term; however, as proposed it is not consistent with the wording given in the latest draft of 40 CFR 191. Furthermore, any changes made in the EPA definition when it becomes final should be reflected in 10 CFR 60. While DOE has not developed a complete alternative definition at this time, we recommend that groundwater to be considered as part of the accessible environment should be limited to significant quantities of readily available potable water located at, or past, a distance (site specific) from the repository. Further discussions between NRC, EPA, and DOE are warranted to develop a commonly accepted definition of this term.

10 CFR 60.2 "Container"

NRC Proposed Wording:

10 CFR 60.102(e)(2) states: "The container which is the first major sealed enclosure that holds the waste form."

Recommended Revision:

Delete the term "container" and, if such a term is necessary, replace with "canister" with the following definition in section 60.2: Canister - a component of the waste package that provides the means of safely handling the waste form after production, during waste package

10 CFR 60.2 "Container" (continued)

assembly, or during any required movements or transport between the sites of production of the waste form and assembly of the waste package.

Rationale:

In the comments on The Advanced Notice of Proposed Rulemaking, DOE noted that "canister" is a more commonly used term than "container" and further that NRC's definition included the unclear term "first" and that the canister may or may not be a sealed component of the waste package. These comments still apply since, although the definition of "container" was removed from 60.2, the term "container" remains in 60.102. (Note that the definition of canister does not preclude the canister from performing an isolation function, but does permit the assignment of such functions to other components of the waste package.) References to "container" might be appropriately replaced with references to "overpack".

10 CFR 60.2 "Containment Period"

NRC Proposed Wording:

While not defined in 60.2, the discussion of "containment" in 60.102 states, "Early during the repository life, when radiation and thermal levels are high and the consequences of events are especially difficult to predict rigorously, special emphasis is placed upon the ability to contain the wastes by waste packages within an engineered system. This is known as the containment period."

10 CFR 60.2 "Containment Period" (continued)

Recommended Revision:

In section 60.2 define "containment period" as: "The time after closure of the repository when the containment of the radioactive waste must be virtually complete within the engineered system."

Rationale:

The concept as expressed in section 60.102 is not clear and would benefit from a definition in section 60.2. The discussion in section 60.102 could then be amended to explain that for HLW and spent fuel, the containment period would coincide with the time period when radioactivity levels and heat production within the waste are dominated by fission product decay. This period is more precise than the stated "when levels are high and the consequences of events are especially difficult to predict rigorously."

10 CFR 60.2 "Decommissioning"

NRC Proposed Wording:

"Decommissioning", or "permanent closure", means final backfilling of subsurface facilities, sealing of shafts, and decontamination and dismantlement of surface facilities.

Recommended Revision:

"Decommissioning" or "permanent closure" means the final backfilling and sealing of underground excavations, including main entries, shafts, and boreholes; the decontamination and dismantlement or retirement of surface facilities; the off site transport of any

10 CFR 60.2 "Decommissioning" (continued)

materials not disposed of on site; and site restoration work. This does not preclude decommissioning of portions of the repository earlier than the time of permanent closure.

Rationale:

The clarification of the excavations to be backfilled during decommissioning emphasizes the differences between "final backfilling" and room backfilling which may be performed prior to decommissioning. The dismantlement of surface facilities should not be mandatory as it may be desirable to leave portions of the facilities as markers or to employ them for other purposes; hence, retirement from use as a component of the waste disposal system should be an option. Material disposal and site restoration work should be included in the definition to ensure that such activities are considered within the scope of decommissioning activities.

10 CFR 60.2 "Disposal"

NRC Proposed Wording:

"Disposal" means the isolation of radioactive wastes from the biosphere.

Recommended Revision:

Disposal - the permanent emplacement of radioactive waste in a geologic repository to isolate the wastes from the biosphere.

10 CFR 60.2 "Disposal" (continued)

Rationale:

The definition as currently stated would appear to be applicable to storage as well as permanent placement. The recommended revision recognizes that disposal is an act which is performed with the intent to achieve isolation.

10 CFR 60.2 "Disturbed Zone"

NRC Proposed Wording:

"Disturbed zone" means that portion of the geologic setting that is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste.

Recommended Revision:

"Disturbed Zone" means that portion of the geologic setting whose physical or chemical character has changed as a result of subsurface facility construction or from heat generated by the emplaced radioactive wastes such that the resultant changes of character may have a significant effect on the performance of the disposal system. Investigations of the disturbed zone conducted in accordance with section 60.123(b) will not determine the real extent for the establishment of controls required by section 60.121(b).

Rationale:

"Significantly affected" could be interpreted to apply to any measurable effect, whether or not it would have any impact on the performance of the waste isolation system. The recommended revision ties

10 CFR 60.2 "Disturbed Zone" (continued)

the concept of disturbances to significant effects on the performance of the disposal system. Note that changes in actual values would not necessarily result in changes in character of the geologic setting. Induced changes which would not significantly affect performance should not be considered to be disturbances. Also, the proposed phrasing could be rigidly interpreted to refer to the frictional heat generated between canister and emplacement hole, because of the wording "heat generated by the emplacement of radioactive waste" rather than "heat generated by emplaced radioactive waste". Section 60.123(b) requires certain investigations to be conducted at specific distances. We recommend the addition of the last sentence to avoid the possibility that the distance, chosen for those investigations, would determine the real extent for the establishment of controls required by section 60.121(b).

10 CFR 60.2 "Engineered System"

NRC Proposed Wording:

"Engineered system" means the waste packages and the underground facility.

Recommended Revision

"Engineered System" - Includes the repository waste package, backfill and seals, and includes a portion of the host rock. The extent of this inclusion of the host rock will be determined on a case-by-case basis.

10 CFR 60.2 "Engineered System" (continued)

Rationale:

Since "underground facility" excludes shafts, boreholes, and seals, the above definition implies that these entities, along with surface facilities, are not engineered. If the intended concept is "engineered barrier system", that term should be used with a clarification in the concept section. However, note that the control of release requirement which is placed on the engineered system would, in fact, become a requirement on the waste package. While we believe that the proposed 10^{-5} release rate criterion should be dropped or modified, in the event that the Commission chooses to retain this criterion, DOE would recommend that some acknowledgement be made of the isolation capabilities of the host rock. The extent of the rock, or rocks, which will be included in the engineered system will be proposed in the license application related to a specific site.

10 CFR 60.2 "Geologic Repository"

NRC Proposed Wording:

"Geologic repository" means a system for the disposal of radioactive wastes in excavated geologic media. A geologic repository includes (1) the geologic repository operations area, and (2) the geologic setting.

Recommended Revision:

Repository - The surface and sub-surface areas where waste handling activities are or have been performed.

10 CFR 60.2 "Geologic Repository" (continued)

Rationale:

The 10 CFR 60 definition as currently written would include the geologic setting which is generally considered to be distinct from the repository but part of the waste disposal system. The repository is designed to act in conjunction with the geologic setting and the waste packages to provide isolation of nuclear wastes and to permit the necessary waste handling operations associated with waste disposal. Note the recommended definition for "waste disposal system" on page 8-15; this term should be used in place of "geologic repository" when the intent is to include the entire system.

10 CFR 60.2: "Geologic Repository Operations Area"

NRC Proposed Wording:

"Geologic repository operations area" means a HLW facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

Recommended Revision:

Delete the term.

Rationale:

Refer to our recommended revision (page 8-10) to the NRC term "geologic repository". It is suggested that "geologic repository operations area" be replaced by the term "repository". This would eliminate the need for defining an additional term which is not in general use, thereby increasing the clarity of the regulation.

10 CFR 60.2: "Geologic Setting"

NRC Proposed Wording:

"Geologic setting" or "site" is the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste.

Recommended Revision:

"Geologic setting" is the spatially distributed geologic, hydrologic, and geochemical systems at and around the site.

Rationale:

It is recommended that geologic setting not be synonymous with site. The term "site", while related to geologic setting, is sometimes applied in a broader sense than geologic setting, to mean a geographical location. An example of this appears in section 60.21(c)(1)(ii)(A) which refers to the meteorology of the site. (A recommended definition for site as a separate term is included later.) The geologic setting should be considered to be the geologic features of the site and the surrounding region. Note also that while some portions of the geologic setting provide isolation, other aspects of the geologic setting may have no role in providing isolation.

10 CFR 60.2: "Overpack"

NRC Proposed Wording:

"Overpack" means any buffer material, receptacle, wrapper, box, or other structure, that is both within and an integral part of a waste

10 CFR 60.2: "Overpack" (continued:

package. It encloses and protects the waste form so as to meet the performance objectives.

Recommended Revision:

The "overpack" is a component of the waste package to contain the waste during the containment period.

Rationale:

The recommended revision avoids listing the various possible configurations of the overpack and more clearly states the functions of that waste package component commonly referred to as a overpack.

10 CFR 60.2: "Retrieval"

NRC Proposed Wording:

This term is not defined in 10 CFR 60.

Recommended Revision:

Retrieval - The act of intentionally removing radioactive waste from the underground location at which the waste had previously been emplaced for disposal.

Rationale:

Some of the concerns over the retrieval requirements in 10 CFR 60 may be alleviated by providing a definition of the term and a discussion of the concept.

10 CFR 60.2: "Retrieval" (continued)

It should be noted in the discussion of the concept that retrieval is performed in the event that the specific waste isolation system has demonstrated an inability to meet its established performance objectives and that waste is considered to have been retrieved when it has been removed from the subsurface facility.

10 CFR 60.2: "Site"

NRC Proposed Wording:

Defined as synonymous with geologic setting.

Recommended Revision:

Site - The location, both at and below the surface, where the repository is constructed.

Rationale:

(See previous comments on geologic setting). The proposed definition conveys the fact that the site is a tract of land to be characterized and controlled by DOE. The site would include surface features within the specified area and the geologic setting underlying this area. Note that site characterization, as defined in 60.2, would actually consist of geologic setting characterization for a particular site.

10 CFR 60.2 "TRU waste"

NRC Proposed Wording:

"Transuranic wastes" or "TRU wastes" means radioactive waste containing alpha emitting transuranic elements, with radioactive half-lives greater than five years, in excess of 10 nanocuries per gram.

Recommended Revision:

Delete definition of TRU wastes in 10 CFR 60.

Rationale:

It is not appropriate to consider TRU wastes in the context of this regulation (see related comments in enclosure A, page 30). If the Commission should decide to keep TRU waste provisions in 10 CFR 60, DOE recommends that a common definition be adopted by EPA, NRC, and DOE for TRU waste and included in 60.2.

10 CFR 60.2: "Underground Facility"

NRC Proposed Wording:

"Underground facility" means the underground structure, including openings and backfill materials but excludes shafts, boreholes, and their seals.

Recommended Revision:

Delete the term and replace references to it with references to subsurface facility.

10 CFR 60.2 "Underground Facility" (continued.

Rationale

The necessity for using two terms, "underground facility" and "subsurface facility", is not obvious. The similarity between the two terms could be a source of confusion to the reader. Unless there is a specific need for both terms, DOE recommends deleting the term "underground facility."

10 CFR 60.2: "Waste Disposal System"

NRC Proposed Wording:

This term is not defined in 10 CFR 60.

Recommended Revision:

Define Waste Disposal System as: "The configuration of man-made and natural features which provides for the handling, disposal, and isolation of nuclear wastes. This system includes: waste packages, the repository, the site, and those portions of the geologic setting which provide for isolation of the wastes." Replace references to geologic repository with references to the waste disposal system.

Rationale:

(See comments on Geologic Repository.) The term geologic repository is used in the draft 10 CFR 60 to refer to the entire waste disposal system. It is recommended that this new term be introduced to more clearly describe the system.

10 CFR 60.2 "Waste Package"

NRC Proposed Wording:

"Waste package" means the airtight, watertight, sealed container which includes the waste form and any ancillary enclosures, including shielding, discrete backfill and overpacks.

Recommended Revision:

"Waste Package" means the waste form, canister, canister overpack, and any additional enclosures or materials (including backfill) that separate the radioactive waste from the unexcavated host rock.

Rationale:

The definition as currently stated in 10 CFR 60 is not consistent with the waste package concept used by the DOE program as the definition requires that the outer-most part of the waste package be airtight, watertight, and sealed (hole backfill would thus have to be within this enclosure). The components of the waste package, with the exception of the overpack and the waste form, should be optional at the discretion of the waste package designer. The recommended definition encompasses all material between the waste and the host rock, and hence by definition the waste package is in contact with the host rock. This raises concern that the 10^{-5} release rate criterion applies only to the waste package itself as it is not possible to take credit for the isolation capabilities of the host rock (see comments on the definition of engineered system). Obtaining agreement between DOE and the Commission on the definition of waste package is essential for rational discussions during the licensing process.

10 CFR 60.10(c)

NRC Proposed Wording:

As provided in section 51.40 of this chapter, ...

Recommended Revision:

None, but we wish to state our understanding of the intent of this section.

Rationale:

DOE believes that this section, when read together with the procedural provisions of Parts 51.40, 60.10(a) and 60.21(a), provides (1) that DOE is to include in its license application site characterization of alternative sites in accordance with NEPA and the requirements of Part 60.10, (2) that the information regarding the alternative sites, as identified in the Site Characterization Report, are to be described fully in the license application and accompanying environmental report, and are provided so that the NRC will be able to evaluate alternative sites in accordance with NEPA; and (3) that the standard by which the NRC will determine the adequacy of DOE's selection of alternative sites and its preferred site is whether the alternative site analysis was performed in accordance with NEPA.

10 CFR 60.10(d)(1)

NRC Proposed Wording:

Investigations to obtain the required information shall be conducted to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

10 CFR 60.10(d)(1) (continued)

Recommended Revision:

"Investigations to obtain the required information shall be conducted in a manner to limit adverse effects ..."

Rationale:

The NRC proposed language does not place the emphasis of the sentence properly.

10 CFR 60.21(c)(1)(i)(B)

NRC Proposed Wording:

The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other permeable anomalies.

Recommended Revision:

Change last phrase "or other permeable anomalies" to "or other potentially permeable features".

Rationale:

An "anomaly" is a deviation from normal, an abnormality. The statement clearly refers to salt. Although they are deviations from the majority of the salt body, solution features and breccia pipes are not unusual features in salt bodies. They are neither necessarily anomalous nor permeable; some are less permeable than some other parts of the salt body. It is, of course, important and necessary to describe and assess the significance of these features--we just don't believe it proper for the rule to state the results in a prejudicial way (i.e. "permeable").

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10 CFR 60.51(a)(2)(ii)

NRC Proposed Wording:

Placement of records of the location of the geologic repository operations area and the nature and hazard of the waste in the archives of local and Federal Government agencies, and archives elsewhere in the world that would be likely to be consulted by potentional human intruders.

Recommended Revision:

Replace "geologic repository operations area" with "repository".

Rationale:

Consistency with recommended revisions to Section 60.2.

10 CFR 60.111

General Comment:

We have noted several concerns relating to the requirements of this section in our Issue Commentary on retrievability, TRU waste, and the alternative approach. Because these concerns are so fundamental, we believe that significant revision to this section is in order. This revision could take the form of alternative language and/or the insertion of major qualifying statements. We believe that the details of alternative language might well be the topic of further interagency staff discussions and are providing revised language for portions of 60.111 for your consideration.

10 CFR 60.111(a)(2)

NRC Proposed Wording:

(2) The geologic repository operations area shall be designed so that the entire inventory of waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are complete. A reasonable schedule for retrieval is one that requires no longer than about the same overall period of time that was devoted to the construction of the geologic repository operations area and the emplacement of wastes.

Recommended Revision:

"The repository shall be designed so that any of the emplaced waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are initiated. This time period may be considered on a case-by-case basis for each repository consistent with the planned performance confirmation program. This requirement shall not preclude a decision by the Commission to allow backfilling or decommissioning part or all of the repository prior to the use of the designated retrieval period."

Rationale:

The discussion of the DOE position on retrievability, including the rationale for our recommended revision, is included in the enclosure labeled Issue Commentary.

10 CFR 60.111(b)

NRC Proposed Wording:

(Not repeated here due to length.)

Recommended Revision:

(b) Performance of the geologic repository after permanent closure.

(1) Overall system performance

The geologic setting shall be selected and the engineered system shall be designed so as to provide reasonable assurance that, following permanent closure, the release of radionuclides into the accessible environment is within the limits defined by the generally applicable environmental standards established by the Environmental Protection Agency.

(2) Performance of the engineered system

(i) Containment of waste

The engineered system shall be designed so that there is reasonable assurance that containment of the HLW will be virtually complete during the period when the radiation and thermal output are dominated by fission product decay. As a performance objective, this period of containment will be a nominal 1000 years after permanent closure of the repository unless it is established to the satisfaction of the Commission that an acceptable level of overall system performance can be achieved with a shorter containment period. Among the factors that may be taken into account in proposing an alternative containment period are the radionuclide content and the thermal output of the waste. The

10 CFR 60.111(b) (continued)

capability of the engineered system to meet the performance objective after permanent closure shall be evaluated on the basis of anticipated processes and events and the assumption, where appropriate, that available void spaces in the underground facility are filled with groundwater. During the containment period, the nominal annual fractional rate of release of radionuclides from the engineered system need not be zero but should be less than one part in 100,000 or 1×10^{-5} of the inventory at the time of release. Those radionuclides whose contribution is less than 0.1% of the curie inventory at the time of release need not be included in any consideration or calculation relative to this objective. This requirement shall not be construed to mean that there shall be no releases during the containment period; the standard of compliance will be "reasonable assurance".

(ii) Control of releases

The engineered system shall be designed so that there is reasonable assurance that any release should be a gradual process which results in small fractional release rates extending over long times, and will not cause the overall performance standard on releases at the accessible environment to be exceeded. As a performance objective this annual fractional release rate shall not exceed one part in 100,000 of the inventory after the containment period unless it is established to the satisfaction of the Commission that an acceptable level of overall system performance can be achieved at other expected release rates. Among the other factors that may be taken into account in proposing an alternate release rate are the radionuclide

10 CFR 60.111(b) (continued)

content and the thermal output of the waste. The capability of the engineered system to meet the performance objective after the containment period shall be evaluated on the basis of anticipated processes and events and the assumption, where appropriate, that available void spaces in the underground facility are filled with groundwater. Those radionuclides whose contribution is less than 0.1% of the curie inventory at the time of release need not be included in any consideration or calculation relative to this objective.

(3) No change recommended.

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Rationale:

The rationale for these changes is presented in the Issue Commentary enclosure to this response, under "Alternative Approach."

10 CFR 60.121(a)

NRC Proposed Wording:

Requirements for ownership and control of the geologic repository operations area.

(a) Ownership of the geologic repository operations area. The geologic repository operations area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use. ...

10 CFR 60.121(a) (continued)

Recommended Revision:

(a) Ownership of the site. The geologic site shall be located in and on ... .

Rationale:

DOE has substituted the term "site" for geologic repository operations area to be consistent with our recommended revision of the definition of "geologic repository operation area."

10 CFR 60.122

NRC Proposed Wording:

Each of the following conditions may contribute to the ability of the geologic setting to meet the performance objectives relating to isolation of the waste. In addition to meeting the mandatory requirements of section 60.112, a geologic setting shall exhibit an appropriate combination of these conditions so that together with the engineered system, the favorable conditions present are sufficient to provide reasonable assurance that such performance objectives will be met.

Recommended Revision:

Each of the following conditions are likely to enhance the ability of the geologic setting to meet the performance objectives of the geologic waste disposal system. The presence of one or more of any of these conditions will be considered as a favorable factor during the license application review. In addition to meeting the mandatory requirements of section 60.112, a geologic setting should exhibit one or more of

10 CFR 60.122 (continued)

these conditions so that together with the engineered system, the favorable conditions present are sufficient to provide reasonable assurance that such performance objectives will be met.

Rationale:

While we recognize the staff's intention is to enumerate conditions that would be considered as favorable attributes, we do not feel that the proposed language properly identifies the intent of the section.

10 CFR 60.122(a) and (b)

NRC Proposed Language:

(a) The nature and rates of tectonic processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(b) The nature and rates of structural processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

Recommended Revision and Rationale:

Reference is made to structural processes (in 60.122(b)) right after reference to tectonic processes in 60.122(a). The distinction between structural and tectonic processes is not clear to many, and could be interpreted differently. Therefore, we strongly urge that these terms be explained or defined clearly so that the intended distinction between structural and tectonic processes is clear to any reader or reviewer.

10 CFR 60.122(h)

NRC Proposed Wording:

(h) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having increased capacity to inhibit radionuclide migration.

Recommended Revision:

"will remain unaltered, or if altered such alternation will not reduce their capacity to inhibit radionuclide migration to an extent that the overall system performance objective would not be met."

Rationale:

The text states that mineral assemblages, when subjected to anticipated thermal loading, should remain unaltered or altered so as to have increased capacity to inhibit radionuclide migration. While this sounds good, it may rule out some otherwise favorable sites which, upon thermal loading, might have a diminished capacity to inhibit radionuclide migration but which may still be acceptable in regard to radionuclide migration.

10 CFR 60.123(a)(5)

NRC Proposed Wording:

A fault in the geologic setting that has been active since the start of the Quaternary Period and which is within a distance of the disturbed zone that is less than the smallest dimension of the fault rupture surface.

10 CFR 60.123(a)(5) (continued)

Recommended Revision:

Add: Or, where the length of the smallest dimension is unknown, a fault in the geologic setting that has been active since the start of the Quaternary Period and whose active segment is within 1 km of the disturbed zone.

Rationale:

The potential structural condition described is unclear. First, definition of the smallest dimension of the fault rupture surface is difficult. Does the Commission use last movement or total length as the critical dimension? Secondly, there appears to be no direct correlation between the nature of the fault rupture surface (earthquake fault plane) and the magnitude of an earthquake. Once the magnitude of an earthquake is defined, the peak acceleration as a function of distance can be more credibly extrapolated. We are not sure that this adverse condition, as defined, is beneficial in defining the waste isolation characteristics of the repository.

10 CFR 60.123(b)

NRC Proposed Wording:

Adverse conditions in the disturbed zone. For the purpose of determining the presence of the following conditions within the disturbed zone, investigations should extend to the greater of either its calculated extent or a horizontal distance of 2 km from the limits of the underground facility, and from the surface to a depth of 500 meters below the limits of the repository excavation.

10 CFR 60.123(b) (continued)

Recommended Revision:

"... of 500 meters below the repository horizon. Within the limits of the engineered system such investigations will be made by non-invasive methods such as geophysical sensing, wherever possible, to reduce creation of potentially adverse conditions.

Rationale:

The NRC wording could be interpreted to suggest that these investigations would be made only by boreholes or other invasive procedures within the repository boundaries. We believe that such a requirement is too restrictive and inconsistent with other portions of the rule.

10 CFR 60.123(b)(2)

NRC Proposed Wording:

(2) Evidence of drilling for any purpose.

Recommended Revision:

Add: "other than repository siting or construction."

Rationale:

The proposed languages fails to allow for exploratory activities.

10 CFR 60.123(b)(3)

NRC Proposed Wording:

(3) Resources that have either greater gross value, net value, or commercial potential than the average for other representative areas of similar size that are representative and located in the geologic setting.

Recommended Revision:

Delete " ... that are representative of and located in the geologic setting."

Rationale:

The evaluation of the resource potential at a site by comparison with an equivalent potential in a larger geographic area is a valid approach. However, we are concerned that restricting the range of evaluation to "areas of similar size" located in the geologic setting (i.e., site) may be inappropriate because unique structured formations may be unnecessarily discriminated against. Specifically, we note that a salt formation is a unique feature in the geologic setting and may be considered a resource. But the ubiquitous nature of salt does not make a particular small body of salt an important resource. We do not believe that the Commission's intent is to eliminate salt from consideration as a potential host rock, given its many particular advantages.

10 CFR 60.123(b)(9)

NRC Proposed Wording:

More frequent occurrence of earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

Recommended Revision:

Delete the section.

Rationale:

Whether there is "more frequent occurrence of earthquakes" is irrelevant; what matters is whether the frequency and/or intensity of earthquakes is at an acceptable level.

10 CFR 60.123(b)(14)

NRC Proposed Wording:

Groundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could affect the solubility and chemical reactivity of the engineered systems.

Recommended Revision:

Change last clause to: "...that could increase the solubility of the radionuclides and chemical reactivity of the engineered system, thus increasing the rate of release and migration of radionuclides.

10 CFR 60.123(b)(14) (continued)

Rationale:

As written, the emphasis is on the engineered system. We suggest that the materials of concern are the radionuclides and that the section be reworded for clarity.

10 CFR 60.123(b)(15)

NRC Proposed Wording:

Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered system.

Recommended Revision:

"...would reduce sorption of radionuclides, result in ..."

Rationale

For clarity we suggest the insertion.

10 CFR 60.124(b)

NRC Proposed Wording:

The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural conditions; and ...

10 CFR 60.124(b) (continued)

Recommended Revision:

"The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using realistic yet conservative analyses and assuming anticipated processes and events, and the evaluation used is sensitive to the adverse human activity or natural condition; and"

Rationale:

The term "conservative analyses and assumptions" could be construed to mean the speculative scenarios that have been used often in reactor siting. What is required in waste isolation is a realistic yet conservative analysis which assumes anticipated processes and events.

10 CFR 60.130(b)(1)(vi)

NRC Proposed Wording:

"A radiation alarm system to warn of increases in radiation levels,"

Recommended Revision:

"A radiation alarm system to warn of increases approaching a safety set point value below maximum permissible levels,"

Rationale:

Increases in very low levels need not be alarmed.

10 CFR 60.132(b)(1)(v)

NRC Proposed Wording:

"The alarm system shall be designed with redundancy and in situ testing capability."

Recommended Revision:

"The alarm system shall be designed with high reliability and in situ testing capability."

Rationale:

Consistent with nuclear power plant practice, not all radiation alarms in the repository operations area need be redundant.

10 CFR 60.130(b)(2)(i)

NRC Proposed Wording:

"The structures, systems, and components ... shall be designed ... to accommodate the effects of environmental conditions so as to prevent interference with normal operation ... ."

Recommended Revision:

"The structures, ... to prevent interference with necessary safety functions during the entire period of construction and operation."

10 CFR 60.130(b)(2)(i) (continued)

Rationale:

The goal of the design of safety systems should be the maintenance of the safety of the facility, not normal operations. It would be unnecessary to design the facility to operate normally through a tornado or an earthquake.

10 CFR 60.132 (d)(2)

NRC Proposed Wording:

"Ensure sufficient structural stability of openings and control of groundwater to permit the safe conduct of waste retrieval operations."

Recommended Revision:

"Ensure ... groundwater to permit the safe conduct of waste emplacement operations. Structural support shall be provided, as required to ensure structural stability of the openings upon removal of any backfill material which may have been emplaced, or upon preparation of the unbackfilled storage rooms prior to retrieval and for the duration of retrieval operations in each module;"

Rationale:

The regulation should not arbitrarily preclude backfilling emplacement areas prior to decommissioning.

10 CFR 60.132(e)(3)(v)

NRC Proposed Wording:

"The ability to construct the underground facility as designed so that stability of the rock is enhanced."

Recommended Revision:

"The ability to construct the underground facility as designed so that the stability of the rock is not significantly reduced."

Rationale:

It is impossible to "enhance" the stability of the natural formation while driving tunnels through it.

10 CFR 60.132(g)(6)

NRC Proposed Wording:

"If linings are required, the contact between the lining and the rock surrounding subsurface excavations shall be designed so as to avoid the creation of any preferential pathway for groundwater or radionuclide migration."

Recommended Revision:

Change "avoid the" to "minimize the potential for".

10 CFR 60.132(g)(6) (continued)

Rationale:

It may be impossible in a practical sense to "avoid" the contact being a preferential pathway. At the time of decommissioning, isolation will be established by the sealing system covered in section 60.133.

10 CFR 60.132(h)(2)

NRC Proposed Wording:

"Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure;"

Recommended Revision:

"Permit continuous occupancy of all open and operationally active areas ... ;"

Rationale:

- There is no obvious personnel or nuclear safety basis for this requirement. An emplacement room that has been filled can be sealed off from the repository by doors and the ventilation to that room dampered off with no safety consequences. This requirement would needlessly preclude backfilling of emplacement rooms prior to repository decommissioning and would also not allow for monitoring of backfilled areas as part of the performance confirmation program.

10 CFR 60.132(i)(2)

NRC Proposed Wording:

Barriers shall create a waste package environment which favorably controls chemical reactions affecting the performance of the waste package.

Recommended Revision:

Relocate to section 60.135 and revise to: "Backfill shall, to the extent possible, assist in creating a waste package environment ... ."

Rationale:

Barriers (backfill) alone can alter the chemical environment only to a degree, e.g., backfill cannot absorb all the oxygen that was introduced during the operational phase.

10 CFR 60.132(i)(3)

NRC Proposed Wording:

"Backfill placed in the underground facility shall be designed as a barrier.

(i) Backfill placed in the undergrond facility shall perform its functions assuming anticipated changes in the geologic setting.

(ii) Backfill placed in the underground facility shall serve the following functions:

(a) It shall provide a barrier to groundwater movement into and from the underground facility,

10 CFR 60.132(i)(3) (continued)

(b) It shall reduce creep deformation of the host rock that may adversely affect (1) waste package performance or (2) the local hydrological system,

(c) It shall reduce and control groundwater movement within the underground facility,

(d) It shall retard radionuclide migration.

(iii) Backfill placed in the underground facility shall be selected to allow for adequate placement and compaction in underground openings."

Recommended Revisions:

Relocate to section 60.132 and revise as follows:

Backfill placed in the underground facility shall:

(i) Perform its functions assuming anticipated changes in the geologic setting

(ii) Serve one, or more, of the following functions as appropriate:

(a) Provide a barrier to groundwater movement into and from the underground facility,

(b) Reduce creep deformation of the host rock that may adversely affect (1) waste package performance or (2) the local hydrological system,

(c) Reduce and control groundwater movement within the underground facility,

(d) Retard radionuclide migration.

(iii) Be selected to allow for adequate placement in underground openings.

10 CFR 60.132(i)(2) (continued)

Rationale:

This is an excessive requirement. Requiring all backfill in the repository to serve all possible functions of backfill is probably not possible and is certainly not necessary. Backfill at each location in the repository will be selected to perform a specific set of design functions which is not necessarily the same as for backfill at some other location. Backfill that is part of the waste package may be designed to keep groundwater from reaching the canister, backfill in the emplacement rooms may be designed for support, and tunnel backfill may be designed to inhibit radionuclide migration. Backfill that is a "jack of all trades" will probably be a "master of none".

10 CFR 60.133(a)

NRC Proposed Wording:

"Shafts shall be designed so as not to create a preferential pathway for migration of groundwater and so as not to increase the potential for migration through existing pathways."

Recommended Revision:

"Shafts shall be designed to minimize to the extent practicable the potential to create a preferential pathway for groundwater or radionuclide migration or to increase migration through existing pathways."

Rationale:

Shafts will continuously be preferential pathways until they are sealed at decommissioning.

10 CFR 60.133(b)(1), (2), and (3)

NRC Proposed Wording:

(b) "Shaft and borehole seals. Shaft and borehole seals shall be designed so that:

(1) Shafts and boreholes will be sealed as soon as possible after they have served their operational purpose.

(2) At the time of permanent closure sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. In the case of soluble rocks, the borehole and shaft seals shall also be designed to prevent groundwater circulation that would result in dissolution.

(3) Contact between shaft and borehole seals and the adjacent rock does not become a preferential pathway for water."

Recommended Revision:

Combine paragraphs (1), (2), and (3) into the following single paragraph:

At the time of permanent closure, shafts and access tunnel systems and boreholes will be sealed so that the seal material, the seal contact with the rock, and the adjacent rock do not become pathways that compromise the engineered system and the site's ability to meet the overall performance objectives.

Rationale:

The statement that shaft and borehole seals shall be designed so that at the time of permanent closure, sealed shafts and boreholes will

10 CFR 60.133(b)(1), (2), and (3) (continued)

inhibit transfer of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass, etc., creates a problem. It is inappropriate to specify performance criteria for shaft design and shaft and borehole seals by comparison with the undisturbed units of rock. As illustrated by the example in the Issue Commentary section of this response, for a very good site with highly impermeable rock, it may be impossible to design seals to meet the specified criterion. Thus, a very good site might tend to be rejected from consideration.

Moreover, the requirement that the contact zone between the seal and the rock does not become a preferential pathway is probably impossible to meet. Further, how we might demonstrate compliance with such a requirement by normal engineering techniques is unknown. The goal of seal design is to reduce leakage through this preferential pathway to an acceptable level.

10 CFR 60.133(c)(5)

NRC Proposed Wording:

"Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place, grappled, and ready for transport."

Recommended Revision:

Delete

10 CFR 60.133(c)(5) (continued)

Rationale:

This requirement is a design specification rather than a performance requirement. This assumes a method of hoisting waste packages that may or may not be the method actually used. Also there may be "hoists important to safety" that will never handle waste packages.

10 CFR 60.134(e)

NRC Proposed Wording:

"Control of explosives. If explosives are used, the provisions of 30 CFR 57.6 (explosives) issued by ... shall be met.... ."

Recommended Revision:

Delete.

Rationale:

This paragraph is needlessly redundant to 60.130(b)(10).

10 CFR 60.134(f)

NRC Proposed Wording:

"Water control. The construction specifications shall provide that water encountered in excavations shall be removed to the surface and controlled in accordance with design requirements for radiation control and monitoring."

10 CFR 60.130(v) (continued)

Recommended Revision:

Delete "for radiation control and monitoring."

Rationale:

Prior to emplacement, there is no public health and safety reason for treating the water as if it were contaminated.

10 CFR 60.143(c)

NRC Proposed Wording:

The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.

Recommended Revision:

Either delete the section or replace the word "shall" with "may", in both locations.

Rationale:

We believe that requiring the performance of laboratory experiments in which field conditions are simulated at the same time that in situ testing is under way is unnecessary and technically ill-advised. We agree that on a site-specific or medium-specific basis, ongoing testing in laboratories may be desirable, but such testing could easily

10 CFR 60.143(c) (continued)

be initiated or continued if deemed needed at that time. To require such a testing program would unnecessarily restrict scientific judgment or engineering flexibility from the confirmatory program.

10 CFR 60.150(a)

NRC Proposed Wording:

Quality assurance is a multidisciplinary system of management controls which address safety, reliability, maintainability, performance, and other technical disciplines.

Recommended Revision:

"Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements."

Rationale:

We suggest using the wording above which comes directly from 10 CFR 50, Appendix B.

10 CFR 60.151

NRC Proposed Wording:

The quality assurance program applies to all systems, structures, and components important to safety and to activities which would prevent

10 CFR 60.151 (continued)

or mitigate events that could cause an undue risk to the health and safe of the public. These activities include: exploring, site selecti-e, designing, fabricating, purchasing, handling, shipping, storing, c eaning erecting, insta'ling, emplacing, inspecting, testing, operating, main-taining, monitoring, repairing, modifying, and decommissioning.

Recommended Revision:

"The quality assurance program applies to all systems, structure and components important to safety and to those activities which wou'd prevent or mitigate events that could cause an undue risk to the health and safety of the public. These activities include: site character'za-tion, facility and equipment const-uction, facility operation (including performance confirmation), and decommissioning. Construction comprises all those activities that are required to build a rep sitory."

Rationale:

All site characterization activi-ies, not just exploring or site selecting, should be subject to quality assurance programs.

Suggest lumping all activities into four categories: (1) site characterization, (2) facility and equipment construction, (3) facility operation (including performance confirmation), and (4) decommissioning. This categorization would seem to be consistent with the wording in section 60.102(d). Construction is an all-inclusive term which comprises equipment, materials, design, fabrication, examination, testing, inspec-tion, and all those activities required to build a facility (Reference: ASME Code Section III, NCA-1100).

Also, suggest deletion of section 60.153 (see comments on section 60.153).

10 CFR 60.153

NRC Proposed Wording:

The quality assurance program sha'l include the program of tests, experiments and analyses essential to achieving adequate confi-dence that the emplaced wastes will remain isolated from the accessible environment.

Recommended Revision:

Delete section 60.153.

Rationale:

Performance confirmation is addressed in Subpart F of the proposed regulation and will be conducted during the repository's opera-tional phase. It would be more appropriate to include performance confirmation in section 60.151 as one of these activities subject to quality assurance. This paragraph is redundant and should be deleted.

emp

COVINGTON & BURLING

November 3, 1981

(49)

PR-60
(46 FR 35280)

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTN: Docketing and Service Branch

Re: Disposal of High-Level Radioactive Wastes in Geologic Repositories, 46 Fed. Reg. 35280 (July 8, 1981)

Dear Sir:

These comments, submitted on behalf of Kerr-McGee Corporation and Kerr-McGee Nuclear Corporation (Kerr-McGee), are addressed to 10 C.F.R. Part 60, "Disposal of High Level Radioactive Waste in Geologic Repositiories".

Proposed § 60.2 defines transuranic wastes (TRU) to mean "radioactive waste containing alpha emitting transuranic elements, with radioactive half-lives greater than five years, in excess of 10 nanocuries per gram." Kerr-McGee objects to this definition to the extent that it suggests that deep repository disposal is required for all TRU waste with this activity or above or to the extent that it classifies TRU waste in excess of 10 nCi/gm as "high level" waste. The definition, if so applied, appears unjustified, unsupported, and unduly stringent. 1/

Based upon Kerr-McGee's current decommissioning experience with a mixed oxide fuel plant, Kerr-McGee estimates that NRC's proposed TRU definition, if applied to require deep repository disposal, would increase the need for geologic storage volume to hold high level waste from similar operations by at least a third over that which would be required if the definition specified a level of 100 nCi/gm. Requiring deep repository disposal would unduly tax limited space in such repositories.

1/ Kerr-McGee also objects to the definition to the extent that it is intended to be a standard on the ground that NRC lacks authority to issue such standards. That authority was transferred to the Environmental Protection Agency (EPA) under Reorganization Plan No. 3 of 1970 (assuming arguendo the validity of the transfer of authority under that Plan).

11/9/81 emp

Page Two --

The "10 nCi/gm" limit appears to be totally arbitrary. The AEC Manual indicates that it was established without scientific support and is simply "derived from the upper range of concentration of radium-226 in the earth . . . ." AEC Manual, Chapter 511 at p. 51 (Sept. 19, 1973). Indeed, the manual suggests that the 10 nCi/gm figure is subject to revision upon further study. Deep repository disposal, which will be very expensive ($200 per cubic foot or more) obviously should not be required on so flimsy a foundation. TRU waste which is in excess of 100 nCi/gm may be satisfactorily disposed in near surface facilities as low-level waste, at only a fraction of that cost (10% or less). Requiring deep geologic disposal for ordinary waste from a plutonium fuel operation would place an unnecessary burden on such operations.

Kerr-McGee's view is supported by the epidemiological investigation being conducted by the Los Alamos National Laboratory. The investigation examines the impact of low level exposure from internal deposition of and external radiation from plutonium. As reported by a press release from the Los Alamos National Laboratory dated October 15, 1981, considerably lower mortality was observed in the population of Los Alamos workers exposed to plutonium than would be expected from the mortality rate of white males in the United States. Kerr-McGee's view is further supported by the Department of Energy which reportedly does not believe that deep repository disposal is required for TRU waste in excess of 10 nCi/gm.

Kerr-McGee accordingly requests the Commission to make clear (1) that deep repository disposal is not required for TRU waste in excess of 10 nCi/gm and (2) that TRU waste in excess of 10 nCi/gm need not be disposed of as "high level" waste.

Respectfully submitted,

Peter J. Nickles
Charles H. Montange

Attorneys for Kerr-McGee Corporation and Kerr-McGee Nuclear Corporation

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emp

Carl Walske
President

November 5, 1981

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PROPOSED RULE PR-60
(46 FR 35280)

The Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Chairman Palladino:

We separately submitted to the Secretary of the Commission on November 5, 1981 comments on the proposed rule on technical criteria, "Disposal of High-Level Radioactive Wastes in Geologic Repositories". A copy of these comments is enclosed.

Continuing discussions between the AIF group that prepared the comments and the NRC staff have resolved certain differences between the two. A number of important differences, however, remain, some of which may be accommodated in the next printing of the proposed rule. Nonetheless, we expect the next printing to be sufficiently different from the proposed rule published on July 8, 1981 and from the rule that we believe should be adopted to warrant the NRC's seeking further public comment on the rule, once it has been reissued.

Further, we do not believe that 10 CFR Part 60 should be published in final form for adoption until EPA has published the standards to which the NRC rule should conform. Adherence to this sequence of regulatory actions would, we believe, simplify further proceedings involving the two rules. We have written to EPA Administrator Anne M. Gorsuch urging publication of the EPA standards at the earliest possible date.

Sincerely,

Carl Walske

CW:gee
Enclosures

11/9/81 emp

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DOCKETED
USNRC

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emp

Carl Walske
President

November 5, 1981

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PROPOSED RULE PR-60
(46 FR 35280)

Secretary of the Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Docketing and Service Branch

Re: Comments on Proposed Rule 10 CFR Part 60. Disposal of High-Level Radioactive Wastes in Geologic Repositories. Technical Criteria.

Dear Sir:

The AIF's Working Group on 10 CFR 60, the members of which are listed in an attachment hereto, has prepared the enclosed comments on the NRC's proposed rule setting forth technical criteria for disposal of high-level radioactive wastes in geologic repositories. Part I of the enclosure responds to the six specific issues on which the NRC requested special comment. Part II includes detailed comments on specific sections of the proposed rule.

The enclosed comments reflect a difference of opinion between the Working Group and the NRC staff on philosophical approach as well as on certain specific technical details. This difference of opinion has persisted on major issues since publication of the Advance Notice on May 13, 1980, though numerous discussions with the NRC staff have resulted in some desirable modifications. Additionally, the NRC staff has indicated its willingness to make further modifications. Although these [illegible] show up in a variety of ways throughout the [illegible] comments, most of them can be reduced to the following:

- The proposed rule calls for [illegible] performance criteria for each of the major components of the repository system in addition to meeting as yet unissued EPA standards for the system. The Working Group believes the proposed rule should permit a systems approach where the designer has the latitude to adjust each of the components to meet the overall performance requirement set by EPA. The NRC approach could unnecessarily eliminate adequate geologic sites, does not allow alternate solutions to meeting overall requirements and could result in a poor cost-to-benefit ratio. By using the NRC criteria as guides rather than requirements, we believe that the prescribed safety goals can be achieved in the most cost effective manner.

- The proposed rule specifies containment of all radionuclides for the waste package for a period of 1,000 years following permanent closure of the repository; and, after the first 1,000 years, an annual release rate of not more than one part in 100,000 of the inventory of any radionuclide present. The NRC staff has failed to justify these requirements either by modeling or by other calculational techniques. Therefore, these performance criteria should only be used as guides.

- The 50-year period established for retrievability cannot be justified on either cost-effective or institutional grounds. If, as we understand from the NRC staff, the 50-year period is intended as guidance rather than as a mandatory requirement that would foreclose backfilling at an earlier date, the rule should so indicate.

- Although the EPA has been developing standards for off-site protection of public health and safety, those standards have not yet been issued for comment. In the several years during which they have been under development, the system performance criteria have been changed. There is no certainty that they will not be changed again. While there is every expectation that EPA standards will be met within the framework of the NRC proposed rule, it would be premature for NRC to promulgate 10 CFR Part 60 in final form until EPA standards have been issued and adopted.

A final observation that extends beyond the general comments set forth above, and beyond the detailed comments enclosed, is that the proposed rule in its present form is unduly complex. There are numerous ways in which it could be simplified to the advantage of DOE as the licensee as well as to those in NRC who will be responsible for its implementation.

In light of the above, we respectfully request that the rule in its present form be reworked and reissued for comment. Although we appreciate that such action could delay promulgation of a final rule by as much as a year, it is our understanding that such a delay would not adversely impact DOE's schedule for bringing a waste repository into operation.

Sincerely,

Carl Walske

CW:gao
Enclosures

8.106

Comments on Proposed 10 CFR 60
prepared by
AIF Working Group

The following comments are in two parts, both of which have been prepared by the AIF Working Group on 10 CFR 60. Part I responds to NRC's request for comments on six specific issues. Part II expands on some of the comments provided in Part I and also addresses additional sections of the proposed rule.

Part I. Comments requested in the proposed rule by the NRC on six specific issues.

1. Retrievability (46 FR 35282): The Commission seeks comments on the degree to which the 110-year requirement for retrieval will govern thermal and mechanical design of the repository, on whether some shorter period would be adequate and on whether there are ways other than an overall retrievability requirement to preserve options before permanent closure.

The AIF Working Group on 10 CFR 60 accepts the principle of retrievability. However, we feel strongly that regulations should not preclude closing shafts or drifts in sections of a repository that have been filled after a reasonable assessment has been completed of the performance characteristics of that section of the repository. It is our understanding from discussions with NRC staff that the rule will not require that drifts be kept open. The specific retrievability period is meant to be a design criterion rather than an operational one. A technical paper* by the Office of Nuclear Waste Isolation notes that the period of retrievability will depend on the length of time to demonstrate performance and will be site and design specific. The paper shows that a test period of about 3 - 5 years is needed to reach a decision point. We believe that adequate monitoring can be maintained throughout the emplacement period. Thus a 50-year

*Wayne A. Carbiener, "Retrievability: The NWTS Position:, Battelle, Office of Nuclear Waste Isolation, "Waste Management '81", ANS Topical Meeting, Tucson, Arizona, February 23-26, 1981.

observation time following waste emplacement is excessive. However, a reasonable retrievability period would not be a major problem if sections of the repository can be partially or entirely backfilled prior to the end of the retrievability period.

2. Human Intrusion (46 FR 35282): The Commission seeks comments on alternative approaches to the human intrusion question.

The discussion of human intrusion is logical and practical and places this issue in clear perspective; namely, that intrusion into the repository is a low probability event unless it is the result of a deliberate and conscious decision to do so in which case proper precautions will be taken. This conclusion is based on the requirements proposed in 10 CFR 60, which call for selection of sites having minimal resource value, reliable documentation of the site, and the placement of appropriate site markers. Thus, in response to the request for comment on this approach, we conclude that the proposed approach to the human intrusion issue is reasonable.

3. Alternative approaches (46 FR 35283): The Commission seeks comments on three alternative approaches for prescribing the performance criteria for a geologic repository.

1. "Prescribe a single overall performance standard that must be met. The standard in this case would the EPA standard;
2. "Prescribe minimum performance standards for each of the major elements, in addition to requiring the overall system to meet the EPA standards; and
3. "Prescribe detailed numerical criteria on critical engineering attributes of the repository system."

The Commission prefers Alternative 2 as a "reasonable and practical compromise" between a single overall performance standard and detailed criteria on the critical attributes of the repository system.

In our comments on the FR May 13, 1980 Advance Notice of Proposed Rulemaking. we noted:

> "The approach being taken by the NRC is not consistent with the objective stated on page 31396 nor with the 'systems approach' recommended by the IRG. We believe that the NRC should be establishing appropriate criteria and standards for the performance of the overall system, rather than defining specific performance values for individual components. The systems designer (DOE) should have the flexibility, for example, to permit optimum trade-offs between the waste form and the container design as long as the overall system meets those criteria that insure public health and safety."

We have carefully considered the NRC staff's comments and logic supporting its preference for Alternative 2. However, we continue to recommend an overall systems approach to the design of a geologic repository. By this we mean that the engineered features and the geologic features of a repository would be optimized to work together to meet the overall performance objectives of the repository. We find no well defined technical justification for specific numbers, such as a 1000-year containment period for a waste package. Many decisions remain on the final choice of a repository, the waste form, and the design of a waste package. The design values that might be required for one site could very well be different for another site. Thus, prescribing a specific set of design criteria in the proposed rule could be overly restrictive, and would not give the system designer the flexibility to make trade-offs desirable to optimize a system that would meet overall performance objectives.

NRC requests those who recommend Alternative 1 to indicate ways in which NRC "might find reasonable assurance that the ultimate standards are met without prescribing standards for the major elements of a repository." We do not understand the basis for the concern implied in this request. Only one applicant, DOE, will be applying for a license for a high level waste repository, and this applicant is carrying out a thorough and integrated implementation process. Thus, NRC should be able to find "reasonable assurance" through careful review of DOE's analytical, experimental and decision-making processes that DOE is meeting the goals of Alternative 2. There would appear to be no basis for writing the rule as though there will be a number of applicants of varying backgrounds and qualifications undertaking parallel projects.

While continuing to support an overall systems approach, i.e., Alternative 1, if the NRC believes it necessary to define quantitative performance criteria for the various components of a repository, we strongly recommend that these criteria take the form of "design guidance", not minimum or fixed criteria. This "design guidance" should permit the designer flexibility in choosing specific design parameters on a specific case basis, as long as the overall system performance objectives can be shown to be attainable. We have reflected this latter approach, which in a sense is a combination of Alternatives 1 and 2, in our specific comments on the proposed rule.

4. <u>Population-related siting requirements (46 FR 35284)</u>: The Commission seeks comments on whether population-related siting requirements should be included in the final rule and how they might be implemented.

Because of the inherent safety of the geologic repository, especially during the containment period, the distance between the repository and a large population center is immaterial from a safety standpoint. From a practical standpoint, political considerations will undoubtedly prevent a repository from being located near a larger population center. Furthermore, projection of population movements beyond the containment period would be highly speculative and would not be governed by any rule written in 1982. Therefore, we conclude that a population-related siting requirement is not needed.

5. <u>Design and construction criteria (46 FR 35285)</u>: The Commission seeks comments on formulations for the design and construction criteria in the rule.

The requirements given in the proposed rule are much too detailed. Many of them more properly belong in supporting documents such as NRC Regulatory Guides. Only those design and construction requirements which are important to safety should be included in the rule. Also, "important to safety" needs to be defined. Our proposed definition is given in Paragraph 60.2. Detailed recommendations are given in the comments on Section 60.130-60.135 under the heading "Design and Construction Requirements".

6. <u>ALARA (46 FR 35299)</u>. The Commission seeks comments on whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases.

We believe it is unnecessary to apply an ALARA principle to the performance requirements dealing with containment and control of releases from a geologic repository. If the overall system performance criteria are satisfied, the risks to the health and safety of the public from high-level waste disposal will be so low as to be inconsequential. Thus, expenditure of additional effort to further reduce the risk would be unwarranted. Furthermore, it is not evident that exceeding the performance requirements for waste-package containment and control of releases would have any significant effect on further enhancing overall system performance. Finally, since there would be no basis for determining whether ALARA had been achieved, individual judgment would have to apply which could lead to endless and futile debate between the regulator, applicant and intervenors. We conclude, therefore, that ALARA should not be applied to the performance requirements, and that reference to ALARA should be removed from the discussion of performance objectives in the Supplementary Information.

<u>Part II Comments on Specific Issues of 10 CFR Part 60 Technical Criteria - Disposal of High Level Radioactive Waste in Geologic Repositories.</u>

<u>p. 35281 (Background)</u>. Comment: The term "saturated zone" as used here and elsewhere in the regulation is misleading, and could be interpreted in different ways for different geologic circumstances. We suggest using the term "beneath the groundwater table."

<u>Para. 60.2 Definitions</u>.

Some of the definitions are unclear. In the suggested versions that follow, new wording is underlined.

"Accessible Environment" means those portions of the environment <u>outside the geological repository operations area</u> and directly in contact with or readily available to human beings. <u>For surface access, the accessible environment is defined as the site boundary; for groundwater flow, the accessible environment is defined as the point at which the groundwater enters a potable surface or near surface water body</u>.

"Decommissioning" or "permanent closure" means <u>the sealing of subsurface openings consisting of shafts, boreholes, and all or part of the underground excavation with a barrier system consisting of an appropriate combination of engineered structures and backfill; the decontamination and dismantlement of surface facilities; and completion of all other appropriate site restoration work.</u>

"Far field" means the portion of the geologic setting that lies beyond the <u>geologic repository operations</u> area.

"Geologic repository operations area" means a HLW facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted. <u>It is an area which encloses the physically disturbed zone, and extends at least 0.5 km laterally beyond the limit of openings mined and developed for the repository operations.</u>

"Important to safety," with reference to structures, systems and components, means:

a) <u>those items essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or</u>

beyond the nearest boundary of the controlled area during facility operations;

b) those features of the waste package that are necessary to control, within specified performance limits, the release of radioactive materials to the geologic environment after permanent closure; and

c) those aspects of the subsurface facility and the geologic setting that are necessary to assure that releases of radioactive materials to the accessible environment following permanent closure conform to the overall system performance objectives.

Discussion:

"Important to safety" is a designation used to identify those items and activities that provide reasonable assurance that the radioactive waste can be received, handled, and stored without undue risk to the health and safety of the public. Special design, procurement, construction and quality assurance requirements are applied to such items to assure that they retain their safety functions under all normal and abnormal conditions.

Features or aspects of the repository system that are needed to assure that the performance objectives for the system are satisfied after permanent closure are also considered "important to safety."

"Medium" or "geologic medium" is a rock type which could be used for a geologic repository.

"Stability" means that the geologic processes and their rates of operation during the Quaternary (or late Cenozoic) period have been identified and do not jeopardize containment or isolation when projected to future times.

Additional clarification is requested for the following:

"Biosphere" used in the definition of "Disposal" should itself be defined.

"Geologic setting of site" is not clear because the intended meaning of "Geologic system" and "Hydrologic system" is vague. Is a geologic system a topographic feature,

structural feature, structural or tectonic province, or region characterized by a particular assemblage of rock types? Is a "Hydrologic system" a groundwater basin or a single artesian aquifer? :

Add the following definitions:

> "Containment period" means the prescribed period following repository closure, when the radiation and thermal levels of the waste are high, during which special emphasis is placed upon containing the waste by the waste package.

Para. 60.21 Content of application

Item 60.21(c)(1)(i) If literally interpreted, these requirements could be a tremendous task to complete. More precise definition of "in the vicinity" and the multiplicity of required observations should be addressed.

Item 60.21(c)(3) The last sentence of this item requires that the SAR include a "comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation." This is inappropriate in a Safety Analysis Report which should focus on the particular design being proposed. This type of comparative evaluation, which is really a cost/benefit analysis, should be in the repository Environmental Impact Statement if it is done at all. Furthermore, the way the requirement is stated puts no limit on the number of alternatives to be evaluated. Such a requirement should ask for a description of alternatives that have been considered.

Para. 60.101 Purpose and nature of findings

To be consistent with proposed changes to Paragraph 60.111, it is suggested that Item 60.101(a)(2) be changed to read as follows:
(new section in quotes)

> Item (a)(2) While these performance objectives and criteria are generally stated in unqualified terms, it is not expected that complete assurance that they will be met can be presented. .....For 60.111 and other portions of this subpart that impose

objectives and criteria for repository performance over long times into the future, "it is recognized that proof of performance of engineered systems and geologic media during such long time periods is not available in the ordinary sense of the word. However, even though less than perfect performance of individual components of the repository system might occur, collectively they provide a degree of redundancy such that there can be a high level of confidence that satisfactory repository system performance will be achieved. Thus reliance is not placed on any single system component at the risk of compromising the performance of the overall system. Therefore, these objectives should be viewed as design guidance rather than rigid requirements. The general standard should provide reasonable assurance, based on the record before the Commission, that these objectives will be met, making allowances for the time period and hazards involved. These objectives provide flexibility to permit appropriate system trade-offs and allow for incorporation of future technological developments. Such changes will be acceptable provided that it is shown that a comparable level of repository system performance is predictable.

<u>Para. 60.102 Concepts</u>

Item (b)(4) Addressing TRU waste in this rule is inappropriate since the Commission has not yet established regulations dealing with the disposal of TRU. Furthermore, the requirements for TRU in this rule could set inappropriate precedents with respect to future TRU regulations that might be proposed. Therefore, it is strongly recommended that all reference to TRU waste in this rule be deleted. Accordingly, it is recommended that paragraph 60.102(b)(4) be changed to read as follows:

> "Item (b)(4) HLW includes irradiated reactor fuel as well as reprocessing wastes. However, if DOE proposes to use the geologic repository operations area for storage of radioactive waste other than HLW, such as transuranic-contaminated waste (TRU), the requirements pertaining to the storage of such radioactive waste will be established on a case basis and/or in accordance with such other applicable regulations as may be promulgated by the Commission."

It is noted that HLW is also TRU waste, especially following the 1,000 year containment period. That is, it contains more than 10 nanocuries per gram of transuranic elements. Clearly, the term "TRU waste" is not intended to include HLW. Therefore, a more quantitative definition of TRU waste is needed.

<u>Para. 60.111 Performance objectives.</u>

Item (a)(1) Add a paragraph on accident dose limit, as follows:

> "The dose or dose commitment to any individual located at or beyond the site boundary during the facility operations period shall not be greater than 5 rem to the whole body, or to any organ, from any design basis accident".

This definition is based upon and is consistent with the definition of accident dose limit in 10 CFR 72.

Item (a)(2) A number of commentators have expressed concern about the specified length of the retrievability period, thinking that the requirement implies that all mine openings must be maintained for the length of the retrievability period. Although we do not believe that this was the NRC intent, for clarity, it is suggested that Item 60.111(a)(2) be reworded as follows:

> "The geologic repository operations area and the waste package shall be designed so as not to foreclose the option of retrieving the entire inventory of waste on a reasonable schedule starting at any time during a designated retrievability period that follows completion of waste emplacement operations. The design objective for the retrievability period should be 50 years unless it is established that a shorter period is justifiable. This design objective is not to be construed as prohibiting the closure or backfilling of all or part of the underground structure during the retrievability period, nor is it intended to preclude decommissioning during this period. A reasonable schedule for retrieval is one that requires about the same overall period of time as was devoted to the original construction of the repository operations area and the emplacement of wastes."

Proposed changes to Item (b)(2) Performance of the engineered system

As indicated in the comments on alternative approaches, if NRC believes it necessary to define specific performance criteria for the various components of a repository, we recommend that these be in the form of "design guidance" and not fixed criteria. To accomplish this, it is suggested that parts of Paragraph 60.111 be changed to read as indicated below. The proposed revisions include the EPA proposed 10,000 year time period over which performance is to be evaluated, as well as the recommendation that reference to TRU waste be deleted. Also incorporated are proposed performance objectives for subsurface facility seals that would replace those in Item 60.132(i), 60.133(a) and 60.133(b).

Item (b)(2)(i) Containment of wastes

> "The waste package shall be designed to provide containment of radionuclides during the time period when the potential hazard from the short-lived radionuclides and the effects of the waste thermal loading on the geologic setting are significant so as to provide added assurance that the overall geologic repository system performance objective will be met. As design guidance, the containment period should be * years after permanent closure of the repository, unless it is established that an acceptable level of geologic repository system performance can be achieved with a shorter containment period. The design basis containment period shall be evaluated on the basis of anticipated processes and events and the assumption that the quantity of groundwater available to interact with the waste package, following permanent closure, is the maximum predicted under anticipated conditions. This evaluation need not consider unlikely processes and events."

*To be established by the NRC on the basis that this time period (designated in the 7/8/81 draft rule as 1,000 years) provides confidence that the overall system performance objective will be met.

Item (ii)(A) Control of releases

> "For HLW the engineered system shall be designed so that, in the time interval from the end of the containment period to 10,000 years following permanent closure, the release rate of radionuclides to the geologic setting, will assure that the repository system performance objective is met. As design guidance, the annual release rate of any radionuclide should be at most one part in * of the maximum amount of that radionuclide calculated to be present in the waste deposited** in the underground facility (assuming no release from the underground facility) at any time during the specified time interval, unless it is established that an acceptable level of geologic repository system performance can be achieved with a higher release rate. The design basis release rate shall be evaluated on the basis of anticipated processes and events and the assumption that all available void spaces in the underground facility, following permanent closure, are filled with groundwater. This evaluation need not consider unlikely processes and events nor radionuclides that constitute less than 0.1% of the total inventory of radionuclides predicted to be present in the waste at the end of the containment period."

We recommend that Item (3) Performance of the geologic setting be changed as follows:

Item (i) Containment period

> "During the containment period, the geologic setting shall mitigate the impacts of postulated but credible failures of components of the engineered system. The ability of the geologic setting to isolate wastes during the isolation period in accordance with paragraph (b)(3)(ii) of this section shall be deemed to satisfy this requirement.

*To be established by the NRC on the basis that the release rate (designated in the 7/8/81 draft rule as one part in 100,000) provides confidence that the overall system performance objective will be met.

**Control of releases should be limited to those from the wastes alone. As it is presently written, the language could be interpreted to include radionuclides naturally occurring in the medium.

Item (ii) Isolation Period

"During the time interval from the end of the containment period to 10,000 years following permanent closure, the geologic setting shall be capable of inhibiting the transport of radionuclides released from the engineered system into the geologic setting to assure that the overall geologic repository system performance objective is met. The capability of the geologic setting to perform this function shall be evaluated based on the assumption that those processes operating on the site will be those that have been operating on it during the Quaternary Period, with perturbations caused by the presence of the emplaced radioactive waste superimposed thereon."

We recommend that an Item (4) Performance of subsurface facility seals be added as follows:

"Prior to or at the time of final closure, subsurface openings consisting of shafts, boreholes, and all or part of the underground excavation shall be sealed with a barrier system consisting of an appropriate combination of engineered structures and backfill. The functions of this barrier system are the inhibition of radionuclide transport through the pathway consisting of the interconnected network of subsurface openings with the objective of providing additional assurance that the overall geologic repository system performance objective is met; the inhibition of groundwater movement into and from the underground facility; and, where required, the reduction of creep deformation of the host rock that could adversely affect the performance of the geologic repository. The capability of this barrier system to perform these functions shall be evaluated considering the ambient geochemical and hydrological environments and anticipated changes thereto, anticipated changes in the geologic setting including anticipated rock deformations, and other applicable in-situ conditions."

60.112 Required characteristics of the geologic setting

Item (c) should be deleted as a required characteristic as it is more properly included under "Favorable conditions", Item 60.122(f)(4). However, if Item 60.112(c) is retained, the meaning of "accessible environment" should be clarified as suggested earlier under 60.2 "Definitions".

Para. 60.122 Favorable Conditions

This paragraph contains language such as "...shall exhibit..." which could lead to the interpretation that these are mandatory requirements like the preceding ones. This is in conflict with the statement in the introduction (p. 35284) that these are not absolute requirements but merely considerations entering into a judgmental determination. This should be expressed in this paragraph, the heading should be deleted or changed from "requirements" to "considerations", and "shall" be replaced by "should" wherever it occurs.

The language concerning projections of tectonic, structural, hydrologic, geochemical, and geomorphic processes into the future (items (a) through (e)) should acknowledge that more stringent standards apply for the first 10,000 years than thereafter.

Item (f)(3) calling for "...inhibition of groundwater flow... along shafts, drifts or boreholes" is difficult to satisfy if taken literally. Instead of a positive effect (inhibition), it should merely say that rock types that facilitate establishment of preferential pathways along shafts, etc., are undesirable or require specific countermeasures. Therefore this item should be placed under Para. 60.123 Potentially Adverse Conditions.

The language in Item (f)(4) "...substantially exceed 1,000 years" is unnecessarily vague, and should be replaced by "...or at least 1,000 years".

Para. 60.123 Potentially adverse conditions

In Item (b), the demand for "investigation...to a depth of 500 meters below the limits of the repository excavation" without specifying the type of investigation, is excessive. Non-invasive techniques (i.e., seismic) are reasonable, but invasive techniques (drilling or shaft sinking) would unjustifiably degrade the integrity of the host rock.

Item (b)(2) is considered too restrictive since it may eliminate too many otherwise desirable sites. It would be illogical to preclude drilling--with appropriate precautions--for the purpose of site characterization, and preexisting drillholes should be evaluated with consideration of depth, plugging and sealing, casing left in the hole and general care of execution (include documentation). It must also be recognized that there is a potential for the existence of undocumented drillholes within the operations area.

In Item (b)(3), the gross value of a resource, without regard to extraction cost, is a meaningless basis for comparison. Commerical potential is the only valid measure for judging the likelihood of future attempts at   raction.

Item (b)(8) is too stringent. Wide area uplift or subsidence are both very common and without effect on the integrity of the host rock. The real intent of this item, to the extent it is practical, is already expressed in (b)(7).

<u>Para. 60.130 - 60.134 - General design requirements for the geologic repository operations area.</u>

A HLW repository is expected to have few, if any, structures, systems or components which are designated as "important to safety" in order to assure protection of the public against undue radiological risk during the repository operations period. Thus, it should not be necessary for items 60.130 through 60.134 to deal so extensively with design and construction requirements for items "important to safety" that will not be present or functional after the following operations period has passed. For example, it is recommended that the following sections be deleted as they provide unnecessary regulatory detail and may imply a level of design assurance not necessitated by the safety function of the items involved:

> 60.130(b)(2)(i), 60.130(b)(4)(iii), 60.130(b)(4)(iv), 60.130(b)(5)(i), 60.130(b)(6)(ii), 60.130(b)(6)(iii), 60.130(b)(6)(iv), 60.130(b)(7), 60.130(b)(9), 60.133(c), 60.134(a), and 60.134(g)

Item 60.130(b)(1) - Paragraphs (i) through (vi) of Item 60.130(b)(1) could be eliminated without significantly changing the regulatory content of the section since these requirements are implicit to meeting the requirements of Part 20.

Item 60.130(b)(1)(vi) - The type and extent of redundancy in the radiation alarm system should be specified if this requirement is retained. For example, is redundancy of

the detection instruments sufficient or is it intended for the redundancy to include the annunciators and the electrical power supply? It is not apparent that any redundancy should be specified as this tends to prejudge the design and the extent of the hazards involved. (Note that 10CFR 72 does not require redundancy for the radiation alarm system. If the wording of 10CFR 72 is appropriate, it is recommended that it be used without change in 10 CFR 60.)

Item 60.130(b)(2) - The intended difference between Items (i) and (ii) is not clear. Both paragraphs deal with anticipated natural phenomena and environmental conditions for the design of structures, systems and components important to safety. Paragraph (i) applies to interference with normal operation during the period of construction and operations, while Paragraph (ii) applies to failure to achieve the performance objectives in any relevent time period. Therefore, Item (ii) would appear to encompass all of the requirements of Item (i).

Since an "anticipated event" is defined as one that is "reasonably likely to occur during the period the intended performance objective must be achieved", is it the NRC intent that important-to-safety items required for the operations period be designed to retain their safety function for a 100-year earthquake, and that the engineered barriers used for long-term protection be designed to withstand a 10,000-year earthquake? The NRC intent needs to be more clearly expressed.

Item 60.130(b)(9)   The statement that "systems shall be designed with sufficient redundancy to ensure that adequate margins of safety are maintained" is vague. The statement should be deleted or if retained rewritten as follows;

> "When instrumentation and control systems are necessary to monitor and control the behavior of engineered systems 'important to safety', they shall be designed to cover anticipated ranges for normal operation and for accident conditions."

Item 60.130(b)(10) - In the context of this paragraph, the statement that the repository operations area shall "include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions" makes no sense. This paragraph should be rewritten with the intent clarified.

<u>Para. 60.131 Additional design requirements for surface facilities in the geologic repository operations area</u>

Item 60.131(a) - The waste package design may preclude the need for a decontamination facility for waste containers in the surface facility; e.g., if the self-shielded package design is used. Thus, this section of the rule is too design specific and should be modified accordingly. Furthermore, "wastes" cannot be decontaminated.

Item 60.131(c) - This section contains requirements that are very similar to those of Section 60.130(b)(1). It is recommended that these sections be combined in Section 60.130.

<u>Para. 60.132 Additional design requirements for the underground facility</u>

Item 60.132(a)(1) - The commission's intent for the additional design requirements for the underground facilities, listed as Item (1), is too broad. The NRC should define what is meant by "interactions among geologic setting, the underground facility, and the waste package."

60.132(c)(1) - Delete "or retrieval" since if waste retrieval occurs, concurrent excavation activities would, in all likelihood, stop -- and would surely stop if retrieval operations were impaired. Even with this change, it is not clear why this separations criterion should be a regulatory requirement. Deletion of this section is recommended.

Item 60.132(d)(2) - If retrieval occurs, the regulations should be sufficiently flexible to allow for re-excavation of original openings, excavation of new openings, and the addition of new underground features for the control of groundwater. This paragraph should be revised accordingly or deleted.

Item 60.132(e)(1) - Since backfill may be added soon after waste emplacement, it may not be necessary to maintain

stability for all subsurface openings throughout the operations period, but rather, for a much shorter period only and before local bulk temperatures have increased significantly. Thus, this paragraph appears to be overly restrictive in requiring all openings to be designed to maintain stability throughout the operations period.

Item 60.132(e)(3)(v) - This is an impossible requirement. Creating any subsurface opening cannot enhance stability of the rock. The word "enhanced" should be replaced by the words "not unnecessarily diminished" or this item should be deleted.

Item 60.132(f) - This paragraph seems to preclude any method of excavation except continuous mining. The paragraph should be deleted since there is a more appropriate statement contained in 60.134(d) that deals with damage to and fracturing of rock.

Item 60.132(g) - The extent to which water and gas control needs to be established for repository design is dependent upon the specific site and rock medium being used. For this reason, some of the requirements in this section may not be applicable or appropriate to a specific repository design. The section should state, therefore, that the requirements apply only where appropriate, or those requirements that are not generic to all sites and media should be deleted. Sections (g)(1) through (g)(6) should be replaced with the following:

> "Water and gas control shall be provided, as appropriate, to control and monitor the quantity of water or gas in the subsurface facilities during the construction and operation periods."

Item 60.132(h)(2) - It should not be required to ventilate all excavated areas through the time of permanent closure. Many areas will be closed to personnel or backfilled. This requirement if retained would impose an enormous load on the ventilation system and would require the sinking of additional vent shafts. This item should be deleted.

Item 60.132(h)(4) - The requirement for redundant and fail safe features of the subsurface ventilation system should be determined on a case-by-case basis based on "important to safety." For example, under emergency conditions, air packs may provide an adequate backup to a non-redundant ventilation system in the event of system failure.

Item 60.132(i) - This section on engineered barriers should be deleted. Subparagraphs (1), (3)(i), and (3)(ii) should be covered by a new performance objective added to 60.111 (see proposed Item 60.111(4)). Subparagraph (2) is adequately covered in 60.135. Subparagraph (3)(iii) is unnecessary since this requirement must be met to fulfill the backfill functional requirements specified in the new performance objective of 60.111.

Item 60.132(j)(1) - This paragraph calls for "positive, fail-safe designs." These issues can only be addressed on a site specific and design specific basis. Therefore we recommend that the words "to have positive, fail-safe designs" be deleted, and specific criteria be developed in Regulatory Guides.

Item 60.132(k)(2) This item should be deleted since the items are adequately covered by 60.132(k)(1). Also, Item 60.132(k)(2)(iii) makes no sense. What will cause the temperature in the repository to cycle?

<u>Para. 60.133 Design of shafts and seals for shafts and boreholes</u>

Item 60.133(a) and (b) We suggest that these items be deleted and covered by a new performance objective as proposed in Item 60.111(4).

Item 60.133(c) - Paragraph (4) calls for a reliable system of interlocks. This is unclear. What are the interlocks supposed to do? Also, Paragraph (c)(5) is unclear and, depending on the system design, might not be applicable. This paragraph seems to assume a particular type of system, which is inappropriate in the regulation.

<u>Para. 60.134 Construction specifications for surface and subsurface facilities</u>

Item 60.134(a) - In effect, this paragraph states that the requirements of this regulation shall be met. This paragraph should be deleted.

Item 60.134(b) - It appears inappropriate and unnecessary for the regulations to require that "construction specifications shall facilitate the conduct of a construction management program" that will ensure construction does not adversely affect site suitability and that the facility is constructed as designed. This paragraph should be deleted or restated to clarify the intent.

Item 60.134(f) - This paragraph requires all water brought to the surface be monitored for radioactive contamination. This is overly restrictive and could be very expensive. There is no reason to expect that water from areas undergoing excavation will be contaminated since these areas will be separate from areas where waste is emplaced. There is also little reason to monitor water from areas containing waste since waste packages will be clean when they are transferred to the underground facility and the probability of an undetected failure of package containment during the construction phase is essentially zero. This requirement should be carefully reconsidered so as not to impose unnecessary and expensive restrictions on repository construction.

<u>Para. 60.140 General requirements</u>

Item 60.134(g) - Construction specifications are not the appropriate vehicle to provide for demonstration of waste handling equipment under operating conditions. While testing of equipment for waste package emplacement and retrieval will be required, it will most likely be performed by repository operating personnel as part of the post construction test program. Therefore, this requirement is inappropriate in this section of the regulation and should be deleted or placed in Subpart F - <u>Performance Confirmation.</u>

<u>Para. 60.135 Requirements for the waste package and its components</u>

Item (a)(1) and (a)(2) are highly redundant. Furthermore, some of the factors to be considered, as listed in Paragraph (a)(2), are not even applicable to the site (e.g., hydriding of the host rock is certainly not a factor to be considered). It would be more appropriate to combine these two paragraphs into one entitled something like "Waste package/site interaction effects:"

Item 60.140(a)(2) This item requires that the performance confirmation program ascertain that components designed or assumed to operate as barriers after permanent closure are functioning as intended and anticipated. In many cases it will be impossible to ascertain that a barrier is functioning as intended. For example, how will one confirm that the tunnel backfill is functioning as a barrier if there is little groundwater available? In such a case, one will have to depend on design, knowledge of material properties, and analysis to predict that the backfill will perform its function. Thus, this should be reworded to allow for flexibility in the methods of performance confirmation.

AIF Working Group on 10 CFR 60 -
Technical Criteria

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October 30, 1981

(51)

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Secretary of the Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Docketing and Service Branch

SUBJECT: Proposed Rule 10 CFR Part 60
Disposal of High-Level Radioactive Wastes
in Geologic Repositories (46 CFR 35280)

Gentlemen:

We have reviewed the subject proposed rule and wish to submit the following comments for your consideration:

1. We endorse the basic comments and position of the American Nuclear Society as stated in its letter of October 14, 1981. Specifically, an overall performance criterion for the entire repository system would be superior to the individual subsystem performance criteria in the proposed rule.

2. The proposed 50-year retrievability period (60.111(a)(2) should be approached with caution and deliberation. Considerable thought and detailed analysis must be applied to the negative impacts of long-term retrieval upon long-term isolation. Establishing an arbitrary 50-year retrieval requirement at this time appears to be based upon little logical rationale to support the general concept or the specific time interval. Until such rationale is thoroughly explored, the possibility exists that a long-term retrieval requirement might actually increase the risk to the health and safety of present and future generations.

   - What is the rationale for 50 years versus shorter or longer intervals? The logical interval should be a function of the uncertainties concerning the site geologic system, the waste form and package, and their interactions. Thus, the retrieval interval could and should vary, dependent upon the chosen site and waste form and package.

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   - Longer retrieval intervals require numerous facility design features and operating procedures that tend to degrade the repository's long-term isolation capabilities. For example, considerable additional support structure would be required which certainly would make backfill and natural closure less reliable sealing processes. Also, much more material would be removed from underground openings as they attempt to creep and close, and the consequent degree of surface subsidence and geologic deformation would be somewhat greater. The long-term isolation confidence would thereby be reduced.

   - A 50-year retrieval interval might very well preclude a given material as a viable host rock even if that material should prove to be the best choice for long-term isolation. Therefore, retrieval options must be balanced against long-term isolation requirements. Much more study is required in this area before long-term retrieval can be accepted as the best approach. For example, retrieval in a period of time about equal to that during which the waste was emplaced would require that all the underground shafts, main corridors, and ventilation ducts be kept open for over 100 years before retrieval ends. This long period of access may be possible in highly plastic salt but would be very costly and could increase risk both to workers operating the repository and to the public.

   - Considerable funds, manpower, and material would be devoted to keeping a long-term retrieval repository open and operable. Those limited resources would possibly be better allocated elsewhere in the repository.

   - Again, the length of the retrieval interval should be weighed carefully against the overall functional requirements of a repository before establishing arbitrary and invarying criteria.

Thank you for your consideration of our comments and position.

Respectfully yours,

STEARNS-ROGER ENGINEERING CORPORATION

Arthur M. Krill

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Project Executive

AMK/dgm

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emp

Comments on:

Nuclear Regulatory Commission

10 CFR Part 60

Disposal of High Level Radioactive Wastes in Geologic Repositories

(52)

PROPOSED RULE PR-60
(46 FR 35280)

Comments by:

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These views are formed on the basis of the extensive research for over ten years at the largest and most broadly based nuclear waste research effort at any independent institution. They do not represent any official view of the university, or the research group, but are the personal views of the author.

11/9/81...emp

General statement

I believe the 10CFR60 rule is moving in the right direction, as compared to many earlier attempts to assure the maintenance of radionuclide levels below the EPA standards. The principal novelty in 10CFR60 is the dual reliance on :

a) The waste package (=containment)

b) The geologic isolation system (= isolation)

instead of exclusive reliance on the latter. The argument developed in the text (p. 35281, col. 3) that the waste package performance is more easily measured and guaranteed is very sound. The issue of what the precise wording (p. 35289, col. 2) .. "the waste packages will contain all radionuclides for at least the first 1000 years ... after permanent closure .." means, needs to be clarified. I have two comments on this:

a) There can, in principle, be no such thing as zero release of anything. Hence it would be better to provide some reasonable numerical or percentage limit.

b) Up to now there has been so little measurement of the total waste package effectiveness in retaining radionuclides that no one - DOE, NRC, or EPA - could possibly know whether these are reasonable or unreasonable limits.

The enormous DOE and smaller but regrettably parallel NRC effort in "leach testing" of waste forms is, of course, totally irrelevant to determining this value - release of radionuclides from the waste package. The rationale for any waste form-in-water evaluation has never been publicly presented mainly because it has never been clearly thought about. I append hereto one document relevant to the issue on how to evaluate waste packages and the danger of continuing leach tests. I note as additional evidence of the community swing to this view, that when I again presented my critique of the leach test concept at the Julich meeting in June 1981, the French and Belgian groups went much further than I, in criticizing the continued use of these absurd tests.

Can a well designed waste package "contain all radionuclides" for 1000 years in a water saturated repository? No one knows. In my opinion many systems will be able to meet these specifications, provided that no catastrophic tectonic activity is around which could shear through the canister, and admit large volumes of flowing water. In a static water saturated repository with minor leaks in canister, etc. using a metal or concrete matrix waste form, a titanium canister, a cold Cs-Sr doped overpack in compacted clay or concrete, at a repository thermal limit of 250°C and 200 bars pH_2O, one can estimate that essentially all radionuclides will be contained within the package.

Since it will be at least 50 years before any commercial waste repository starts to function, DoE R&D on the waste package can reasonably be expected to meet these specifications. Furthermore, since so little research has been supported as compared to engineering, step function innovation is possible, indeed highly likely.

Comment on separate specs on containment and isolation

I believe that the rule is overly cautious in not permitting any credit for the linear sum of containment and isolation especially for fission product ions. Surely as long as no nuclides reach the biosphere in 1000 years it is enough. Risk analysis on catastrophic repository failure can be factored in, but credit for the adsorption and isolation should not be excluded.

Comment on retrievability (60.111, a(2))

I support the NAS CRWM study on geologic criteria in its criticism of the 50 (-110) yr retrievability concept. This is bound to damage the final quality of the repository. It may exclude salt altogether. Most importantly, it eliminates the grouting concept which may be the safest procedure (including worker exposure).

I believe an alternative can be a demonstration phase to prove out the area, and the procedures, etc., on site using cold nuclides in a full scale pilot demonstration of any mined or grouted repository. This could be monitored for 20 years before NRC approval for the real version go-ahead. The latter would then use the optimum technological situation instead of compromising the technology for the regulation.

Comment on "Control of Releases" (60.111, b(2) ii)

I appreciate the fact that it is extremely difficult to word such regulations. The annual release of 10^{-5} of the total α-radionuclide content strikes me as awkward.

Can this be attained by the technologies available now or likely to be developed in the next 50 years - the minimum time we have? On the basis of very extensive research in our laboratories such levels could be attained in partitioned wastes with present technology. That is not the most significant question. The technology can, with increased costs, simply add layers of protection of many kinds. For example, the Belgian Pamela process (glass beads in a lead matrix) would certainly add some orders of magnitude of actinide insolubility to any waste package if substituted for bulk glass. But is it worth it? Why not put the funds saved by going to a much more cost effective technology - grouting or in-can solidification in a cement matrix composite - into improving other parts of the N-waste or hazardous waste, or radiation hazards, threats to health.

Appendix to Comments by R. Roy on NRC 10CFR60

This is part of Chapter 10 in the book Radioactive Waste Disposal, Part II: Solid Phase Immobilization System
Pergamon Press, Spring 1982

WASTE PACKAGE EVALUATION:
Leach Tests: wrong target; wrong conditions

In the attempt to evaluate the waste package, three very serious scientific errors were committed, starting in the early fifties, and persisting to this day. The first error is to equate the waste form with the waste package. A glance at Figs. V, XX and the figures below will show that this is a ludicrous assumption, namely: that by measuring the radionuclide release from the waste form, one will be able to deduce the radionuclide release from the waste package. The second major error was a misunderstanding of the relation of thermodynamics and kinetics. Tests were devised under conditions which were easy to accomplish in the laboratory—e.g., at temperatures from 25-90°C rather than those which were expected in the repository (up until the mid-seventies, this design temperature was 300-500°C). It was then expected that by measuring at a few temperatures in the range 25-90°C, one could extrapolate to higher temperatures. The error, of course, is that the reaction(s) which occur(s) at the higher temperatures may well be completely different from those which occur at low temperatures. In this event, absolutely nothing can be learned about the high temperature processes by studying in great detail the lower temperature processes.

As the multibarrier nature of the waste package itself became more widely understood, a third error was introduced. This was the concept of the "linear sum" of radionuclide release. According to this concept, the waste form, canister, overpack, rock etc. do not interact at all as a system (in other words, there is no simultaneous chemical reaction between, say, waste form, solution and overpack). Hence one could study waste form dissolution, then corrosion of canisters, then overpack interaction with solution etc. The models were very naive. For example, the overpack adsorption of ions putatively released from the waste form were calculated, but never the reaction of the ions released from the overpack with the waste form.

Since the middle seventies, work in this laboratory has in fact radically transformed the concept behind testing of the waste package. Before dealing with the practice and results of such alternative tests, we need to look in more detail at the so-called "leach tests" as they are performed.

Previous and Current Practice of the Leach Tests; and Some Results

Although there are a large number of variations, essentially leach testing consists of soaking either powder or a solid specimen in water—either distilled or deionized—at temperatures between 25°C and the boiling point. Pruncheviez (22) lists thirteen individual variations of leach test arrangements that have been used in the U.S., Canada, and Europe. In 1978-79 in an attempt to standardize leach testing practices, the Materials Characterization Center established by the DOE set up, tentatively, a new standard "leach test." This test requires the following procedure:

> "Monolithic" specimens are suspended by teflon monofilaments into a leachate at 90°C in a static environment. The ratio of geometric surface area to specimen volume is maintained at $1x10^{-1}$ mm^{-1}. One leach test container is to be used for each test. The resulting leachates are to be analyzed and the solution analyses reported as normalized leach rates at a given test time in g/m².

A very large body of data exists (which we will not refer to in detail) on the leach rates of borosilicate and phosphate waste glasses,* the better materials yielding cesium or other alkali leach rates of $1x10^{-5}$ to $1x10^{-7}$ grams per sq.cm. per day (23,24). Comparably detailed data in regard to concentration of radionuclides, exposure of radiophases, etc., have not been reported for all alternate waste forms. However, many of the data reported on the more developed ceramic forms such as the tailored ceramics of McCarthy and Ringwood and some cement forms all fall in the range from $1x10^{-5}$ to $1x10^{-9}$ gm/cm² (25,26,27). This is an important and key finding of the "leach rate" data. The scatter in the data within a laboratory due to procedure and sample to sample variation is not less than a factor of 10. Including different samples made by and measured by different laboratories, the scatter is at best between 10^1 and 10^2. But the leach rate differences between a good cement encapsulant sample, a good glass, and a good polycrystalline ceramic is probably within the $\pm 10^2$ scatter, although the order of increase of the dissolution rate is probably in the order above.

From dissolution rate measurements, a certain amount of knowledge has been accumulated on the mechanisms of the leaching reactions.

The leach rate of waste glasses typically decreases with time and increases with temperature. The fall-off in the leach rate of glasses is assumed to be due to the buildup of surface barrier layers, but few detailed characterizations of waste form surfaces have been made. Analysis of the outer few micrometers of leached simulated glasses (24) revealed a complex superposition of inward-diffusing hydrogen, outward-diffusing alkali and alkaline earth metals, and a buildup of barrier layers of some rare earths and transition metals. For the same reaction, the leach rate appears to increase exponentially with temperature and probably exhibits Arrhenius behavior—that is, a linear relationship between the logarithm of the leach rate and the reciprocal of the absolute temperature.

Analogous studies on the kinetics and mechanisms of dissolution of the principal ceramic radiophases and on ceramic aggregates have been underway in our laboratories, under the direction of W.B. White and his colleagues (27). These data show for example the very slow dissolution rate of pollucite and the even slower rate of monazite, and also the major changes

*See Appendix I for some of the details.

which can occur with changes of pH (in the case of pollucite, the dissolution rate is hardly closely proportional to H_3O^+ activity.

In exactly analogous vein to the pH influence, the oxidation potential, Eh, of leaching solutions influences the rate of dissolution of variable valence elements. As a general rule, for the heavier elements, higher oxidation potentials yield more soluble species. Examples include uranium (and the transuranics) in which U^{6+} compounds are far more soluble than U^{4+} compounds, and the technetium in which Tc^{7+} compounds are both soluble and volatile, whereas Tc^{4+} compounds are refractory and probably very insoluble. Few dissolution measurements of waste packages have taken account of oxidation potential and little is known about the rates at which, for example, the uranium in spent fuel, would oxidize to a more soluble form. There is a great deal of data on UO_2 stability as a function of pH and Eh.

Conceptual Errors in Using the Leach Test to "Evaluate the Waste Form"

The most important of the errors has already been pointed out above. One cannot meaningfully evaluate the waste form outside the specific waste package system in which it is embedded. If the waste, canister, overpack and/or host rock interact, there is no direct connection between the leaching data obtained in de-ionized water, and those which would be obtained in the chemical potential dictated by some real waste package.

However, the errors do not end there. Certainly any evaluation of the waste package should consider both the normally functioning mode and failure modes. It is clear that we must consider the most probable failure modes as well as the less likely ones. In Fig. 22 below we illustrate the two key variables involved in a repository failure. The first is the solution: solid ratio during the time of reaction, and the second is the ratio of the time for transit of a volume of solution through the waste package compared to the time for equilibration of the solution with the solid phases of the waste form, canister, overpack and rock.

The much more probable failure mode is one in which relatively small amounts of liquid breach the waste package, and the transit through the package is relatively slow (compared to the equilibration time). This means that an evaluation of the waste package for the high probability failure defines two experimental conditions:

a. a low water:solid ratio.

b. an essentially static or closed system test, since equilibrium is obtained between the solution and all the different solid phases of the waste package.

Using the same argument, containment failure is most likely when the temperatures in the repository are highest. This temperature can of course be adjusted by design—with considerable impact on cost and repository size—but it seems to vary from 100°-450°C for various currently proposed national systems. Hence it is clear that waste package evaluation should be carried out at these temperatures (and pressures).

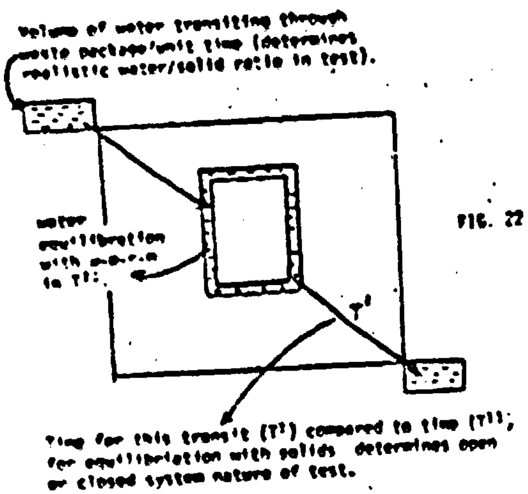

FIG. 22 Shows components of realistic waste repository and the actual solid phase immobilization system which is an interactive set consisting of waste-overpack-rock-metal-solution (w-o-r-m-s). The most probable failure scenarios are those in which T'>T'' for the solution transit through the waste package compared to the equilibration time. T'' from lab experiments at temperatures of say 200°C is in the order of months.

c. at modest temperatures and moderate water pressures:

Fig. 23 below shows that the "leach test" conditions fail to simulate all three of the most significant parameters which would describe the environment of the repository in the most probable failure mode

The question may therefore be raised: Are there any conditions where the leach test data may apply? One less likely failure could be a great increase in the volume of fluid phase, and more rapid transit of the fluid. Indeed the more rapid transit will lower the temperature somewhat. But even in such a case, while the direction of change from the repository simulation will be *towards* the leach test conditions, it will not remotely approach those conditions.

The more significant question is Are the leach test data merely meaningless or can they be positively misleading? Here the new results coming from the new repository-simulating tests begin to speak for themselves. The use of leach data to rank waste forms as a means of qualifying or rating waste forms or waste package is grossly misleading and hence dangerous nonsense. The temperature, the pH, the overpack composition can completely invert the order of radionuclide release from two different waste forms. Here the simple-minded use of leach data (with the limitations already noted) can therefore mislead national policy by suggesting that a particular waste form may be more "leach resistant" than another, when in fact the reverse may be true, or there may be no differences whatsoever. Given the nature of the typical waste form, especially the glasses, and the typical overpack and rock, the leach test is almost certain to overstate by some orders of magnitude the source term of ions supplied for migration.

The Alternative: The Repository Simulation Test

The reasoning developed above suggests that to evaluate meaningfully the waste package performance, at least under the most probable failure conditions, any test should simulate the repository with respect to the following parameters.

a. temperature (and pressure)

b. chemical potential of all species caused by the rock, canister, overpack

c. water:solid ratio, and closed-open system

Having been involved since 1948 in experimental petrology research to simulate the p,t conditions of the earth's crust at various depths, it was natural that The Pennsylvania State University group introduced *hydrothermal experimentation* to the radioactive waste management community for evaluating waste forms (28). These hydrothermal studies simulated the (a) condition much better than the MCC-type leach tests. Moreover, in the very first paper on hydrothermal waste form reactions, we explicitly recognized the influence the host rock would have on the reactions. We next introduced the practice of incorporating waste-rock interaction under repository p,t conditions as a means of waste package evaluations (29). Over the next few years, experiments, numbering in the several thousands, were performed to evaluate the stability of waste forms using methodologies developed in these laboratories and at the Carnegie Institution in Washington over the last three decades (30). Pieces of the waste form and the host rock were sealed into noble metal tubes with small amounts of water and held for periods of time up to 1 and 12 months maximum, which our experience has shown provides a not unreasonable simulation of reactions found to occur in geological times. (The lower the temperature, the less reliable this approximation.) Thus these experiments, in our judgment, most closely simulated the effects likely to be encountered in a repository failure--low water:solid ratios, and an effectively closed system. We then first extended this work (31) to the open system simulation involving the rock and the waste form. These flow-through experiments where water saturated in various rocks at elevated p,t was allowed to react with the waste form, at elevated p,t. The most recent test put into place has been as a result of the work we have done on overpack or backfill reactions. This overpack material now appears to be the most *significant part of* the chemical environment seen by the waste form, and it must be included as part of the closed (or open) system being evaluated. The overpack (backfill) is also by far the most easily "engineered" of the barriers, which will influence the chemical environment of the repository. Hence the backfill-solution-waste reactions will dominate the repository simulation environment, except in the case of rock salt (where the backfill will still be very influential). Next, it was shown that while the canister may be quite inert it must also be included in the experiment since it does react differently in different environments.

The tests of the waste package system which at present appear to be the most useful in providing the best experimental simulation of the waste package-in-repository environment are as follows:

1. A physical assemblage not unlike a scaled-down version of waste package: Surrounding a pellet of waste form in a series of concentric layers of canister metal, overpack, and host rock; it is all sealed into a gold capsule with a small amount of water.

2. The runs are made at modest H_2O pressures (100-300 bars) at temperatures from 100-300°C.

3. After cooling, the elements in solution are analyzed, and the chemical and structural changes in each of the waste-package layers determined by diffraction and electron (or ion) probe analyses.

4. An open system test with the rock-saturated groundwater extremely slowly entering and leaving the chamber with the simulated waste package will also be significant—although none of these have been carried out so far.

Experimental Results from M.R.L.

The potential of "engineering" the overpack materials to control the chemical environment has recently been recognized by a few groups. Thus Apps and Cook (32) state, "The control exercised over engineered barriers should resolve the questions of variability and uncertainty, *so that there will be less than those inherent in the geologic media*." Even more explicitly, H.W. Nesbitt et al. (33) state, "In this paper we show that the thermodynamic stability and kinetic reactivity of waste forms will be influenced—*and even controlled*—by the nature of the backfill and repository materials" (emphasis added). Their experiments show the greater stability of sphene over perovskite in a waste form + clay + granite system. Extensive studies by Freeborn and White (34) and Scheetz and White (35) in this laboratory have shown the major differences made by the host rock material on the nuclides taken into solution from a variety of waste forms, in different waste-rock-solution configurations. Similar studies in sealed teflon containers which include the metal canisters show remarkable differences in corrosion rates of the canister candidates depending on the same rock or waste variables, showing that the *linear addition* concept of the 'corrosion' or 'leaching' of each of the components is totally untenable. Table 24 is one summary of such evaluation. Recently, Sasaki, Komarneni, Scheetz and Roy (36) have specifically demonstrated the major impact of the backfill on the reaction and dissolution of several ceramic waste forms. Although unable to provide the basis for a quantitative estimate of release from a specified waste package, these results constitute more than sufficient evidence to demonstrate that "leach tests" must be abandoned now and be replaced by such repository simulating tests, in order that we may start accumulating data for evaluating the technological subsystem's effectiveness, for the first time.

REFERENCES FOR CHAPTERS 9 AND 10

1. National Research Council. Committee on Radioactive Waste Management, Panel on Waste Solidification (1978), Solidification of High Level Radioactive Wastes, National Academy of Sciences, Washington, DC.
2. A. Jacobson and R. Pusch, "Deposition of High-Level Radioactive Waste Products in Boreholes with Buffer Substance,", KBS Teknisk Rapport 03, Stockholm (1977).
3. C.J. McCarthy and M.T. Davidson, Ceramic Nuclear Waste Forms: I, Crystal Chemistry and Phase Formation, Bull. Amer. Ceram. Soc. 54, 782 (1975).
4. J.W. Braithwaite et al. (1979), Corrosion Considerations for Nuclear Waste Isolation Canisters, Scientific Basis for Nuclear Waste Management, Vol. 1, Ed. G.J. McCarthy, Plenum Press, NY, p. 283.
5. J.D. Sundquist (1979), Preliminary Corrosion Test of a Glass-Ceramic Candidate for a Nuclear Waste Canister, Scientific Basis for Nuclear Waste Management, Vol. 1, Ed. G.J. McCarthy, Plenum Press, NY, p. 289.
6. T. Mattsson (1979), Corrosion Resistance of Canisters for Final Disposal of Spent Nuclear Fuel, Scientific Basis for Nuclear Waste Management, Vol. 1, Ed. G.J. McCarthy, Plenum Press, NY, p. 271.
7. J.W. Braithwaite et al. (1980), Corrosion Resistant Metallic Canisters for Nuclear Waste Isolation, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 3778.
7a. W.N. Rankin (1980), Canister Compatibility with Carlsbad Salt, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 393.
8a. R.E. Westerman (1981), Development of Structural Engineered Barriers for the Long Term Containment of Nuclear Waste, Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. J.G. Moore, Plenum Press, NY, p. 515.
8b. F. Casteels et al. (1980), Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 385.
8c. S.C. Pitman, D. Griggs and R.D. Elmore, "Evaluation of Metallic Materials for Use in Engineered Barrier Systems," Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. J.G. Moore, Plenum Press, NY, p. 523.
9. National Research Council, Committee on Radioactive Waste Management (1980), A Review of the Swedish KBS-II Plan for Disposal of Spent Nuclear Fuel, NAS-NAE-NRC, National Academy of Sciences, Washington, DC.
10. Engineered Waste Package: Conceptual Design. Westinghouse Electric Corporation. Report to ONWI Contract E512-06400, March 1981.
11a. R. Roy. Presentation to ERDA team at University Park, PA, June 20, 1973. See Mendel, McElroy, Platt, "High-Level Radioactive Management," pp. 106-109, M.H. Campbell, editor, ACS, 1976.
11b. R.W. Nesbitt et al. (1981). "The Stability of Perovskite and Sphene in the Presence of Backfill and Repository Materials," Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. J.G. Moore, Plenum Press, NY, p. 333.
12a. B. Allard et al. (1977), "Sorption of Long-Lived Radionuclides in Clay and Rock," KBS Tech. Report, Stockholm, p. 55.
12b. B. Allard et al. (1980), "Possible Retention of Iodine in the ." Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 673.
13a. E.J. Nowak (1980), The Backfill as an Engineered Barrier for Nuclear Waste Management, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 403.
13b. E.J. Nowak (1981), Composite Backfill Materials for Radioactive Waste Isolation by Deep Burial in Salt, Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. C. Northrup, Plenum Press, NY, p. 545.
14. G.W. Bird and V.J. Lopata (1980), "Solution Interactions of Nuclear Waste Anions with Selected Geological Materials," Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 419.
15. D.G. Brookins (1980), Clay Minerals Suitable for Overpack in Waste Repositories, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 427.
16. S. Komarneni and R. Roy (1980), "Superoverpack: Tailor-Made Mixtures of Zeolites and Clays," Scientific Basis for Nuclear Waste Management, Vol. 2, C.J. Northrup, Jr. (Ed.) pp. 411-418.
16a.
17a. S. Komarneni and D.M. Roy, "Effect of Layer Charge and Heat Treatment on Cs Fixation by Layer Silicate Minerals," J. Inorg. Nucl. Chem. 40, 893-896 (1978).
17b. S. Komarneni and D.M. Roy, "Shale as a Radioactive Waste Repository: The Importance of Vermiculite," J. Inorg. Nucl. Chem. 41, 1793-1796 (1979).
17c. S. Komarneni and D.M. Roy, "Hydrothermal Effects on Cesium Sorption and Fixation by Clay Materials and Shales," Clays and Clay Minerals 28, 142-148 (1980).
18a. S. Komarneni and R. Roy (1981), Hydrothermal Transformations in Candidate Overpack Materials and Their Effects on Cs and Sr Sorption, Nucl. Tech. 54, 118.
18b. S. Komarneni and W.B. White (1981) Hydrothermal Reactions of Clay Minerals and Shales with Cesium Phases from Spent Fuel Elements," Clays Clay Miner. 29 (in press).
18c. S. Komarneni and R. Roy (1981), Interactions of Backfill Materials with Cesium in a Bittern Brine Under Repository Conditions, Nucl. Tech. (in press).
19. R. Roy and S. Komarneni (1981), Design of Overpack (= Backfill) Materials, "NBS Workshop on the Research and Development Needs in Backfill for Underground Nuclear Waste Management," National Bureau of Standards Proceedings, Washington, DC.
20. C.F. von Weizsacker, "The Politics of Peril," Seabury, NY, 1978, Chapter 6.

21. R.C. Burkholder (1980), Waste Isolation Performance Assessment: A Status Report, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 689.
22. S. Tymochowicz (1977), A Collection of Results and Methods on the Leachability of Solidified High Level Radioactive Waste Forms, Hahn-Meitner Institute Report, HMI-B241.
23. J.E. Mendel et al. (1977), Annual Report on the Characteristics of High-Level Waste Glasses, BNWL-2252, Battelle, Pacific Northwest Laboratories, 99 pp.
24. C. Hauser, I.S.T. Tsong, and W.B. White (1979), Characterization of Leached Surface Layers on Simulated High-Level Waste Glasses by Sputter-Induced Optical Emission, Scientific Basis for Nuclear Waste Management, Vol. 1., Ed. G.J. McCarthy, Plenum Press, NY, p. 131.
25. A.B. Harker, C.M. Jantzen, P.E.D. Morgan, and D.R. Clarke (1980), Tailored Ceramic Nuclear Waste Forms: Preparation and Characterization, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 139.
26. A.E. Ringwood, K.D. Reeve, and J.D. Tewhey (1980), Recent Progress on Synroc Development, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY, p. 147 (see also p. 163).
27a. G.J. McCarthy (1977), High-Level Waste Ceramics: Materials Considerations, Process Simulation and Product Characterization, Nucl. Technol. 32, 92.
27b. T. Adl and E.R. Vance, $CaAlSi_4O_{12}$, Possible Host for ^{137}Cs Immobilization, J. Mat. Sci. (in press).
27c.

28. G.J. McCarthy et al. (1978), Interactions Between Nuclear Waste and Surrounding Rock, Nature 273, 216.
29. National Waste Terminal Storage Program Conference on Waste Rock Interaction, D.M. Roy, Chairman, Y/OWI/77/14260, July 1977.
30. R. Roy and O.F. Tuttle (1956), Investigations Under Hydrothermal Conditions, Physics and Chemistry of the Earth 1, Pergamon Press, p. 138.
31. B.E. Scheetz, W.B. White and S.D. Atkinson, Dissolution of Aluminium, Titanium and Zirconium-based Crystalline Waste Form Components, (Accepted for publication in J. Nuclear Technology).
32. J. Apps and N.G.W. Cook (1981), Backfill Barriers: The Use of Engineered Barriers Based on Geologic Materials, Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. C. Northrup, Plenum Press, NY, p. 291.
33. R.W. Nesbitt et al. (1981), The Stability of Perovskite and Sphene in the Presence of Backfill and Repository Materials: A General Approach, Scientific Basis for Nuclear Waste Management, Vol. 3, Ed. C. Northrup, Plenum Press, NY, p. 131.
34. W.P. Freeborn, et al. (1980), Shale Rocks as Nuclear Waste Repositories: Hydrothermal Reactions with Glass, Ceramic and Spent Fuel Waste Forms, Scientific Basis for Nuclear Waste Management, Vol. 2, Ed. C. Northrup, Plenum Press, NY p. 499.
35a. S. Komarneni and B.E. Scheetz (1981), Hydrothermal Interactions of Basalts with Cs and Sr of Spent Fuel Elements: Implications to Basalt as a Nuclear Waste Repository. J. Inorg. Nucl. Chem. 43, 1967.
35b. B.E. Scheetz, et al. (1980). Hydrothermal Interaction of Simulated Nuclear Waste Glass in the Presence of Basalts. Scientific Basis for Nuclear Waste Management, Vol., 2, C.J. Northrup, ed., Plenum Press, NY p. 207.
35c. W.B. White, et al. (1979). Brine-Waste Form Interactions under Mild Hydrothermal Conditions. Scientific Basis for Nuclear Waste Management, Vol. 1, G.J. McCarthy (ed.) Plenum Press, NY
36. K. Sasaki, S. Komarneni, B.E. Scheetz and R. Roy. Backfill-Overpack-Waste Interactions in Repository Simulating Tests (accepted for publication)

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November 2, 1981

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PROPOSED RULE PR-60
(46 FR 35280)

Mr. Nunzio J. Palladino, Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Palladino:

In response to the notice of July 28, 1981 by the U.S. Nuclear Regulatory Commission inviting comments on the proposed rule 10 CFR 60, I am transmitting herewith the attached document:

> "Technical Criteria for Geologic Disposal of Radioactive Waste: Comments on the Rule 10 CFR 60 Proposed by the U. S. Nuclear Regulatory Commission", UCB-NE-4013, November, 1981.

This document was originally prepared in September 1981 at the request of the Board on Radioactive Waste Management of the National Research Council, National Academies of Science and Engineering, to serve as a working paper and to provide a technical basis for a separate letter report to you from that Board. The document has benefited from review and input by individual members of the Board on Radioactive Waste Management and by individual members of the National Research Council's Waste Isolation System Panel. The Board on Radioactive Waste Management has kindly consented for this document to be modified for transmittal to you as my own individual comment on the proposed rule. I hope that the attached document will be useful to the Nuclear Regulatory Commission in its further considerations on this subject of geologic disposal of radioactive wastes.

Sincerely yours,

Thomas H. Pigford
Professor

Attachment

THP:mm

Acknowledged by card. 11/9/81 amp

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UCB-NE-4013
November, 1981

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PR-60
(46 FR 35280)

Technical Criteria for Geologic Disposal of
Radioactive Waste:

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Comments on the Rule 10 CFR 60 Proposed by
the U. S. Nuclear Regulatory Commission

Thomas H. Pigford

University of California
Berkeley, California

Topics

1. Purpose of the Proposed Rule
2. The Absence of a Safety Goal
3. NRC's Assumption of an "EPA Standard"
4. NRC's Purpose of Simplifying Licensing Review
5. There Should be a Clearer Rationale for the Technical Criteria
6. The Proper Role and Place for Numerical Technical Performance Criteria
7. The Possibility of Extreme and Unknown Safety Margins
8. Criteria and Prediction of Long-Term Waste Isolation Performance
9. 1,000-yr Containment by the Waste Package
   - 9.1 NRC's purpose for proposing the 1,000-yr containment
   - 9.2 The importance of 1,000-yr containment to overall performance
   - 9.3 Temperatures assumed by NRC
   - 9.4 Temperature effects must still be considered
   - 9.5 Extrapolation from current knowledge
   - 9.6 Can compliance with the 1,000-yr containment requirement be verified?
   - 9.7 NRC's estimate of cost
   - 9.8 Summary
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Technical Criteria for Geologic Disposal of Radioactive Waste: Comments on the Rule 10 CFR 60 Proposed by the U.S. Nuclear Regulatory Commission

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1. Purpose of the Proposed Rule

NRC's proposed rule 10 CFR 60 specifies technical criteria for disposal of high-level radioactive wastes in geologic repositories. NRC considers the criteria to be necessary for it to fulfill its statutory obligations concerning the licensing and regulating of facilities used for the receipt and storage of high-level radioactive waste. In its Notice of Rulemaking and in the accompanying Rationale for Technical Performance Objectives, NRC states four purposes for these criteria:

1. To specify site and design criteria which, if satisfied, will support a finding of no unreasonable risk to the health and safety to the public.

2. To enhance NRC's confidence that the EPA standard will be met.

3. To simplify the NRC review of DOE's application to construct a licensed repository.

4. To guide DOE in siting, designing, and constructing a repository in manner that public health and safety will be protected.

This review of NRC's proposed rule and accompanying rationale addresses the question of whether or not the proposed technical criteria have been shown by NRC to be either necessary or sufficient to achieve the stated purposes. NRC's technical bases for the numerical technical criteria are also reviewed.

2. The Absence of a Safety Goal

NRC has not identified what safety standard of "unreasonable risk to health and safety to the public" its technical criteria are intended to achieve. NRC has submitted no evidence, rationale, or discussion concerning "unreasonable risk to the health and safety to the public" and the relation of the technical criteria thereto. Consequently, there is no basis for concluding that the technical criteria are either necessary or sufficient for the first purpose stated by NRC.

The EPA standard for geologic isolation of radioactive waste is yet to be determined, so it is premature for NRC to conclude that its proposed technical criteria will enhance confidence that the EPA standard can be met.

In this regard, NRC states:

> "The Environmental Protection Agency[1] (EPA) has the authority and responsibility for setting generally applicable standards for radiation in the environment. It is the responsibility of the NRC to implement those standards in its licensing actions and assure that public health and safety are protected. Although no EPA standard for disposal of HLW yet exists, these proposed technical criteria for regulating geologic disposal of HLW have been developed to be compatible with a generally applicable environmental standard."

Although many of the descriptive criteria proposed by NRC are reasonable considerations to follow in selecting a site and in developing a repository design, the specification of numerical values for technical criteria, which are to help meet and be compatible with the EPA standard, is premature without the existence of the radiation safety standard which these technical criteria are intended to help achieve. NRC has submitted no evidence that the numerical criteria can "support a finding of no unreasonable risk to the health and safety to the public".

3. NRC's Assumption of an "EPA Standard"

In analyses of long-term repository performance referenced in NRC's rationale performance is measured in terms of future radiation doses to individuals, which has been the practice in existing NRC licensing of fuel-cycle facilities. The numerical technical criteria in the NRC's proposed rule were originally evolved earlier under a similar assumption that the radiation performance standard would be in the form of a radiation dose limit to an individual[3]. Even so, there is no showing in NRC's rationale that its technical criteria would be either necessary or sufficient to meet the individual dose limits assumed in these studies referred to by NRC.

The new EPA radiation standard may be proposed as a limit on the integrated radiation exposure of some future population. This would depart markedly from individual radiation dose limits that have been implemented in the past by NRC in its regulations and guides. From descriptions of the low level of population dose being considered by EPA, it is evident that the corresponding dose to future individuals could be orders of magnitude below those which would be assumed from existing regulatory practice. The form in which the EPA standard is finally adopted can have a large effect upon how, and with what means, the standard is to be met. Foreseeing what may be a very large departure from previous practice in radiation standards, NRC's assumptions of the content and form of the EPA standard must be highly tentative.

An NRC representative[4] has stated that in developing its rationale for its proposed technical criteria NRC has adopted a set of release limits of radionuclides to the accessible environment, which is identified as the "EPA standard" referred to in the proposed rule 10 CFR 60. These limits are said to appear in an unpublished internal draft regulation by EPA. EPA derived these release limits on the basis of its tentative overall performance goal, expressed in terms of integrated radiation effects to a future population. These limits apply for releases during a period of 10,000 yr after the wastes are emplaced in a repository.

We find nothing in NRC's notice of rulemaking nor in its rationale document which refers to these release limits assumed by NRC or which shows how NRC's proposed numerical technical criteria relate to meeting these release limits.

There is no mention of these assumed release limits in any of the supporting references quoted by NRC. Repository performance analyses[5,6,7] referred to in NRC's technical rationale[2] are all in terms of radiation dose to future individuals, rather than curie releases or doses to future populations. Even with NRC's assumption of the "EPA standard", there is no showing by NRC that its proposed technical criteria are either necessary or sufficient to meet or support this assumed standard.

4. <u>NRC's Purpose of Simplifying Licensing Review</u>

NRC argues that its proposed technical criteria will simplify the NRC review of an application by DOE to construct a licensed repository. NRC states that if the DOE-proposed site, underground facility, and waste package perform according to the technical criteria specified by the proposed regulation, including the specific numerical criteria, NRC evaluation of repository performance will be greatly simplified. The objective of simplifying the licensing review appears to be a main purpose for many of the technical criteria in the proposed regulation.

While it is desirable to simplify licensing review so as to focus on the main issues of public health and safety, we question whether the present NRC approach does not, in fact, detract from focusing on long-term radiation safety. Requiring DOE to show that its design of components meets specific numerical criteria might simplify initial licensing review by NRC staff, but licensing review does not end there. If NRC criteria are not adequately founded and are not shown to be necessary or sufficient to achieve the overall safety standard, there is substantive basis for challenging the criteria and the rule.

More importantly, such a regulatory approach, in the absence of a showing that detailed numerical criteria are related to an overall performance goal, can interfere with and detract from suitable emphasis upon overall safety. The difficulty and challenge of complying with NRC's proposed numerical criteria, as discussed later in Sections 9.6, 10.5, 11, and 13.4, can overshadow the more important task of focusing on overall safety performance of the waste isolation system. It can divert DOE from its central responsibility of providing reasonable assurance that the performance of the overall system and of the subsystems and components will meet the overall performance required of the geologic isolation system, in terms of health and safety to the public. It can divert NRC from its responsibility of evaluating the overall system performance.

This approach by NRC towards its regulation for public health and safety has come under increasing scrutiny and criticism in recent years. The danger of this approach was forcefully articulated by the President's Commission on the Accident at Three Mile Island[8], which stated that:

> "The existence of a vast body of regulations by NRC tends to focus industry attention narrowly on the meeting of regulations rather than on a systematic concern for safety."

The NRC was also strongly criticized for not setting or identifying goals of public health and safety to be achieved, and for not sufficiently relating its detailed technical guidelines and regulations towards achieving those goals.

In later sections we question the validity of portions of the NRC analyses which led to some of the numerical criteria in the proposed rule. Without sufficient validity, or foundation, the proposed technical criteria are more likely to complicate rather than simplify the overall licensing process.

This is not to say that NRC regulations and guides should never incorporate numerical criteria for performance of components and subsystems. There are many examples in NRC practice which do indeed simplify the regulatory process and do not interfere with the careful development of technology aimed at solving the more important problems of safety. However, the numerical criteria now proposed by NRC are premature for that purpose.

5. <u>There Should be a Clearer Rationale for the Technical Criteria</u>

The purpose of technical criteria in regulations and guides should be to help achieve public health and safety. When sufficient and necessary, such technical criteria can be useful as long as their technical bases remain sound. Regardless of how well founded and formulated such technical criteria may be at the time promulgated by NRC, it is likely that increased technical knowledge will warrant change, particularly in the case of numerical technical criteria. It is likely that better technical knowledge in the future will result in less uncertainty in predicting performance and will thereby justify less margin for uncertainty than was incorporated in the numerical criteria when originally adopted.

If the technical purpose and foundation of the original criteria are not clear and sound, and if the numerical criteria are adopted without adequate reference to their basis, then the technical framework for later review and challenge of the need and adequacy of such technical criteria has been lost. The technical criteria then become viewed as arbitrary numbers which are sacred within themselves, rather than as representing necessary technical functions and performance which these numerical criteria are intended to achieve. To the extent that numerical technical criteria are finally adopted by NRC, adequate descriptions of their technical purpose, foundation, and assumptions should be included.

6. <u>The Proper Role and Place for Numerical Technical Performance Criteria</u>

To the extent that numerical technical performance criteria by NRC are justified, they are better suited to be incorporated in NRC's regulatory guides rather than in its regulations. When numerical criteria appear in regulations, they are formally enacted and consequently difficult to change. NRC has utilized the guideline approach for promulgating most of the vast body of its technical requirements in other licensing procedures. When numerical criteria do become justified, they should be incorporated in NRC guides, along with the technical bases for their justification.

7. <u>The Possibility of Extreme and Unknown Safety Margins</u>

The proposed rule appropriately mentions uncertainties in site characterization, engineering design, and prediction. However, NRC has not analyzed these uncertainties, and unknown safety margins underlie NRC's views of performance of subsystems and components necessary to meet the yet undetermined EPA standard of overall performance. In the absence of sufficient technical analysis by NRC, adopting such criteria with unknown safety margins is not justified, especially if considerable safety margins are likely to be incorporated into the EPA standard. Without adequate evaluation of the uncertainties before establishing the regulations and standards there will emerge a set of mandated requirements which provide some degree of public health and safety, but without that degree of protection known or understood by the regulators, the implementors of the technology, or the public.

A more meaningful approach would be to establish the safety goal, determine the means of achieving that goal on a realistic basis, analyze the uncertainties inherent in achieving that goal, and then consciously incorporate the necessary margins and safety factors to distinguish expected performance from necessary performance. To accomplish that, it is necessary to know the safety goal and the safety margins incorporated in that goal. There is needed a better technical knowledge of performance and performance uncertainties than is reflected in NRC's proposed rule and rationale.

NRC's assumptions of uncertainties in justifying its proposed numerical criteria are discussed in the following sections.

8. Criteria and Prediction of Long-Term Waste Isolation Performance

NRC relies upon three references[5,6,7] for predictions of the long-term performance of the waste isolation system. These performance analyses predict the effect of repository and site parameters upon the long-term release of radionuclides to the environment, the concentrations of these radionuclides in the aquifer to which they are released, and the radiation doses to future individuals maximally exposed from these releases. The times under consideration extend to millions of years, when some of the important environmental releases of actinides and their decay daughters, e.g., uranium-234 and radium-226, are predicted to occur. The long delay in such releases is caused by the adsorption of these radionuclides on the rock media, thereby reducing their transport velocity. Similar analyses of radiation doses to future individuals over such long time periods have appeared in reports for other waste isolation projects[9,10].

However, the draft EPA standard, adopted by NRC as the "EPA standard" for the purpose of this proposed rulemaking, would require a different kind of performance analysis. Rather than dealing with radiation doses to future individuals, where the concentration of released radionuclides in the accessible environment will determine the radiation dose to an individual, the EPA draft standard deals instead with a total dose to a future population, integrated over time. It therefore emphasizes a cumulative release of radionuclides over a long period of time, rather than the concentration in water at the time of release. Whereas the performance analyses relied upon by NRC calculate doses to maximally exposed individuals at times extending to millions of years, the "assumed EPA standard" requires the calculation of total cumulative release of radionuclides up to a time of 10,000 yr after the wastes are emplaced in a repository. There is nothing in NRC's notice of rule[1], in its rationale[2], or in its draft environmental impact assessment[11], relating to this EPA approach towards performance analysis of the geologic waste isolation system.

Here we do not address the questions of whether waste isolation performance should be evaluated in terms of individual or population dose and whether future radiation doses should be discounted if they incur after some set time period like 10,000 yr. Even though these questions are relevant to the unissued EPA draft standard which NRC has adopted as its "assumed EPA standard", NRC has presented no data or discussion concerning population dose or a 10,000 yr cutoff. Therefore, we have before us no basis for considering these issues. These questions are to be dealt with when the EPA standard is issued for review, assuming that it emerges in the form now assumed by NRC. Rather than make a value judgment now on unissued EPA standard, we instead restrict our considerations here to the performance evaluation adopted by NRC in its rationale for its proposed criteria, i.e., the predicted radiation dose to future maximally exposed individuals over the long term to millions of years after emplacement in a geologic repository.

NRC references such performance analyses[5,6,7] in its rationale for selecting numerical criteria for three parameters of the waste-isolation system: (1) the time delay from waste emplacement until the onset of dissolution of the waste by groundwater, (2) the fractional rate of release of radionuclides from the waste to the groundwater, and (3) the time for groundwater to travel from the repository to the accessible environment. The authors of two of these references[5,6] have dealt quantitatively with the effect of these and other parameters upon overall repository performance, with performance measured in terms of radiation dose to future maximally exposed individuals. However, NRC has not utilized the results of the primary studies by these authors[12,13]. NRC refers instead to a progress report[5] and to an unpublished paper[6] presented at an information meeting. In order to develop a better understanding of the basis and importance of NRC's proposed numerical criteria, we have reviewed the more thorough studies by these authors[11,12] on the effects of these parameters on waste isolation performance, supplemented by additional data[14-24] on radionuclide adsorption, solubility, and hydrology for rock media not considered specifically in these published analyses. The results of such peformance analyses, showing the likely importance of each of the three above-mentioned numerical criteria to overall long-term waste isolation are discussed in subsequent sections.

9. 1,000-yr Containment by the Waste Package

9.1 NRC's purpose for proposing the 1,000-yr containment

NRC proposes to require containment of the radionuclides within the high-level waste package for at least 1,000 yr following repository closure. NRC justifies this requirement as necessary to avoid the uncertainties of predicting release and hydrogeologic transport of radionuclides when affected by elevated temperatures of waste, rock, and groundwater. NRC is concerned with "severe" effects of temperature, which could accelerate the leaching of wastes exposed to groundwater and could affect groundwater transport of radionuclides by perturbing the motion of groundwater and by causing mineral phase changes of backfill and near-field rock. These phenomena are more relevant for host rocks which are permeable to groundwater.

Some of NRC's considerations of temperature effects are qualitatively reasonable, but there is no showing that the numerical criterion of 1,000-yr containment is important in attaining a safe overall performance. As is shown in the following sections, existing technical knowledge of repository heating and effects therefrom have not sufficiently entered into the NRC considerations. NRC's 1,000-yr containment requirement will not avoid the need to reduce uncertainties in predicting effects of heating on repository performance. Meeting NRC's proposed numerical criterion may introduce more technical uncertainty than exists in the problem which NRC seeks to avoid.

9.2 The importance of 1000-yr containment to overall performance

Some of the temperature effects identified by NRC could increase the time for released radionuclides to reach the environment; others could decrease the transport time. It is the uncertainties from such effects that is NRC's concern. However, for typical repository sites under DOE consideration, the time for released radionuclides to travel through the heated zone of the repository is predicted to be small compared to the total travel time for radionuclides through the adjacent unheated rock media, so local changes in the water flow rate and nuclide transport rate in the heated zone do not necessarily cause large changes in the overall travel time. The references[17,13] show that future radiation doses from long-term releases of radionuclides to the environment are not appreciably affected by perturbations in radionuclide travel time, for typical values of repository and site parameters, and they show that delaying the onset of dissolution of the waste has little or no effect upon long-term overall waste isolation performance. Those radionuclides which are essentially completely attenuated by decay will not emerge for even much shorter water travel times. The few that do emerge are so long-lived that they will still emerge even for much longer water travel times or waste-containment times. These considerations further question the importance of NRC's proposed 1,000-yr containment in helping achieve suitable overall waste isolation performance.

The extent to which temperature affects radionuclide release and transport will depend in part upon the rock medium in which the waste is emplaced. To the extent that such effects are important, temperature effects should enter into the selection of the rock medium for emplacement. However, such considerations would have little import under the mandated 1,000-yr containment criterion.

Although having questioned here whether or not possible uncertainties in predicting repository performance during the first 1,000 yr are important in predicting the release of radionuclides to the environment, we turn next to a more specific evaluation of NRC's discussion[2] of the uncertainties introduced by "severe" effect on temperature during the first 1,000 yr.

9.3 Temperatures assumed by NRC

NRC assumes much higher repository temperatures than will necessarily exist. Repository temperature rises quoted by NRC are as much as 60% greater than those in current DOE reference designs[25]. There are several design options available to DOE to relax temperatures and to decrease the uncertainty of repository performance analysis, should it become necessary. These alternatives should be left as a DOE responsibility in the design process.

NRC does not show its basis for concluding that temperatures after 1,000 yr are low enough to allow release and transport of radionuclides to be predicted with greater confidence. However, NRC's graphs[2] show that after 1,000

yr the maximum rock temperature of a bedded-salt repository will have decreased to about 160°C. Evidently it is the uncertainty of prediction at temperatures greater than this 1,000-yr value that NRC's proposed 1,000-yr containment is intended to avoid. In DOE's current reference design for a bedded-salt repository the maximum rock temperature at any time during the first thousand years of emplacement or thereafter is less than NRC's 1,000-yr value. Therefore, the temperatures of current designs of bedded salt repositories are evidently already low enough to satisfy NRC's concern, so NRC's justification for the 1,000-yr containment would not apply. This is another example of why a uniform and numerical containment criterion should not be mandated.

9.4 Temperature effects must still be considered

Even assuming a repository with temperatures in the range which NRC considers to be severe, NRC's proposed 1,000-yr containment criterion would not eliminate the need to consider temperature effects. Many of the temperature-induced changes in the rock and backfill are likely to be irreversible and will remain and affect radionuclide transport well after the 1,000-yr period. Many of the temperature-induced mineralogical changes in basalt, granite, and tuff are likely to be permanent, and these will affect radionuclide transport for the much longer period of release and transport after the 1,000-yr containment period. Data from field tests in heated rock indicate that if thermally induced fracturing of the rock occurs, increased porosity and permeability for water flow may not become important until well after the 1,000-yr containment period, when compressive stresses due to temperature have subsided. These are two reasons why the effects of temperature upon the properties that affect radionuclide transport must still be considered, regardless of the existence of a 1,000-yr containment.

Even with a 1,000-yr container for the high-level waste, thermally induced flow, due to heating repository rock containing groundwater, will continue beyond the 1,000-yr period and must still be considered in repository design and analysis. Heating groundwater decreases its density and viscosity and induces vertical flow, but such thermal convection is slow to develop. Analyses[26] for conceptual repositories with groundwater flow through hard-rock fractures show that, for the assumed constant-aperture fractures, the maximum water flow rate in the repository will not occur until well after 1,000 yr for spent-fuel waste, and the increased vertical flow will persist beyond 10,000 yr. For reprocessed high-level waste the magnitude of the thermally induced flow is considerably less than for the high-level waste, but near-maximum flow persists well after 1,000 yr. Therefore, for such repositories the 1,000-yr container does not necessarily avoid the need to consider the effects of repository heating upon groundwater flow and upon radionuclide transport from the high level waste.

NRC's proposed 1,000-yr containment would not eliminate the need to consider the effects of temperature upon radionuclide transport even during the 1,000-yr period. Recognizing that transuranic wastes are also in the repository, NRC has proposed that a 1,000-yr container not be required for such wastes if they are not emplaced close enough to high-level wastes that the release rate from the transuranic waste can be significantly affected by the heat generated by the high-level waste. However, radionuclides can still be released by the relatively cool but uncontained transuranic wastes, and some of the transuranic radionuclides, especially americium-241, are of potential concern even during the first thousand years[27]. Even if the released transuranic radionuclides do not themselves transport through the heated rock, their transport will be governed in part by the flow of groundwater. As has been demonstrated by analyses of thermal convection flow of water in heated and unheated zones in conceptual repositories[4,15], repository heating can markedly perturb the flow paths and velocities of groundwater, if groundwater is present in the repository. These flow perturbations occur not only in the heated regions where high-level waste is emplaced, but they also extend to the cooler regions where transuranic wastes may be emplaced. Therefore, the effect of repository heating on the transport of radionuclides even during the first 1,000 yr must still be considered, regardless of the existence of the 1,000-yr container for heated wastes.

NRC has not addressed the question of the importance of these thermally induced effects to the long-term transport of radionuclides in the environment. NRC's assumption that such thermal effects are important to long-term isolation performance remains in question.

9.5 Extrapolation from current knowledge

In considering other possible time periods for waste-package containment, NRC has ruled out waste-package containment time as long as 10,000 yr on the grounds that design of such a package requires a considerable extrapolation beyond DOE concepts and because costs are uncertain and may not be justified by the reduction in uncertainty that might be achieved. NRC should also apply such criteria to its proposed 1000-yr container, which it justifies on the basis of a single report[27] that suggests, with some reservation, that a titanium alloy may be sufficient for a 300-yr containment in a brine solution. The report provides no adequate basis for NRC's conclusion that 1,000-yr containment requires only a small extrapolation.

9.6 Can compliance with the 1,000-yr containment requirement be verified?

NRC has not addressed the question of whether or not compliance with the 1,000-yr containment requirement can be verified. Meaningful experiments involving accelerated corrosion to simulate long-time behavior are difficult to design and interpret, and the complex phenomena involved in the many different types of corrosion mechanisms which must be considered do not lead to reliable theoretical models for long-term extrapolation of performance or to verification of expected performance. This is an important area to be considered in the uncertainty analysis of repository performance, and it does not seem to have entered into NRC's consideration of proposing a 1,000-yr containment criterion.

A regulatory requirement that is not subject to meaningful verification of compliance is of dubious value. Even if sufficient laboratory data were to exist to predict that the designed waste package would contain radionuclides for 1,000 yr, it is likely that the 1,000-yr containment would <u>not</u> be met by all of the waste packages. Manufacturing tolerances are almost certain to result in some defective packages. The NRC criterion seems to require that <u>all</u> packages perform as specified, even though it has not been shown what fraction of the waste packages could undergo partial failure without resulting in a significant release of radionuclides to the environment. The NRC requirement is unrealistic and may be impossible to implement.

Even more difficult will be the problem of verifying compliance with a

numerical EPA standard for overall performance of the waste isolation system, whether the standard be in terms of maximum radiation dose or curie release, unless guidance is provided as to how to comply with the standard. The only means of demonstrating compliance at such long times in the future is through predictive analysis of long-term performance, accompanied by best estimates of uncertainties in that performance estimate and by safety margins to provide for those uncertainties. Recognizing the reality of uncertainties in predictive analysis and providing flexibility and guidance so that compliance can be reasonably verified must be an essential ingredient in whatever overall performance standard is issued by EPA and implemented by NRC. Similar flexibility and guidance for compliance must necessarily accompany any numerical criteria for long-term future performance, but it does not appear in NRC's proposed rule.

9.7 NRC's estimate of cost

To support its conclusion that the cost of incorporating titanium in a waste package would be reasonable, NRC should review what is actually involved in constructing and verifying the performance of such a waste package, and NRC should describe its frame of reference for what costs are "reasonable". The vague cost estimate by Magnini and Braithwaite[29] for a 300-yr waste package of unspecified design shows that NRC's proposed containment criterion could add several billion dollars to the cost of a repository. Such a cost may well be justified if it achieves a significant and necessary increase in public safety. However, there is no basis for such determination at this time.

It would be appropriate for NRC to rely more upon the DOE program that is developing the waste package and costs thereof. It would be appropriate for NRC to clarify to what extent costs will be a consideration in repository licensing.

9.8 Summary

The above analysis shows that NRC's proposed criterion that the radionuclides be confined within the waste package for 1,000 yr is without adequate or valid technical foundation, is based upon questionable assumptions, and may not be important to long term public health and safety. There is no showing by NRC that the proposed criterion is necessary or sufficient for NRC's stated purposes.

10. <u>Maximum Annual Release From the Engineered System After 1,000 Yr</u>

10.1 NRC's proposal

NRC proposes that the maximum annual release of any radionuclide after 1,000 yr from the engineered system, which includes the waste package and backfill, be at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 yr following permanent closure. Taken literally, this means at any and all times after the 1,000-yr period.

10.2 Effect of release rate upon long-term performance

NRC refers to overall performance analyses[5,6,7] of conceptual repositories.

which include parametric studies of the effect of release rate upon long-term performance. These analyses include projections to millions of years. NRC's release rate requirement is not supported by the results of these and more detailed parametric studies[12,13] for groundwater transport, which show that for some typical sites the calculated future radiation doses to the maximally exposed individual from long-term releases to the environment are insensitive to the release rate from the waste package, for fractional release rates in the range of 10^{-3} to 10^{-5}/yr.

This insensitivity to release rate via groundwater transport occurs because of the contribution of radium-226 to the radiation dose. Radium-226 is not initially present in the waste but grows slowly from the decay of the long-lived precursors uranium-234, uranium-238, and thorium-230. A slow fractional rate of dissolution of the waste material allows greater amounts of thorium-230 to build up in the waste before the waste is all dissolved. This buildup, together with a "reconcentration effect"[30] due to simultaneous arrival of radium-226 at a discharge location from earlier decays of a broad band of adsorbed thorium-230, results in the long-term radiation dose varying little with fractional release rate over the range indicated above and for the ranges of other parameters considered in the analyses.

None of these performance studies referred to by NRC compares the expected performance of a conceptual repository with the radionuclide release limits in the "EPA standard" assumed by NRC, nor does NRC show whether its proposed release rate criterion is necessary or sufficient to meet the assumed "EPA standard".

10.3 NRC's assumption of demonstrated technology and cost

In discussing other possible numerical values for the release rate from the engineered system, NRC rejects the more stringent release rate of 10^{-7}/yr on the grounds (a) that DOE has not yet demonstrated whether such a release rate is achievable and (b) that the costs for a waste package with such a low release rate are very uncertain. At the other extreme, NRC rejects borosilicate glasses in current DOE programs as insufficient because of too high a release rate estimated by NRC to be in the range of 10^{-2} to 10^{-3}/yr. For materials to meet its 10^{-5}/yr release-rate criterion, NRC proposes nepheline syenite glasses, ceramic and composite materials, and clay backfill. However, there are not sufficient data on these materials proposed by NRC to meet NRC's requirements of demonstrated technology and reasonable cost. In fact, the technologies have not been developed, and the costs are not known.

10.4 Uncertain extrapolation from laboratory data

We question the validity of NRC's prediction of a long-term fractional release rate for any of these materials in a repository on the basis of existing laboratory data. NRC has adopted laboratory leach data, expressed as dissolution rate per unit surface area and based largely upon 30-day experiments, and has multiplied by the surface-to-mass ratio for repository waste to obtain a fractional leach rate assumed to be applicable to the long-term fractional release of all the important radionuclides contained in the waste packages emplaced in a repository. Members of the Waste Isolation System Panel of the National Research Council, who have reviewed the current knowledge for predicting long-

term performance of wastes in a repository, have concluded that such extrapolation of laboratory leach data for repository performance estimates is not valid. This casts doubt on the validity of NRC's conclusion that the new materials suggested by NRC are necessary and sufficient to achieve a fractional release rate of 10^{-5}/yr, and it casts doubt on NRC's conclusion that waste forms under development in current DOE programs, such as borosilicate glass, will not meet NRC's proposed release rate.

10.5 Can release-rate performance be verified?

Verification of the expected release rate performance, whether at 1,000 to 10,000 yr after emplacement, or whether at millions of years later as would be suggested by NRC's quoted performance analyses, is even more difficult than that of verifying the 1,000-yr containment. The predicted performance depends much upon the local chemistry of the groundwater and upon the long-term failure modes of several of the components of the waste package, and it requires a validated theory of long-term release rate that does not now exist. Until the uncertainty of prediction and verification of waste-package performance is better understood, specification of a fractional release rate as a numerical criterion to be complied with has little meaning.

As has been pointed out before in connection with the 1,000-yr containment criterion, it is likely that not all of the low-release waste packages and backfill will perform as designed, because of statistical imperfections in manufacturing and emplacement. Although some degree of local imperfection will not significantly affect overall performance of the waste isolation system, NRC's release-rate requirement does not seem to allow for such departures from required and expected performance. This is another reason why this NRC requirement is unrealistic and may be impossible to implement.

10.6 Summary

The numerical specification of a fractional release rate of 10^{-5}/yr is of questionable importance to long-term safety and is proposed without a technical valid basis and with invalid assumptions of existing technology and cost if such a numerical criterion were adopted, compliance could probably not be verified. It would be more appropriate for NRC to state the considerations which may help guide DOE in its development and proof of the waste package as one of the possible barriers that may aid in meeting whatever safety standard that emerge. One of the important considerations is for DOE to continue work on developing a means of predicting the long-term performance of waste packages.

11. Required Impermeability of Shaft and Borehole Seals

NRC proposes to require that at the time of permanent closure of the repository sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. NRC also proposes to require that contacts between seals and rock shall not become preferential pathways for water. Both of these requirements may be literally impossible to fulfill or to demonstrate that they are fulfilled, particularly where holes penetrate rock that is impermeable or nearly impermeable to water. NRC does not seem to have considered limitations and inadequacies of field testing techniques to demonstrate the extremely low leakages and permeabilities that are likely to be encountered in some of the rock in the more favorable sites.

NRC has not shown that this technical criterion, in its present extreme, is necessary for overall system performance. For those rock media in which verification of plug and seal performance would be a formidable problem under NRC's proposed criterion, realistic responses to the criterion would be to seek more permeable regions for repositories. The proposed criterion would tend to steer repository development into directions not necessarily beneficial to overall system performance.

A more meaningful technical criterion would be a statement that such leakage pathways are to be considered by DOE and that adequate assurance of satisfactory performance be demonstrated prior to licensing review.

12. Minimum Depth of 300 m

NRC specifies a minimum emplacement depth of 300 m as one of the favorable conditions which, in an appropriate combination, are sufficient to provide reasonable assurance that NRC's performance objectives will be met. NRC has not shown the basis for its conclusion of sufficiency, and no data and analyses have been presented in this regard. Once an overall performance objective of the waste isolation system has been established, it will be possible to analyze the effects on overall performance due to different emplacement depths for different rock media. Some technical considerations argue for deep emplacement; others argue against going too deep. Determination of emplacement depth should be a product of overall system analysis under DOE supervision, subject to final safety evaluation by NRC.

13. Groundwater Travel Time of 1,000 yr

13.1 Purpose

NRC proposes to require that groundwater travel time from the waste to the environment be at least 1,000 yr, determined for conditions prior to waste emplacement. In justification, NRC states that this requirement "...avoids the need to model the thermal effect or the hydrologic system and the geochemical impacts of nuclide transport".

13.2 Effect on overall performance

NRC does not show that a 1,000-yr groundwater travel time is necessary to achieve an overall performance goal. As has already been discussed in Section 9.3, performance analyses[4,5] quoted in NRC's rationale, supplemented by more detailed performance analyses[12,13] and by typical and likely properties for other rock media[14-24], show that future radiation doses to maximally exposed individuals resulting from geohydrologic transport to the environment are relatively insensitive to perturbations in groundwater travel time.

13.3 Thermally affected radionuclide transport must still be considered

As discussed in Section 9.4, the thermal effect on the hydrologic system must be considered, regardless of NRC's specification of 1,000 yr for waste containment and water transport to the environment.

13.4 Can water travel time be verified?

NRC concludes that groundwater travel times of 1,000 yr are achievable, and

travel times of this magnitude and longer are quoted for many locations potentially suitable for repositories. However, the NRC numerical criterion will present a difficult problem of verification. There is no single, unique water travel time for a site, even in the absence of emplaced wastes. The emplacement area will extend over considerable distance, and groundwater flow from the emplacement will follow nonuniform pathways before reaching the accessible environment, reflecting spatially nonuniform potentiometric and transmissivity fields and possible short-circuit pathways through conductive fractures. Each of these pathways can be characterized by its own water travel time, with considerable difference from one pathway to another. If NRC intends to apply its 1,000-yr criterion to that filament of water which arrives first at the environment after contacting the waste, it should so state. NRC should review what is known about the spectrum of water travel times for typical sites. It should consider to what extent localized radionuclide releases along the more direct and rapid pathways to the environment contribute releases that are significant in relation to the overall performance goal.

13.5 Summary

NRC's has not shown need or adequate technical basis for its proposed numerical criterion for water travel time. It would be more appropriate for NRC to state its considerations of water travel time as a contributor to overall safety performance. It would be appropriate for DOE to have the flexibility to select sites with water travel times sufficient so that, in combination with the other properties of the site and of the engineering design, there will be reasonable assurance that a regulatory specified overall performance standard will be achieved..

14. Other Wastes Should be Included

NRC's proposed rule deals with high-level and transuranic wastes but ignores other wastes which are logical candidates for a geologic repository. These include the iodine-129 now required by EPA to be recovered separately in fuel reprocessing, recovered carbon-14, and possibly krypton-85. These radionuclides are all present in spent fuel. Both iodine-129 and carbon-14 are potential contributors to radiation exposures in the environment through hydrogeologic transport. They may be in different forms than the high level and transuranic waste. Other possibilities are parts of retired and dismantled process equipment. These wastes should be considered in the proposed rule..

NRC defines "transuranic wastes" as radioactive waste containing alpha emitting transuranic elements, with radioactive half-lives greater than five years, in excess of 10 nanocuries per gram. This is ten-fold lower than the definition in the EPA internal draft standard. The differences should be resolved.

15. Human Intrusion

The proposed criteria are written to direct site selection towards sites of little resource value and for which there does not appear to be attraction for future societies. The consideration is worthwhile. While it is difficult to make meaningful predictions of what will constitute important resources several hundred years from now, predictions on the basis of present views of potential resources would be useful guidance.

NRC also suggests that the emplaced wastes may attract future intrusion. This should appear more explicitly as a consideration in the selection of the waste package and waste form. Relevant here are the value of unreprocessed spent fuel if emplaced as waste and the value of special and expensive materials which may be incorporated in the waste package.

16. Retrievability

NRC proposes to require that the engineered system be designed so that wastes can be retrieved, if necessary, for up to 50 yr after completion of all emplacement. It is understood that the method of retrievability is to be left to DOE, subject to final review by NRC, and that retrieval could include mining of emplacement rooms that have previously been backfilled and sealed. NRC has not justified the numerical requirement of 50 yr of retrievability after the last emplacement. The general concept of the retrievability option is more complex than revealed in NRC's rationale, and it should be more thoroughly evaluated.

17. Population Density

NRC has requested comments on whether population-related siting requirements should be included in the final rule. The "EPA standard" assumed by NRC does not require population data or projections, even though it is intended to meet a specified integrated dose limit to future populations. Instead, it relies upon worldwide averages for consumption of food and water by populations and assumptions of worldwide population growth. However, if the finally accepted EPA standard is still based upon meeting some release limit derived from a population dose limit, the actual population-related features of proposed sites should be considered.

In any event, it is reasonable that geologic repositories for high-level waste be located in areas removed from dense population.

18. Content of the License Application

In paragraph 60.21(C) NRC would require that the license application include data on expected releases of radionuclides to the accessible environment as a function of time. This is not sufficient. Assuming that the basic safety standard will be in the form of some radiation dose or dose rate to a maximally exposed individual or to a population, the application should include the evaluation of site-specific pathways for released radionuclides to reach humans and the radiation doses and dose rates therefrom.

19. What Guidance is Needed by DOE?

Many of the general considerations stated in NRC's proposed rule may be useful guidance to DOE, in that they define some of the issues which NRC will question in its review of a future license application by DOE. However, there is no showing by NRC that the numerical criteria are useful to or needed by DOE. DOE representatives[31] have expressed no such need. Instead, they have observed, as have we, that these numerical criteria could steer the DOE program in unprofitable directions.

DOE's contractors for site exploration must be guided by knowledge of [illegible] characteristics desirable for overall waste-isolation

performance, and DOE's designers of the waste package and of the repository need to design to performance specifications of systems and components. However, developing a technological data base for such specifications and providing these specifications to the repository contractors is a primary responsibility of DOE in managing and implementing the national waste isolation program. It is from DOE that such guidance is to be expected.

However, the national program for geologic waste isolation urgently needs guidance in terms of the overall goal for safety performance. As has been shown in Section B, the published performance analyses by DOE contractors and others, including those relied upon by NRC[5,6,7] assume an overall performance standard in terms of radiation dose to a maximally exposed individual, based upon past precedence in NRC licensing, and these analyses have included estimates of such individual doses for hundreds of thousands of years in the future. Yet, the "EPA Standard" assumed by NRC is based instead upon a specified maximum number of total premature cancers to a population, rather than to individuals, calculated for future times no greater than 10,000 years. The two approaches are markedly different, and the differences should be resolved. This is where guidance is needed, but it has neither been discussed nor supplied in NRC's proposed rule and rationale.

20. Should NRC's Proposed Numerical Criteria be Interpreted More Flexibly?

There have been suggestions[4,32] that the numerical criteria should be interpreted flexibly, and that sites and repository designs could trade high performance in some of the areas specified by NRC's numerical criteria against weaker performance in other areas. Whereas guidance as to interpretation and compliance is an important and vital ingredient in a workable rule, there are two problems with the suggested more liberal interpretations of the rule as now proposed. First, such interpretation is not mentioned in the rule nor in its rationale. Good intentions by the architects of the proposed rule, if not written into the rule, can become forgotten history to the different individuals who must implement the rule in the future. Second, when the numerical criteria are, to a large extent, arbitrary and not based upon clearly understood contributions to overall safety performance, there is little technical basis for settling tradeoffs on such performance parameters.

Flexibility of interpretation and means of verifying compliance should be primary considerations when the overall performance standard is proposed.

21. Summary

The above questions the need, sufficiency, and technical validity of NRC's proposed numerical criteria. Verification of compliance with the numerical criteria would be very difficult, if not impossible.

NRC should carefully review the technical justification for these numerical criteria in light of the comments herein. Any consideration of promulgating numerical criteria should await the enactment of the EPA standard, which these criteria are intended to support. To the extent that any numerical criteria are adopted by NRC, they should appear in regulatory guides rather than in formally enacted rules. They should be accompanied in these guides by clear rationale as to purpose, need, technical basis, and assumptions. The NRC rule should be based as a single overall performance standard.

This review has been limited largely to the technical information and rationale offered by NRC in justifying its proposed criteria. Deficiencies noted in this rationale are not to be interpreted as deficiencies in the national program for geologic isolation of high-level waste. There are data and programs of research, development, and design that bear upon all of the issues raised in this document. It is important that at this stage of waste-isolation development there be sufficient flexibility to apply this information towards achieving reliable waste isolation performance, without the limiting constraints of the numerical criteria proposed by NRC. It is important to avoid adopting parameters which, because of their questionable basis, can steer the national program in directions which may be unproductive in achieving long-term public health and safety.

22. Acknowledgement

This document was prepared by the author in September 1981 at the request of the Board on Radioactive Waste Management of the National Research Council, National Academies of Science and Engineering, to serve as a working paper and to provide a technical basis for a letter report from that Board to the Nuclear Regulatory Commission on the proposed rule 10 CFR 60. The document has benefited from review and input by individual members of the Board on Radioactive Waste Management and by individual members of the National Research Council's Waste Isolation System Panel. The Chairman of the Board on Radioactive Waste Management has transmitted a separate letter report to the Nuclear Regulatory Commission concerning the proposed rule.

The Board on Radioactive Waste Management has kindly consented for the working paper to be revised and issued as an individual contribution to the Nuclear Regulatory Commission, to provide more specific comment and analyses concerning the proposed rule. The views represented herein are those of the author.

23. References

1. U. S. Nuclear Regulatory Commission, Proposed Rule 10 CFR 60, Disposal of High-Level Radioactive Waste in Geologic Repositories," Federal Register, 60-11, July 24, 1981.

2. U. S. Nuclear Regulatory Commission, Rationale for Performance Objectives and Required Characteristics of the Geologic Setting: Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste," June, 1981.

3. U. S. Nuclear Regulatory Commission, Proposed Rule 10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories," Federal Register, 60-11, May, 1981.

4. M. J. Bell (U.S. Nuclear Regulatory Commission), Meeting of Board on Radioactive Waste Management, National Research Council, September 17, 1981.

5. M. C. Burkholder, "Management Perspectives for Nuclear Fuel Cycle Wastes," Nuclear Waste Management and Transportation Quarterly Report, Jan.-Mar., 1976, Battelle Pacific Northwest Laboratories, Richland, WA.

6. M. O. Cloninger, "A Perspective Analysis on the Use of Engineered Barriers for Geologic Isolation of Spent Fuel," Proc. NWTS Info. Mtg., Oct. 30 - Nov. 1, 1979.

7. U. S. Department of Energy, Draft Environmental Impact Statement on the Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-D, 1979.

8. J. G. Kemeny, et al., "Report of the President's Commission on the Accident at Three Mile Island," October, 1979.

9. F. W. Bingham and G. E. Barr, "Scenarios for Long-Term Release of Radionuclides from a Nuclear-Waste Repository in the Los Medanos Region of New Mexico", SAND 78-1730, 1979.

10. National Research Council, "Review of the Criteria for the Site Suitability, Design, Construction, and Operation of the Proposed Waste Isolation Pilot Plant (WIPP)", Progress Report: July 1, 1978 - December 31, 1979, DOE/NE/93023-2 1981. National Academies of Science and Engineering.

11. U. S. Nuclear Regulatory Commission, "Environmental Impact Assessment in Support of Proposed Rulemaking: Disposal of High-Level Radioactive Wastes in Geologic Repositories: Technical Criteria 10 § CFR Part 60:", Draft NUREG-0806, July, 198..

12. H. C. Burkholder, M. O. Cloninger, D. A. Baker, G. Jansen, "Incentives for Partitioning High-Level Waste", Nucl. Tech.:31, 202-217, November, 1976.

13. M. O. Cloninger, C. R. Cole, J. F. Washburn, "An Analysis on the Use of Engineered Barriers for Geologic Isolation of Spent Fuel in a Reference Salts Site Repository", PNL-3356, December, 1979.

14. B. H. Allard, H. Kipatsi, B. Torstenfelt, "Sorption of Long-Lived Radionuclides in Clay and Rock, Part 2, KBS Technical Report 98.

15. L. L. Ames, "Low-Temperature Radionuclide Kd Values for Basalt, Nontronite and Notronite, PNL-2917, 1978.

16. G. S. Barney, "The Kinetics and Reversibility of Radionuclide Sorption Reactions With Rocks", Progress Report for Fiscal Year 1978, RHO-ST-19, 1979.

17. R. E. Gephart, et al, "Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge, RHO-BWI-ST-5, 1979.

18. J. Rennerfeld, "Composition of Ground Water Deep Down in Granitic Rock:, KBS Technical Report 36, 1977.

19. D. Rai, R. J. Serne, D. A. Moore, "Solubility of Plutonium Compounds and Their Behavior in Soils", Soil Sci. Soc. Amer. Jour.:44, 490-495, 1980.

20. D. Rai, R. G. Strickert, "Maximum Concentration of Actinides in Geologic Media", Trans. Am. Nucl. Soc.:35, 185, 1980.

21. D. Rai, R. G. Strickert, D. A. Moore, R. J. Serne, "Influence of Solid Phases on Americium Concentrations in Solutions", PNL-SA-1906, 1981.

22. B. J. Wood and D. Rai, "Nuclear Waste Disposal:Actinide Migration From Geologic Repositories", PNL-SA-9549, 1981.

23. International Nuclear Fuel Cycle Evaluation, "Release Consequence Analysis for a Hypothetical Geologic Radioactive Waste Repository in Hard Rock", INFCE/DEP/WG.7/21, December, 1979.

24. E. A. Bondietti and C. W. Francis, "Geologic Migration Potential of Technetium-99 and Neptunium-237", Science:203, p1337-40, March 20, 1979.

25. Office of Nuclear Waste Isolation, The Reference Repository Conditions Interface Working Group, "Interim Reference Repository Conditions for Commercial and Defense High-Level Nuclear Waste and Spent Fuel Repositories in Salt" (Draft), NWTS-3, December, 1980.

26. J. S. Y. Wang and C. F. Tsang, "Buoyancy Flow in Fractures Intersecting a Nuclear Waste Repository", Heat Transfer in Nuclear Waste Disposal, HTD-Vol. 11, 105-109, ASME, November, 1980.

27. B. L. Cohen, "Effects of ICRP Publication 30 and the 1980 BEIR Report on Hazards Assessment of High Level Wastes", Trans. Amer. Nuc. Soc., 38, 84-85, 1981.

28. J. S. Y. Wang, C. F. Tsang, N. G. W. Cook, P. A. Witherspoon, "A Study of Regional Temperature and Thermohydrological Effects of an Underground Repository for Nuclear Wastes in Hard Rock", LBL-8271, October, 1979.

29. R. J. Magnani and J. W. Braithwaite, "Corrosion-Resistant Metallic Canisters for Nuclear Waste Isolation," Scientific Basis for Nuclear Waste Management, 2., C. J. Northrup Jr., Ed., Plenum Press, New York.

30. M. C. Burkholder and M. O. Cloninger, "The Reconcentration Phenomenon of Radionuclide Chain Migration", The American Institute of Chemical Engineers Symposium Series, No. 179, 74, 1978.

31. C. Heath (U.S. Department of Energy), Meeting of the Board on Radioactive Waste Management, National Research Council, Sept. 17, 1981.

32. U.S. Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, Subcommittee on Radioactive Waste Management, Minutes of meeting of September 2, 1981.

Westinghouse Electric Corporation

Power Systems Company

Nov -6 P1:26

November 4, 1981

(54)

PROPOSED RULE PR-60
(46 FR 35280)

Secretary
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Docketing and Service Branch

SUBJECT: Technical Criteria for the Disposal of High-Level Radioactive Wastes in Geologic Repositories

Dear Sir:

This letter transmits, for consideration by the Commission, Westinghouse comments on the Technical Criteria proposed for incorporation into 10CFR60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," as published in the Federal Register, Vol. 46, No. 130, page 35280, dated July 8, 1981.

Westinghouse has the following general comments on what it considers to be key issues associated with the proposed Technical Criteria.

(a) Westinghouse endorses the use of a multiple barrier approach to waste isolation, including the use of engineered barriers, but we consider that the designer should specify the engineered barriers and associated requirements necessary to meet the overall performance objective for the geologic repository system; namely, the EPA standard. Thus, we disagree with the NRC approach of setting rigid numerical requirements on individual system components, which are not only arbitrary but also tend to establish the specific components to be included in the system. This position is based on a number of reasons including the following.

(1) The number of system components, the degree of redundancy, and the performance requirements placed on the system components depend on a number of factors including the characteristics of the site, the characteristics of the waste, and the performance characteristics of the individual engineered components. Thus, a single set of component performance criteria, as proposed by NRC, is not necessarily appropriate for all situations. For example, if waste having a low heat generation rate (causing a very low thermal pulse in the geology) and a relatively low proportion of long-lived actinides is placed in a repository having highly favorable characteristics (e.g., a very long water travel time), then the need for 1000-year containment and a release rate of one part in 100,000 is highly questionable. Another example is the use of a container having a very long life that is achieved by a favorable combination of material and geochemical environment. If the expected life of the container is several hundred thousand years, then the requirement on the waste form can be relaxed.

11/9/81 wmp

(2) The use of a single set of rigid component performance criteria does not permit the use of trade-offs within the system, thereby precluding innovation by the designer and the use of future technological developments and improved understanding of geologic processes to reduce costs while maintaining the same overall system performance.

(3) The 10CFR60 rules pertain to a single applicant and to a few repositories that will be constructed several years in the future. It seems entirely reasonable for the NRC to evaluate a proposed repository system design on its individual merits at the time of application, rather than prejudging at this time what the system components should be and what requirements should apply to the components.

(4) While safety must be the principal concern in designing a repository system, cost cannot be dismissed as a factor. The rule must be sufficiently flexible to allow the achievement of safety goals in a cost effective manner.

(5) A multiple barrier system implies redundancy; that is, satisfactory system performance is not dependent upon a single component of the system. The level of redundancy provided depends on a number of factors, but ultimately it is based on a judgement made after weighing all of the pertinent factors. The rule should be sufficiently flexible to permit the exercise of that judgement on the part of both the applicant in deriving a design and the NRC in evaluating the design, based on available information.

While we strongly object to including in the rule rigid requirements on individual system components, we also understand that the NRC must be able to establish a basis for concluding that the health and safety of the public will be adequately protected and it is appropriate for the NRC to communicate the factors it currently considers important in establishing that basis. Therefore, it may be appropriate to include in the rule performance guidelines, in the form of design objectives for individual system components, that the NRC currently considers acceptable, together with a clear statement that alternatives will be considered as long as the NRC can establish a satisfactory basis for concluding that the issuance of a license will not constitute an unreasonable risk to the health and safety of the public.

(b) The 50-year retrievability requirement specified in paragraph 60.111(a)(2) has stirred considerable controversy. This paragraph as well as language in the supplementary information imply that tunnels can be backfilled prior to the end of the 50 years, but some of the detailed design criteria imply that the tunnels must be designed to remain open during the retrievability period. If, as we believe the NRC intended, the requirement to maintain the option to retrieve does not preclude the backfilling of underground openings or decommissioning during the retrieval period, then we believe the 50-year retrieval requirement will not have a significant impact on repository design.

However, this must be clarified in the rule. With respect to the waste package, the designs currently under development by Westinghouse for the Office of Nuclear Waste Isolation are impacted very little by the retrievability requirement. Based on the preceding considerations, Westinghouse has no strong objection to the retrievability requirement. However, the specified 50-year period is very arbitrary, and the actual time required to confirm repository performance and reach a decision to decommission is dependent on a number of factors and, while the 50-year requirement may not have a foreseeable impact today, that may not always be the case (e.g., waste package requirements and designs could possibly change). Therefore, we recommend that the specified 50-year period be identified as a design objective and that the rule state that a shorter period will be considered if suitable justification is provided.

(c) Westinghouse considers it appropriate to specify a time period over which reasonable assurance of satisfactory repository performance must be predicted. A time period of 10,000 years after permanent closure of the repository seems reasonable, based on the realization that prediction of processes and events beyond 10,000 years tends to become increasingly speculative.

(d) Addressing transuranic (TRU) waste in this rule is inappropriate. The NRC has not yet established regulations dealing with the disposal of TRU waste, and the overly stringent requirements for TRU waste in this rule might establish inappropriate precedents with respect to future TRU regulations that might be proposed. Accordingly, it is strongly recommended that all reference to TRU waste be deleted from the 10CFR60 Technical Criteria.

(e) Many of the design and construction requirements refer to "structures, systems, and components important to safety." However, without a definition of "important to safety," there is no basis for determining what should be considered under this category. In reality, a repository operations area will have very few structures, systems, or components that are important to assuring the health and safety of the public. However, it is important to specify those components that are important because special design, procurement, construction, and quality assurance requirements will be applied to them.

(f) The design and construction requirements contained in the proposed Technical Criteria are much too detailed, some are conflicting, some are unnecessarily restrictive, and some are completely unnecessary. The rule should contain only top level criteria and requirements and, where appropriate, they should clearly identify the concern being addressed. Details associated with the top level requirements are best contained in supporting documents such as Regulatory Guides.

With respect to specific, detailed comments, the NRC is referred to the extensive list of comments on the proposed Technical Criteria submitted by the Atomic Industrial Forum (AIF). Westinghouse concurs with these comments and recommends their consideration by the Commission. These comments contain suggested wording that would resolve Comments (a) through (e) above, as well as numerous comments

which, if implemented, would improve and simplify the specified design and construction requirements. Westinghouse also concurs with the AIF recommendation that the rule in its present form be reworked and released for comments.

Westinghouse fully recognizes that establishing an acceptable and practical regulation governing the disposal of high level waste is an important step in achieving a successful waste management system. Therefore, Westinghouse is prepared to assist in any way possible, either directly or through organizations such as the AIF, in achieving this goal.

Sincerely,

DUKE POWER COMPANY DOCKETED USNRC

POWER BUILDING

422 SOUTH CHURCH STREET, CHARLOTTE, N. C. 28242

'81 NOV -6 P2:15

WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

November 3, 1981

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

(55)

Mr. Samuel J. Chilk
Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Attention: Docketing and Service Branch

Subject: 10 CFR 60
Disposal of High-Level Radioactive Wastes in Geologic Repositories
File: GS-314.06

Reference: 46 F.R. 35280; July 8, 1981
Proposed Rule

Dear Mr. Chilk:

By the referenced notice, the Nuclear Regulatory Commission published for comment its proposed technical criteria for disposal of high-level radioactive wastes in geologic repositories.

Duke strongly supports the timely adoption of technical criteria for high-level waste disposal, and believes the proposed criteria represent a significant improvement over the draft on which we commented formally on July 14, 1980. In particular, we believe the issues of human intrusion, population-based siting requirements, and ALARA considerations are appropriately treated in the proposed rules.

However, in our view a fundamental problem still exists in the rule as proposed in the area of individual barrier minimum performance standards. The Commission has correctly recognized this as an important issue, and has specifically requested comments on alternative approaches to this question. Duke believes, for reasons detailed below, that it is preferable to prescribe a single performance standard which must be met by the entire disposal system. This is in contrast to the prescription of minimum performance standards for each of the major elements of the system, as embodied in the proposed rule.

Regardless of performance standards imposed on individual system elements, assessment of overall repository performance will have to be performed to assure that the environmental standard which presumably will be promulgated by the EPA is met. This is because meeting the individual performance standards does not guarantee that the overall environmental standard is met.

Acknowledged by card 11/9/81 emp

Such an assessment will necessarily involve the combination of mathematical models of each element of the system, appropriately benchmarked to whatever test data is available and applicable. Since the models and test data used to perform the overall assessment will presumably be the same ones used to demonstrate the effectiveness of each individual barrier, the arbitrary prescription of a number of barrier performance standards is, at best, unnecessary, and at worst, counterproductive, in the sense that a repository system which can be shown to have a very large overall margin of safety might well be judged unacceptable in a licensing proceeding due to a deficiency in only one part of the system.

It goes without saying that such a result would have an undesirable impact on a program of national importance, both in terms of schedule and cost.

We believe this issue must be dealt with by the Commission, in view of the fundamental role it plays throughout the rule as written, and appreciate this opportunity to comment. We wish at this time to endorse the more detailed comments on the proposed rule submitted by the Utility Nuclear Waste Management Group on November 2, 1981.

We hope these comments will be helpful in developing a technically sound rule for the disposal of high-level radioactive wastes, and would be happy to discuss them further if desired.

Very truly yours,

William O. Parker, Jr.

WOP:dyh

(56)

-60
(46 FR 35280)

EDISON ELECTRIC INSTITUTE The association of electric companies
Washington, D.C.

November 3, 1981

Chairman Nunzio Palladino
Commissioner Victor Gilinsky
Commissioner Peter Bradford
Commissioner John Ahearne
Commissioner Thomas Roberts
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

'81 NOV -9 P1:41

Re: Notice of Proposed Rulemaking: 10 CFR Part 60,
Disposal of High-Level Radioactive Wastes in
Geologic Repositories (Technical Criteria)
46 Fed. Reg. 35,280

Gentlemen:

The enclosed comments have been submitted by the Utility Nuclear Waste Management Group (UNWMG) in connection with the above-referenced matter. The Edison Electric Institute (EEI) supports these comments and believes that they are of such import that they should be brought to your direct attention.

In particular, EEI wishes to emphasize the view expressed in the comments that the NRC should utilize the systems approach (identified as "Alternative 1" in the notice of rulemaking) rather than the barrier performance objectives approach ("Alternative 2"), which is the basis for the rule as currently proposed. EEI believes that the specific requirements for separate components and subsystems prescribed in the proposed rule are not only unnecessary, but would deny the DOE reasonable flexibility in achieving overall system safety and performance objectives. Accordingly EEI urges that, in adopting a final rule, the NRC select the approach embodied in Alternative 1 rather than that of Alternative 2, which is now reflected in the rule as proposed.

Sincerely,

John J. Kearney

JJK:rml
Enclosure

11/16/81 cmp

UNWMG
Utility Nuclear Waste Management Group
1111 19th Street, N.W. • Washington, D.C. 20036 • (202) 828-7609

MEMBERS

November 2, 1981

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Docketing and Service Branch

Re: Notice of Proposed Rulemaking: 10 CFR Part 60,
Disposal of High-Level Radioactive Wastes in
Geologic Repositories (Technical Criteria)
46 Fed. Reg. 35,280

Dear Sir:

These comments are submitted on behalf of the Utility Nuclear Waste Management Group (UNWMG) in connection with the above-referenced matter.

The UNWMG has maintained a continuing interest in the development of 10 CFR Part 60 over a number of years. In particular, with respect to the establishment of technical criteria for regulating the geologic disposal of high-level radioactive waste, the UNWMG provided, on July 31, 1980, detailed comments in response to the Commission's advance notice of proposed rulemaking (45 Fed. Reg. 31,393).

The current rule, as proposed, incorporates a number of improvements over earlier versions, and the UNWMG wishes to commend the NRC on its continuing effort toward further improvement. However, the UNWMG continues to have a fundamental concern over the specific, quantitative performance objectives for separate components of the repository system still contained in the rule. We also believe that other provisions of the proposed rule can be improved.

The UNWMG comments on the proposed rule are presented in two separate parts. First, the remainder of this letter addresses the specific areas identified in the notice of proposed rulemaking as being of special interest to the Commission. In particular, the matter of

Secretary of the Commission
November 2, 1981
Page Two

"Alternative 1" (the "systems approach") versus "Alternative 2" (the "barrier performance objectives approach") is discussed in some detail, and -- because of its overriding significance and importance -- is addressed first.

In addition to the responses contained in the body of this letter, the Attachment presents specific, detailed comments on the wording of the rule as proposed in the notice of rulemaking. As discussed more fully below, the UNWMG believes that regulations based on a systems approach would be both more technically sound and workable than those currently proposed by the Commission, which are keyed to the performance of specific nuclide barriers. However, should the NRC choose to retain the current barrier performance objectives approach, we believe the comments in the Attachment will aid in the development of a supportable, practical rule governing the design, construction and operation of geologic repositories.

<u>Alternative approaches: systems approach v. barrier performance objectives (46 Fed. Reg. 35,283-84)</u>

While it is generally agreed that the use of separate nuclide barriers and other features -- such as a reasonably long-lived waste package, a stable waste form and a favorable geologic setting (exemplified, in part, by significant water travel times to the accessible environment) -- is appropriate for a repository system, the fundamental, basic consideration is assurance that such barriers and features operate in a way so as to preclude the excessive release of radioactive materials to the accessible environment. From this perspective the NRC barrier performance objectives approach, as embodied in the current proposed regulations, can only be viewed as the arbitrary imposition, on individual system components, of specific-value standards that are without scientific or other technical support. Moreover, it is intrinsically at odds with an important aspect of sound repository design and operation; <u>i.e.</u>, the interaction of individual components to achieve, on a combined basis, the required level of repository system performance. Further, we cannot agree that the inclusion of such component requirements will increase the ability to show compliance with an overall system performance requirement (<u>e.g.</u>, EPA protection standards), since such a showing will necessarily involve the use of mathematical models independent of specific component performance requirements.

Secretary of the Commission
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Page Three

UNWMG is firmly of the view that overall repository performance should be addressed directly by means of the systems approach. Utilization of an overall performance standard would correctly serve to focus attention on total repository performance. In addition, it would provide for appropriate design flexibility; something which is important in order to both be able to take advantage of new developments, as this new undertaking proceeds, and to accommodate and effectively utilize the specific characteristics of individual sites.

In particular, use of the EPA environmental standards in 10 CFR Part 191 -- which are currently in draft form and, when adopted, will have to be met anyway -- would provide a unified, supportable basis for regulation and, at the same time, preclude the possibility of conflicting regulatory requirements. Utilization of a systems approach, based on such overall system performance standards, would have the additional advantage of being universally applicable to all geologic repositories. Thus, special criteria pertinent to disposal in, for example, the vadose zone, would be unnecessary.

UNWMG notes that the Commission could, consistent with a systems approach, specifically require the utilization of certain components (a waste package, stable site geology, <u>etc.</u>) in any and all repositories. However, the prescription of separate numerical barrier performance objectives should be avoided. This, of course, could be accomplished either by eliminating individual numerical requirements, or by specifying that variations and departures from them would be equally acceptable as long as the overall performance requirements for the repository system were met.

Whether or not the Commission decides to require the use of specific components, however, UNWMG urges that the NRC adopt a rule which properly implements the systems approach by prescribing performance standards for the entire repository system, rather than imposing numerical requirements for individual components.

<u>Retrievability (46 Fed. Reg. 35,282)</u>

UNWMG is of the view that requiring, as a parameter of repository design, the ability to maintain retrievability for a period of up to 110 years is excessive and without adequate supporting rationale. In addition, a design allowing for retrieval over a 50 year period following waste emplacement could, in and of itself, motivate extended and unnecessary delay in final repository closure, <u>i.e.</u>, shaft sealing.

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November 2, 1981
Page Four

A more reasonable and appropriate approach might be to base design requirements for retrievability, if any, on the period of repository operation. Assuming the first waste packages to be loaded into the repository could be in place for about 30 years before all emplacement was complete, and allowing another 30 years (the same time as for original construction and emplacement) for retrieval, would lead to a retrievability design requirement for a total of 60 years. Such a period would be reasonable since any difficulties which are likely to be apparent at any time in the near future will probably manifest themselves quickly. In addition, it would tie retrievability to the period of the waste package monitoring program, which must extend as long as practical up to the time of permanent repository closure.

In any event, the rule, itself, should make clear that the requirement for retrievability does not preclude the back-filling of emplacement rooms and drifts when the operator deems it appropriate. From the discussion at page 35,282 of the Federal Register it is clear that, as the rule is now written, it is not the intent of the Commission to preclude such back-filling. However, to avoid any possible misunderstanding, the wording of the rule, itself, should be clarified.

<u>Human Intrusion (46 Fed. Reg. 35,283)</u>

The treatment of this subject is proper and should be preserved in the final rule. In this same general connection, however, UNWMG believes that the importance of avoiding natural resources, in the siting of a repository, is overemphasized. This point is considered in additional detail in the Attachment to this letter.

<u>Population (46 Fed. Reg. 35,284)</u>

UNWMG supports the approach taken in the proposed rule which does not include any siting requirements dealing directly with population density or proximity to population centers. Over the periods of time involved, such requirements would be virtually meaningless since, among other things, population projections into the far future would be completely speculative. Further, since overall system performance requirements will, presumably, be stated in terms of radioactive material release limitations, population-related siting requirements are unnecessary from a purely regulatory viewpoint.

Secretary of the Commission
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<u>Design and construction criteria (46 Fed. Reg. 35,285)</u>

UNWMG believes that the level of detail required under the rule, as proposed, is excessive and should be greatly abbreviated. This comment is based upon what the UNWMG views of the basic desirability of maintaining flexibility with respect to design and construction wherever possible and minimizing unnecessary cost. It is difficult to identify any repository structure, system or component important to safety in terms of limiting accident doses to the public to levels such as the 0.5 rem prescribed in 10 CFR § 20.105(a) pertaining to allowable levels of exposure in unrestricted areas. Accordingly, the need to specify design and construction requirements, if any, is small.

This matter is considered in additional detail in the Attachment to this letter.

<u>ALARA (46 Fed. Reg. 35,289)</u>

UNWMG is of the view that, with respect to high-level waste repositories, the application of an ALARA principle is superfluous. Projected doses are a small fraction of those resulting from variations in natural background radiation. Further reductions cannot be justified. In addition, the inclusion of an ALARA principle would add nothing to the certainty of performance of any individual component or the overall repository system. Thus, application of ALARA would make no sense and, indeed, could lead to confusion. Accordingly, its use should be avoided.

In concluding this letter we would like to note that, as in the past, the UNWMG would be pleased to discuss these comments -- as well as those in the Attachment -- with the NRC in additional detail, if so desired.

Sincerely,

R. E. L. Stanford
Program Manager

Enclosure

A-178

ATTACHMENT

Secretary, U.S. Nuclear Regulatory
Commission
November 2, 1981
Re: Notice of Proposed Rulemaking
10 CFR Part 60 (46 Fed. Reg. 35,280)

Presented below are specific, detailed comments on the wording of 10 C.F.R. Part 60 as proposed in the above-referenced rulemaking. As discussed in the letter to which this Attachment is appended, the Utility Nuclear Waste Management Group (UNWMG) favors recasting of the currently proposed rule so as to adopt "Alternative 1" (the systems approach). However, the detailed comments presented below are offered in the event that the NRC should choose to retain the current barrier performance objectives approach. It is hoped that, in such a case, the comments will aid the development of a sound, workable rule governing the design, construction and operation of geologic repositories.

- pp. 35, 295-96, col. 3 & 1-2 respectively

Definitions contained in § 60.2 should be modified as follows:

- The definition of "disturbed zone" should specifically refer to the properties of the geologic setting which are of interest insofar as disruption is concerned. In particular, "disturbed zone" would be better defined as "that portion of the geologic setting the physical and/or chemical properties of which is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste."

- In the definition of the term "floodplain," the words "including flood prone areas of offshore islands" should be deleted as they are redundant.
- "HWL facility" should be corrected to "HLW facility."
- The phrase "important to safety" is significant primarily to the extent that it serves to identify structures, systems and components subject to the design, construction and quality assurance requirements specified in §§ 60.130, 60.133 and 60.150. The definition in the proposed rule, however, is overly vague. To cure this, the meaning of "undue risk to the health and safety of the public," as used in the definition, should be specified in terms of a particular dose to a member of the public. In this regard, the UNWMG believes that use of a

dose of 0.5 rem to the whole body; or any organ, similar to that utilized in 10 C.F.R. § 20.105(a) in connection with allowable, annual whole body doses to persons in unrestricted areas, would be appropriate.

Definition of "stability," without reference to a particular type of stability (e.g., structural stability, tectonic stability, hydrogeologic stability, geomorphic stability, etc.) is somewhat confusing. Accordingly, the term should be defined with reference to particular modifiers.

As presented in the proposed rule, the definition of "transuranic wastes" or "TRU wastes" is unduly restrictive. There is no technical justification for a 10 nanocurie per gram limitation. Further -- from a practical standpoint -- such a level is at the extreme low end of detectability. A limitation of 100 nanocuries per gram, as contained in the draft EPA standards for 40 C.F.R. Part 191, would result in a more workable and technically sound definition.

In any event, as discussed below in connection with § 60.102(b)(4), the UNWMG is of the view that regulations pertaining to TRU should be developed in a separate document. Such an approach would, among other things, provide an opportunity for directing needed attention to the unique aspects of TRU waste disposal. In this connection, the UNWMG will be providing additional analysis of TRU waste disposal in its comments on the regulations currently being proposed for 10 C.F.R. Part 61.

p. 35,286, col. 3

As currently worded the requirement contained in § 60.10(d)(2) is confusing. To the extent that the intent is to require that the number of exploratory boreholes and shafts be minimized, the section should be reworded to directly so state.

p. 35,287, col. 1-3

The use of the term "bulk" with respect to geomechanical, hydrogeologic and geochemical conditions and properties in §§ 60.21(c)(1)(i)(C)-(F) differs from normal technical usage. The apparent reference is to the average of such properties and conditions over the disturbed zone. The language should be modified to so state.

With respect to § 60.21(c)(1)(ii)(E), it may be impossible to literally "confirm" models used to perform the required assessments. Rather, it would be more appropriate to require that assessments be <u>supported</u> by tests, data or studies. Further, it is not clear what would constitute "field-verified laboratory tests." Depending on the definition, field-verification may not be possible in some situations. A preferable approach would be to reference and require "appropriate laboratory and field tests."

Under § 60.21(c)(3), "a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation" is required. For the reasons discussed in the letter to which this Attachment is appended, however, such an open-ended, ALARA-type analysis is unnecessary. Simply stated, where projected doses are a small fraction of those which already result from variations in natural background radiation, further reductions cannot be justified. Accordingly, the requirement should be deleted.

p. 35,289,
col. 1-2

In addition, the use of the expression "undiscovered deposits of natural resources" in § 60.21(c)(13) appears to be intended as a term of art (such as used by McKelvey in U.S.G.S. Professional Paper 820), meaning speculative resources; or those suspected but not actually found. If this is, indeed, the case, appropriate references or clarification should be provided to avoid any possible misinterpretations.

More basically, however, whatever the intended meaning of the expression, a prospective site would be explored in such detail during the characterization process that, as a matter of course, the presence or absence of resources should become well enough understood to accommodate the site selection process. Accordingly, § 60.21(c)(13) should be eliminated from the final rule as superfluous.

Finally, the word "sits" in § 60.21(c)(1)(ii)(A) should be "site."

Section 60.101 presents the purpose and nature of findings relevant to technical criteria. Pursuit of the barrier performance objectives approach, however, has resulted in a lack of flexibility. Proposed numerical standards do not accommodate the wide range of variations available for allocating safety functions among separate system components when designing to meet overall performance criteria for repositories in various geologic media. In short, single-value criteria that attempt to cover all options are appropriate for none of them. The use of such criteria, as currently prescribed in the regulation, could bias site selection and design; quite possibly to the extent that achieving required performance would be both more difficult and costly.

In addition, the UNWMG cannot agree with what appears to be the major NRC motivation for the inclusion of such criteria (see page 35,294) that the inclusion of individual component requirements facilitates a showing of compliance with overall system performance requirements (EPA standards). Such a showing will necessitate the use of numerical models, independent of specific, individual component requirements.

To provide an efficient, practical regulatory framework for repository licensing the Commission should assure that the regulations afford sufficient flexibility to both take advantage of new developments, and effectively utilize the specific characteristics of individual sites. Such flexibility could be provided through the addition of a new paragraph (c) in § 60.101 as follows:

(c) Sections 60.111 and 60.112 contain performance objectives concerning the containment of waste in the waste packages; the control of releases from the engineered system; and pre-waste emplacement groundwater travel times through the far field to the accessible environment. The ability to meet specific performance objectives, however, will vary from site to site, particularly as a function of the host rock involved. Accordingly, variations from and/or alternatives to the specific performance objectives are equally acceptable, provided that there is reasonable assurance that the overall system performance objective embodied in the environmental radiation protection standards referenced in § 60.111(b)(1) will be met.

p. 35,288, col. 3

Section 60.102(b)(4) addresses waste form requirements for TRU. Because of the special factors relevant to transuranic waste disposal, however, we believe that regulations pertaining to the management of such material should be developed in a separate document, and that this section of the regulations should so note. If this approach were followed, some of the complexity of the currently proposed rule would be eliminated. This approach would also provide an opportunity for directing needed attention to the unique aspects of TRU waste disposal.

p. 35,299, col. 1-3

As stated in the letter to which this Attachment is appended, the [illegible] is of the view that the provision of § 60.111(a)(2) requiring, as a basis for repository design, the ability to maintain retrievability for a period of up to 110 years is excessive and without substantial

rationale. In addition, a design allowing for retrieval over a 50 year period following waste emplacement could, in and of itself, motivate extended and unnecessary delay in final repository closure.

A more reasonable and appropriate approach might be to base design requirements for retrievability, if any, on the period of active repository operation. Assuming the first waste packages to be loaded into the repository could be in place for about 30 years before all emplacement was complete, and allowing another 30 years (the same time as for original construction and emplacement) for retrieval, would lead to a retrievability design requirement of 60 years, total. Such a period would be reasonable because retrievability, if it is to be designed for at all, should be tied to a concept of performance confirmation, and any difficulties which are likely to be apparent at any time in the near future will probably manifest themselves quickly. Further, such an approach would tie retrievability to the period of the waste package monitoring program, which must extend as long as practical up to the time of permanent repository closure.

In any event, the rule, itself, should make it clear that the requirement for retrievability does not preclude backfilling of the emplacement room and drifts when the operator deems it appropriate.

In addition, § 60.111(b)(2) imposes, as design objectives: (1) that the waste packages contain all radionuclides for at least the first 1,000 years after permanent closure, and (2) that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting -- assuming anticipated processes and events -- is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. It is obvious that literal proof of compliance with these objectives is neither intended nor

possible. To avoid any potential confusion in either the licensing review or hearing process, however, these provisions should be redrafted to emphasize that the specifications are only *design* objectives; *i.e.*, that the intent is to provide for the application of pertinent field, laboratory and analytical information in accordance with good engineering practice.

In particular, with respect to the 1,000 year containment requirement, the rule should specifically provide for a determination based on *reasonable* input parameters, derived from acceptable field and laboratory data and analyses, for a *nominal* (not first-to-fail) waste package. Similarly, the one part in 10^5 release rate requirement should be prescribed in terms of being demonstrable by means of analysis based upon reasonable input parameters. This portion of the rule, too, should specifically provide for analysis based upon typical waste package performance, and reasonable inputs with respect to the underground facility. A period of consideration, *i.e.*, out to 10,000 years as is being utilized by EPA in the case of its draft radiation protection standards, should also be specified.

In addition, § 60.111(b)(2)(i) imposes an assumption of "all or partial saturation of the underground facility." Under certain circumstances, however, (e.g., disposal in salt) such an assumption may not be reasonable. Accordingly, the rule should provide that the waste package design basis may reflect site specific conditions.

Finally, the specific requirements pertaining to TRU waste should be removed from § 60.111(c)(2) for the reasons discussed above in connection with § 60.102(b)(4).

p. 35,299, col. 3

Section 60.112 specifies certain required characteristics of the geologic setting having to do with stability and groundwater travel times. As discussed above in connection with § 60.111 however, it is important that the rule note that a reasonable demonstration of the required characteristics is sufficient, and that a higher level of proof is not required.

Further, the requirement prescribed in § 60.112(e), which limits repositories to locations

exhibiting pre-waste emplacement groundwater travel times through the far field to the accessible environment of 1,000 years or more, could be confusing insofar as disposal in media such as salt is concerned. To avoid possible uncertainty, the 1,000 year groundwater travel time requirement should be worded as follows:

> The geologic repository shall be located so that the travel time of any groundwater flowing between the outermost waste container location and the accessible environment is at least 1,000 years.

p. 35,290, col. 1-2

In § 60.122 the proposed regulations require specified favorable conditions "so that, together with the engineered system, the favorable conditions present are such to provide reasonable assurance that . . . performance objectives will be met." In accordance with the discussion above in connection with §§ 60.111 and 60.112, however, the rule should specify that the indicated "favorable conditions" may be determined on the basis of a reasonable demonstration, and that additional certainty is not necessary.

In addition, §§ 60.122(a)-(e) involve the projection of [illegible] tectonic, structural, hydrogeological, geochemical and geomorphic processes into the future. Such projections, however, should not be left open-ended, and should be specifically limited to the period of analytical consideration; i.e., the 10,000 year period suggested above in the discussion of § 60.111(b)(2).

In this same general connection, UNWMG believes that the absence of groundwater travel times from the geologic setting to the accessible environment of less than 1,000 years should also be indicated as a favorable condition in this section. The 1,000 year flow time from the outermost waste container to the accessible environment, discussed above in connection with § 60.112(c) as a performance objective, is, of course, more significant. However, UNWMG believes that the lack of groundwater communication from anywhere in the entire geologic setting to the accessible environment within 1,000 years would offer an additional advantage sufficient for its identification as a "favorable condition."

Finally, in the tenth line of § 60.122, the word "engieered" should be "engineered."

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p. 27,290-91, col. 2-3 & 1, respectively

Again, the rule should specifically provide for a determination of the existence or non-existence of the potentially adverse conditions identified in § 60.123 on the basis of a reasonable analysis. In this regard, § 60.123(b) requires geologic investigation to a distance 500 meters below the repository. This appears excessive and, under some circumstances, could be counterproductive (as when a deeper aquifer is penetrated by an exploratory borehole). If a numerical value is deemed necessary, 100 meters would seem both more realistic and reasonable.

In addition, § 60.123(b)(14) identifies as potentially adverse "[g]roundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could affect the solubility and chemical reactivity of the engineered systems." Any groundwater, however, will "affect" solubility and chemical reactivity. Accordingly, the proper issue is whether or not there will be a significantly adverse effect. The regulation should be revised to correctly reflect this concern, perhaps by adding "adversely, in a significant way."

after the word "affect" in the proposed text.

pp. 35,292-94, beginning with col. 2 on the first page to col. 3 on the last page

Sections 60.130 to 60.134, inclusive, specify numerous requirements for the design of, and construction specifications for, the geologic repository operations area. As discussed in the letter to which this Attachment is appended, UNWMG believes that the level of detail prescribed is excessive and should be greatly abbreviated. This comment is based upon what the UNWMG views as the basic desirability of maintaining appropriate flexibility with respect to repository design and construction. Nevertheless, UNWMG is of the view that the rule will at least be generally practical if the suggested modification to the definition of "important to safety," discussed above in connection with § 60.2, is adopted. There are, however, several areas which are in need of particular attention.

4-182

First, § 60.132(g)(4) states that "Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained." This requirement is overly vague. It should be recast in terms of controlling and containing unexpected inrushes of water or flooding that can <u>reasonably</u> be hypothesized.

Second, § 60.132(j)(2) requires that handling systems be designed "to minimize the potential for operator error." The design of a handling system, however, is a function of a number of considerations (such as space availability, reliability, maintainability, <u>etc.</u>), and cannot have as a sole goal minimizing the potential for operator error. This section should be revised to reflect this fact.

Third, § 60.133(b)(1) should be deleted. The decision to seal shafts and boreholes is an operational one. Accordingly, it should be made by the operator on the basis of operational considerations.

Finally, § 60.133(b)(2) is unduly restrictive and, in fact, would discriminate against favorable media such as salt. The first sentence should be deleted. A design aim for such seals would be more realistically and soundly based on a performance objective tied to overall system performance, e.g., if it prescribed that shaft and borehole seals be so designed and constructed as not to compromise the overall system performance objective.

p. 35,295, col. 1

Section 60.140(a) requires a performance confirmation program to "ascertain" whether or not certain conditions exist. In some cases, however, it may be impossible to confirm completely certain conditions. Accordingly, § 60.140(a) should be modified to reflect that confirmation is required only to a reasonable extent.

Section 60.140(d)(1) requires that the confirmation program be implemented so as not to

"adversely affect the natural and engineered elements of the repository." Almost any confirmation program, however, will have some adverse effects. Accordingly, the regulation should be reworded to require that the confirmation program not adversely affect the natural and engineered elements of the repository to a significant degree.

- p. 35,295, col. 3

Section 60.150(a) defines quality assurance as "all those planned and systematic actions necessary to provide adequate confidence that the repository and its subsystems or components will perform satisfactorily in service." UNWMG assumes that "adequate confidence" is equivalent to reasonable assurance, and the rule should be modified to so reflect.

- p. 35,296, col. 1

As in § 60.150(a), reference is made to "adequate confidence" in § 60.153, with respect to assuring that emplaced wastes will remain isolated from the accessible environment. As suggested with respect to § 60.150(a), the content of § 60.153 should be modified to indicate that reasonable assurance constitutes "adequate confidence."

LAWRENCE LIVERMORE LABORATORY

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PR-60
(46 FR 35280)

November 4, 1981

Secretary of the Nuclear Regulatory Commission
Washington, D.C. 20555

Reference: Comments on Proposed Rule 10CFR Part 60

Sir:

Enclosed is a copy of a proposed draft ANSI Standard which is in preparation. Earlier drafts have been widely circulated; significant comments have been received from many reviewers. The resulting draft represents a consensus of a broad spectrum of individuals on what constitutes an appropriate approach to evaluating disposal alternatives for radioactive wastes. We, therefore, are submitting this for the record in your deliberating process on 10CFR Part 60.

Very truly yours,

Burton C. Musgrave

BURTON C. MUSGRAVE, Chairman
ANS 40.12, Writing Committee

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Enclosure

11/16/81 emf

DRAFT 6

ANS - 40.12 PROPOSED STANDARD

GENERAL CRITERIA FOR
RADIOACTIVE WASTE DISPOSAL

November 3, 1981

40.12 GENERAL CRITERIA FOR
RADIOACTIVE WASTE DISPOSAL
(This foreword is not part of American National Standard)

Foreword

The disposal of radioactive wastes, as with other of man's activities and many natural events, carries with it certain risks. These risks may be to the health and safety of people or to the quality of the environment.

Zero risk, or perfect safety, is not generally achievable. In fact, overly costly attempts to achieve zero risk in one area will almost inevitably increase, more than proportionately, risks in some other areas. This is because an inordinate amount of society's scarce resources may need to be deployed as risk in one area is pushed toward zero, and these deployments may have other and larger risks and costs associated with them. Even when net risk can be further reduced, if risk is already very small the required expenditure of additional resources may result in a very low marginal return on investment. Such limited resources could be expended much more effectively toward reducing risk in some other activity.

Setting criteria for radioactive waste disposal, or for that matter, just about anything else, involves defining, either explicitly or implicitly, the boundaries of acceptable risk. This is a difficult and controversial task.

One approach to setting such criteria is to examine what society seems to be willing to pay to avoid the statistical occurrence of an injury, a death, or an undesirable environmental impact. For example, in the case of radiation effects arising from the nuclear power industry, an expenditure of $1000 per man-rem of population exposure avoided is embodied in current NRC power reactor regulations. Similar regulations have not been established for other parts of the nuclear fuel cycle or one fuel cycle operations. It is reasonable to assume that this or a similar number would be selected for the fuel cycle, including waste management.

The comparison of protection of society from risk due to disposal of any class of radioactive waste material should not require a greater expenditure of resources than society is generally willing to pay for equivalent protection from other hazardous materials.

However, the social willingness to pay can change in response to changing values, perceptions, and concerns. Thus, the influence of a particular standard can exist long beyond the existing foundation on which that standard was based.

This first approach has an additional problem in the degree of inconsistency implied by many of these social decisions. In the example given above we are spending much more to avoid a radiation-induced death from nuclear power than from medical X-ray equipment or natural sources of radiation*.

These problems, in our opinion, do not invalidate the approach; they do however, call for a degree of conservatism in its application.

A second approach to defining acceptable risk is to require that the proposed activity not result in any net increase in risk. With respect to radioactive waste disposal, this could be accomplished by assuring that the risks from a high level waste repository be no greater than the risks from typical uranium ore bodies which yielded the amount of uranium needed to produce the quantity of wastes.

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*It is also true that we are presently spending much more to avoid a radiation induced injury from nuclear power than we are spending to avoid other preventable injuries.

A comparison of waste disposal with naturally occurring ore bodies and materials is an appealing approach. It is relatively easy to understand. Moreover, in the modeling of certain comparative risks (such as those arising from improbable geological events) errors in the analytical description of events will tend to cancel out, leaving the comparison still valid.

Both the first and second alternative approaches require the development of accepted probabilistic models to characterize normal and abnormal occurrences and release and exposure paths. These models are necessarily complex and difficult to validate. We therefore considered how the analytical problem might be reduced. This resulted in a proposed third approach in which a comparison with a reference natural uranium ore body would be made in each of three aspects: stability of waste form/ore; integrity of host medium; and isolation from the biosphere. This third alternative is similar to the second alternative above; however, a comparison is made of each of the three aspects rather than requiring comprehensive probabilistic models. If the proposed waste repository was judged to be safer than the reference natural uranium ore body in each of these respects, then the more comprehensive analysis required by the second approach would not be needed.

Intentional intrusion should be economically equal to or less attractive than the original ore body. This implies that the combination of the value of the components of the disposed wastes and the cost of recovery should make the net cost of recovery of those components as high as it is for other potential sources of equivalent materials.

Here again, there is the possibility of requiring more risk reduction than is justified, so our proposal is to leave the selection of a particular approach (among the three described herein) to the discretion of the applicant. We suggest that the applicant use the third approach, unless it appears to require additional resource expenditures clearly in excess of the benefits of its marginal reduction in risk, because it is simpler to apply and such an approach will almost certainly assure an overall reduction in the hazard from the earth's crust.

In a comparable manner the expected performance of a disp sal site for low level wastes may be compared to the naturally occurring hazardous materials in the vicinity of the candidate site. Occurring throu[illegible] e. th's surface areas are concentrations of toxic materials such tha[illegible] es survive in the immediate environs. It is reasonable to consider that, if, as shown by appropriate detailed analysis, a proposed low level waste disposal site will have no greater impact than naturally occurring toxic materials, the disposal site will not significantly degrade the environment. To avoid careless disposal of wastes adjacent to a small highly toxic spot, it should be required that the naturally occurring toxicity be averaged over a sizeable area. For this purpose an area 80 km in radius around the proposed disposal site should be sufficient to assume that there will be little or no increase in risk arising from the low level waste disp sal site.

The Draft Standard was developed by the ANS 40.12 working group. This standard writing group was formed by the American Nuclear Society in recognition of an urgent national need for radioactive waste disposal criteria which could be used by the cognizant regulatory agenc[illegible]s by reference in regulations or as guidance.

The group initially met at the invitation of R. I. Newman [illegible]orristown, New Jersey on August 2, 1978. At this meeting the principles [illegible] schedule for development of the standard and a wide-based membership in the preparation were decided upon. Assignments were made for preparation of drafts of backup materials for discussion by the full group. The first meeting of the full working group was in Silver Spring, Maryland, on November 18, 1978*. At this meeting the scope and basic goals of the standards were discussed.

A subsequent meeting was held in Crystal City, Virginia on January 24 and 25, 1979 to discuss a "scope draft" of the proposed standard. At this meeting, a subcommittee was assigned to prepare a draft standard. Discussions were held in Chicago, March 15-16, to resolve specific issues of the definition of a reference natural uranium ore body and its use in evaluation of repository integrity and potential radiation releases. The writing subcommittee met in Detroit, March 26-27, to develop the first complete draft for review by the full working group; this was reviewed by mail, resulting in a second draft.

The full working group met in Washington, D.C. on May 23-24, 1979 where a third draft was developed. The scope of the standard and charter for the working group was approved by the ANS Standards Steering Committee in Atlanta, Georgia on June 5, 1979.

The third draft was mailed to the standard working group for formal balloting June 22, 1979.

The fourth draft incorporating the comment of the standard working group was completed August 30, 1979. This draft was sent to the ANS 40 Committee, informal comments were received from this review.

The fifth draft was developed by the working group in Arlington, Virginia on May 19, 1980. This draft was reviewed by the entire ANS 40.12 group, then formally submitted to the ANS 40 INMB Committee on October 29, 1980.

The ANS 40/INMB Committee reviewed the draft November 20, 1980. Comments received from that review were incorporated into the sixth draft at a meeting in Washington, D.C. on June 12, 1981.

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1. SCOPE

This standard applies to the final disposal of radioactive waste materials from medical, educational, research, defense, and commercial operations. This includes transuranic wastes, mill tailings, low- and high-level beta-gamma wastes. The criteria for the analytical models (including computer codes) used in modeling the waste repository behavior are provided.

2. INTRODUCTION

In developing this standard, special attention was afforded to provide assurance that many concerns displayed by various groups were addressed. While incorporating these assurances into a sound and viable program, our criteria were written with the following conditions in mind:

> Significant quantities of radioactive materials currently designated as waste exist. Taking into account their level of toxicity, these must be disposed of in a manner to assure that the biosphere is adequately protected with relation to its supply of food, water and air. The disposal site selected for each class of waste must be characterized adequately to permit prediction of the waste material behavior in that site, and to allow the impact on the environment to be established. This standard provides criteria that shall be met for safe disposal of radioactive waste in the earth's crust until the relative toxicity of the waste is below that level for which concern is no longer justified as herein defined.

> The applicable radiation protection regulations including the ALARA principle will be met both during operations and throughout any period during which the repository is potentially a greater risk than other hazards to which it might be compared (see Section 5.1).

3. DEFINITION OF TERMS

ALARA: "as low as is reasonably achievable taking 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 socioeconomic considerations;" reference 10 CFR Section 50.34a.

Aquifer: A water-bearing bed or stratum of rock, sand, or gravel capable of yielding considerable quantities of water to wells or springs.

Assure: To make certain, to guarantee.

Capable Fault:* A fault which has exhibited one or more of the following characteristics:

"(1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.

"(2) Macro-seismicity** instrumentally determined with records of sufficient precision to demonstrate a direct relationship with a fault.

"(3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

In some cases, the geologic evidence of past activity at or near the ground surface along a particular fault may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the fault is a capable fault within this definition."

---

* This definition is taken from 10 CFR 100 Appendix A, paragraph III (g):

**Macroseismicity: For purposes of this standard, macroseismicity is here equated with recurring earthquakes having Richter magnitudes of 3 or greater.

Containment: Naturally occurring or engineered barriers that act to keep materials at or very near the place where they were originally implaced.

Dispersibility: The inherent chemical and physical properties of a material that determine the ease and extent to which a material may be redistributed by water or by air.

Disposal: Operations designed to isolate wastes from mankind and his environs without intent to retrieve them.

Engineered Barriers: Those manmade structures and modifications of the properties of hazardous radioactive wastes that are provided specifically to enhance isolation and containment in the repository.

Environmentally Sensitive Areas: These areas include wetlands, flood plains, permafrost areas, critical habitats, recharge zones of significant aquifers, and areas of unique scenic values.

Hazard: The probability that an organism will be harmed by exposure to a substance in a given quantity and manner.

Integrity: The quality or state of being complete; unimpaired condition.

Isolate: To place waste in a location such that the containment barriers provided will inhibit the transport of radioactive material so that amounts and concentrations entering the environment will be kept within accepted limits.

Natural Barriers: Those characteristics of the geological formation which enhance waste containment or inhibit mobility.

Radioactive Waste: A radioactive material of little or no economic value which because of its quantity, concentration of radionuclides, physical or chemical characteristics, may cause a potential hazard to human health or the environment when improperly transported, disposed, or otherwise mismanaged.

Reference Natural Uranium Ore Body: For purpose of this standard a reference natural uranium ore body is defined which is generally typical of those being mined, or planned to be mined, in the United States today. This ore body is 0.2% uranium, located in an aquifer which is [illegible] feet thick and approximately [illegible] feet below the earth's surface. The associated aquifer is in communication with the biosphere through natural seeps and springs and may be penetrated by manmade wells. The aquifer is overlain and underlain by layers of clay and silt. The size of the reference ore body is to be related to the quantity of waste disposed in a repository. (See Appendix A.)

Repository: An engineered location, usually in a geologic formation, for disposal of radioactive wastes.

Retrievability: Ability to remove waste economically and safely from its place in the repository.

Shall, Should, May: The word "shall" indicates a requirement, the word "should" indicates a recommendation, and the word "may" indicates neither a requirement nor a recommendation, but merely permission.

Toxicity: The inherent ability of a substance to produce adverse symptoms or death in an organism.

Toxicity Index: The quantity of water or air required to dilute a given quantity of hazardous materials to levels specified in the applicable regulations as acceptable for human assimilation (ingestion, inhalation, exposure).

4. CATEGORIES OF RADIOACTIVE WASTES

Radioactive waste materials shall be identified, classified, and disposed of into locations in the earth's surface in an environmentally acceptable manner. Each class of waste must be disposed of to assure that the biosphere is adequately protected with relation to its supply of food, water, and air, and that inadvertent intrusion of humans or animals into the disposed waste is as unlikely as intrusion into comparably toxic elements in the earth's crust. The appropriate level of control of these materials varies with the potential hazard.

While an indefinite number of kinds of radioactive wastes can be identified when all sources and physical and chemical forms are considered, only a few characteristics of the wastes are considered to be significant to the question of where the wastes will be disposed. The purpose of classification of wastes is to assure that they are disposed in a manner that will provide the degree of protection required. Waste classes are, therefore, defined according to the disposal method found to be feasible and to provide adequate environmental protection. Only three classes of wastes are operationally significant.

Class 1: Radioactive wastes under this classification include radioactive materials that clearly constitute a hazard if not disposed of with great care. Therefore, these shall be assigned to a deep, engineered geologic repository or disposed of in a manner such as to assure an equivalent degree of isolation.

Class 2: Radioactive wastes in this category are shown by material properties, specific radioactivity, nuclide distribution, and characteristics of the disposal site to be adequately contained in shallow burial or disposed of so as to assure an equivalent degree of isolation.

Class 3: Wastes in this classification contain radioactivity in quantities or concentrations so small that continued control or evaluation for radiation protection is unjustified.

5. CRITERIA FOR RADIOACTIVE WASTE DISPOSAL

5.1 Alternative Approaches to Protection Criteria

Introduction

Assignment of properly classified waste to an appropriate disposal system will provide the control consistent with the potential hazard. The significance of the potential hazard from all three classes of waste can be established through comparisons with other hazardous waste disposal risk reduction actions society undertakes, and an understanding of the relative hazard of naturally occurring materials in the environment.

Three approaches to evaluation of radioactive waste disposal options can be considered.

Acceptable Risk

The first approach is to examine what society seems to be willing to pay to avoid the statistical occurrence of an injury, a death, or an undesirable environmental impact.

One problem is that the social willingness to pay can (and should) change in response to changing values, perceptions, and concerns. Thus, the consequences of a particular standard can exist long beyond the foundation on which that standard was based. This first approach has an additional problem in the degree of inconsistency implied by many of these social decisions. These problems do not invalidate the approach; they do, however, call for a significant degree of conservatism in its application.

Natural Materials Comparison

A second approach to defining acceptable risk is to require that the proposed activity not result in any net increase in risk. With respect to high level radioactive waste disposal, this could be accomplished by assuring that the risks from a high level waste repository be no greater than the risks from typical uranium ore bodies which yielded the amount of uranium needed to

produce the quantity of wastes. In the modeling of certain comparative risks, (such as those arising from improbable geological events) as this approach suggests, errors in the analytical description of events will be of the same direction and magnitude, leaving the comparison still valid.

In some instances this second approach may be much more restrictive than the first approach, and the expenditure of additional scarce resources for marginal reductions in risk may be unwise. Note that many of man's widely accepted non-nuclear activities would not meet the proposed test. In the case of radioactive waste disposal the additional resources needed for meeting criteria based on this second approach are expected to be modest, and it is included herein.

Both the first and second approaches require the development of accepted probabilistic models to characterize normal and abnormal occurrences and release and exposure paths. These models are necessarily complex and difficult to validate.

Three-Stage Natural Ore Body Comparison

To simplify the analytical problems, a third approach was developed in which a comparison with a reference natural uranium ore body would be made for high level wastes in each of the three aspects: stability of the waste form/ore; integrity of the host medium; and isolation from the biosphere. The third alternative is similar to the second; however, a comparison is to be made separately of each of the three aspects rather than performing a comprehensive probabilistic analysis. If the proposed waste form and disposal site is judged to be safer than the reference natural uranium ore body in each of the three respects then a more comprehensive analysis would not be required. This third approach may require more risk reduction than is justified; however, the approach is relatively simple to apply.

In an equivalent manner the risk from a low level waste disposal site may be compared to the overall risk from naturally occurring chemical and/or radiotoxic materials near the earth's surface.

Summary Comparison of the Three Approaches

The first alternative ("Acceptable Risk") reflects, in a conservative manner, society's implied willingness to expend resources to avoid the statistical occurrence of injury, early death, or adverse environmental impact. The risk of an occurrence is the consequences-times-the-probability; the variation in the willingness of members of society to allocate resources depends upon these perceived probabilities and consequences.

The second alternative ("Natural Materials Comparison") provides high confidence that the hazards from radioactive waste disposal are at least as low as the risks from the naturally occurring materials.

The third alternative for high level wastes ("Three-Stage Ore Body Comparison") provides high confidence that for alpha and high-level beta-gamma wastes the contribution to the risk arising from 1) dispersibility of the waste form in relation to its toxicity, 2) lack of integrity of the host medium, and 3) lack of integrity of surrounding media are each less than the contribution to the risk arising from the equivalent aspect of the natural uranium ore body (Appendix A).

5.1.1 At all times the applicable radiation protection regulations including the ALARA principle will be met both during operations and throughout the period of concern for the disposal sites existence.

5.1.2 When the product of the dispersibility and the toxicity index (per unit mass) of the waste disposed in any deep geologic formation (high level waste repository) is comparable to, or less than, the product of the dispersibility and the toxicity index of the reference ore body, then no further consideration of risk from the waste shall be deemed necessary. If periods extend beyond a few thousand years, the confidence in predicting the mobility of species in both the waste and the ore body diminishes. These comparisons, therefore, would not require proof but considered judgment. The period prior to the time when no further consideration of risk shall be deemed necessary is not meant to imply a period of risk, but only a period during which the question of whether a risk exists must be examined.

5.1.3 When the product of the dispersibility and the toxicity index of the waste disposed in any shallow site becomes equal to the average of naturally occurring toxic materials in the undisturbed earth's crust in the region (80 km radius) surrounding the site, the risk from the site shall be considered negligible.

5.1.4 If at the time of disposal the dispersibility, access to aquifers, and the toxicity index of the waste disposed in any shallow site is less than that of naturally occurring hazardous materials in the undisturbed earth's crust in the region (80 km radius)*, the risk from the site shall be considered negligible.

5.1.5 For Alternative 2, the estimated risk to the general public or any individual from any waste disposal site for any generation shall not be greater than that from the reference natural uranium ore body to the general public or any individual.

5.2 Waste Form

The chemical and physical characteristic of the radioactive waste form can provide the waste with its barrier to dispersion and should be engineered to match the toxicity of the waste.

5.2.1 Class 1 wastes shall be in the form of a solid matrix. The waste form shall be selected so that thermal, radiolytic effects and reaction products do not include excessive stress through continued reaction in the host medium. The container of the waste form shall be included in the toxicity/integrity and compatibility evaluation.

* This value is conventionally adopted for evaluations of potential local area impacts. It seems reasonable to require that the comparison be made over a moderately sized area rather than by comparison with a selected hazardous spot that may be completely anomalous.

5.2.2 In application of the third approach the relative dispersibilities of Class 1 wastes and the reference natural uranium ore body shall be inversely proportional to the toxicity indices of the two.

5.2.3 Class 2 wastes are generated in a wide variety of chemical and physical forms. Whether or not a specific waste form should be required for a Class 2 waste in both approaches 1 and 2 depends upon the retention capabilities of the site and the need for the waste form to enhance the integrity of the disposal system. (see 5.4.1).

5.3 <u>Demonstration of Site Integrity</u>

The integrity of the selected disposal site shall be assessed based on accepted predictive models which evaluate the potential release of hazardous material and the characteristics of the site. The computer codes used to describe these models and test the site characteristics shall employ only realistic physical properties and material performance characteristics rather than applying factors of conservatism to these values.

5.3.1 While minor faults and fractures may be expected to occur in the reference natural uranium ore body and the repository site, the repository shall be shown not to encompass capable faults.

5.3.2 For approaches 1 and 2, the pathways identified for ingestion and inhalation, the quantities and probabilities of ingestion and inhalation noted, and the number of persons potentially exposed shall reflect plausible and realistic circumstances. Conservative factors should not be used in calculating expected values.

5.3.3 The model described by the codes shall be founded on physical principles accepted by consensus of experts in the appropriate fields. Uncertainty in modeling and estimating values of parameters shall be treated explicitly and this quantification of uncertainty shall be carried through the calculations.

5.3.4 It is recognized that predictive models require estimation of certain parameters and the probability of deviations from the estimated values. The models should be developed to permit validation of the significant parameters, where possible, which validation in accordance with Section 5.3.3. makes possible the establishment of appropriate engineering margins in the waste form and repository barriers required for safety.

5.4 <u>Repository Barrier Integrity</u>

For alternative approaches 1 and 2, potential radionuclide migration from waste disposal sites shall be predicted and quantified. For all three approaches engineered barriers may be used to reduce the probability of potential release of radionuclides from the repository sites.

5.4.1 During assessment of the potential repository site and disposal mode, evaluations of the existing natural containment features shall be made. Expenditures of effort to increase the integrity of the barriers shall be in proportion to the importance of the barriers in the pathway evaluations.

5.4.2 Control of the movement of waste materials from the repository may be achieved in different ways at different sites; however, the ability of the host medium to maintain isolation of the waste including sealing of bore holes and access shafts to control water movement to at least as low as the original undisturbed condition shall not be significantly degraded by the radiation, chemical, or thermal properties of the waste.

5.4.3 The geologic medium shall be stable enough not to be significantly degraded by exploration, construction, emplacement of waste and post-emplacement sealing.

5.4.4 For Class 2 waste disposal sites, a barrier, which requires periodic maintenance, may be constructed to meet the protection guidelines, provided that there would be significantly greater total expenditures of resources (undiscounted over all time) to achieve a maintenance-free condition, and provide that the interval between required maintenance is 50 years or greater.

5.5 Site Suitability

Waste repository sites shall be selected to avoid use of valuable (in society's current judgment) natural mineral resources or environmentally sensitive areas.

5.5.1 The sites selected for waste disposal shall allow for flexibility in the operation and disposal mode at any one site to permit change if warranted by new technology.

5.5.2 The repository site shall provide naturally occuring barrier(s) to waste migration and to penetration by water.

5.5.3 The site shall be selected where the probability of inadvertent human intrusion in search of useful resources is low.

5.6 Waste Retrievability Monitoring and Identification

Retrievability of the waste during the operational period for any repository shall be maintained until safe repository performance is demonstrated subject to the following specific criteria.

5.6.1 The long-term integrity of the repository and its contained waste shall not be significantly degraded by any consideration of retrievability. Therefore, the ease of retrievability must be weighed against the possible reduction in repository integrity.

5.6.2 The extremities of the repository shall be marked at the surface with symbols indicating the composition and content of the material disposed.

5.6.3 For Class 1 disposal sites only nonintrusive monitoring through wells and natural features in the vicinity, shall be maintained. For Class 2 disposal sites, monitoring capability shall be provided whereby the integrity of the barrier can be tested at appropriate intervals.

APPENDIX A

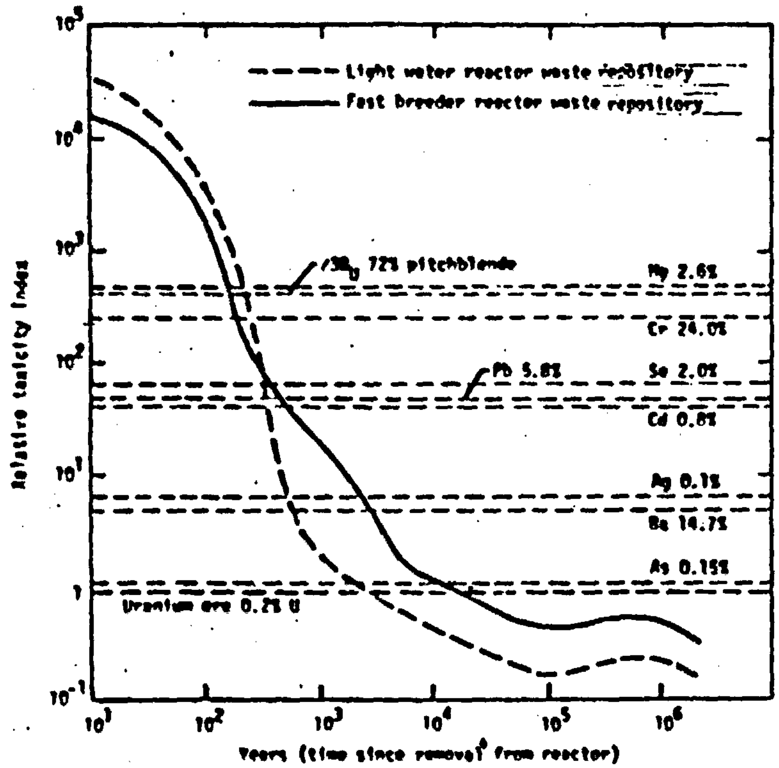
REFERENCE NATURAL URANIUM ORE BODY

The development of a definitive model to describe the expected repository behavior requires the determination of numerous parameter values and establishment of a consensus among experts as to the uncertainty and significance of these various factors. Acceptable comparison among alternate approaches to waste disposal can be made without establishing the absolute risk of any one approach. For the purpose of establishing the acceptability of a specific approach, it is reasonable to compare that approach with similar natural occurring materials of similar toxicity or, if preferred, potential hazard. For periods of thousands of years, the uncertainty in predictions of the repository behavior becomes larger. However, it has been shown (Ref. 1) that in about 1000 to 5000 years the waste repository becomes less toxic than the ore bodies from which the uranium originated. The repositories can be easily made less accessible to dispersion to the environment than the ore body. Therefore, if the repository integrity can be projected to be secure during the time which is required for the toxicity of the waste to decay to that of natural uranium ores, then the long-range comparison need be made only with uranium ore bodies.

The relative toxicity of the conceptual high-level waste repository as a function of time is shown in Fig. A-1.[1] The relative toxicity of several types of naturally occurring ore bodies is also shown on the graph.[2] This standard requires the comparison of the repository behavior with the least toxic materials on the graph. Commonly occurring non-radioactive ores are factors of 10 to 1000 more toxic than a 1000-year-old high-level waste repository and 0.2% uranium ore.

For the purpose of comparisons required in this standard, it is necessary to define a Reference Natural Uranium Ore Body. Uranium deposits of commercial value occurring in the United States are typically sedimentary rock formations

Figure A-1 Relative toxicity of nuclear waste over time, compared with that of average mineral ores of toxic elements.



primarily in the semi-arid to arid regions of the Western United States. These ore bodies have been reasonably well characterized. Data are available on the depth, rock type, grain size, porosity, water content, water quality, the over- and underlain strata, and the location of aquifers in nearby strata. Many of these ore bodies serve as aquifers through seeps, springs, or manmade wells, for use by the wildlife, domestic livestock, and human habitants of the area. For application in connection with this standard, definitive or statistical evaluation of the characteristics of these known ore bodies is unnecessary. We define here a reference ore body based on characteristics of these known ore bodies.

The Reference Natural Uranium Ore Body[a] is associated with a medium-to-fine-grained sandstone aquifer that is 100 feet thick and approximately 500 feet below the earth's surface. The sandstone is partially cemented with calcium carbonate. Layers of silt, clay and/or other tightly bedded materials separate the ore-bearing layer from other aquifers in the vicinity. Other aquifers are located above and below the ore-bearing layers. Separation of those aquifers from the ore body is maintained by the presence of a minimum of 25 feet of clay or equivalent. The ore bearing layer is tilted at a slope of 1.5 per cent from the vicinity where water recharge occurs toward locations 15 kilometers from the center of the ore deposit where the formaion outcrops and natural springs feed into a creek that is used as drinking water supply for livestock and wildlife. The water leaving the rock formation at this point or withdrawn from the formation in the vicinity of the ore body is within EPA requirements (July 1979) for drinking water for most chemicals and radioisotopes. Some chemicals and radionuclides, especially radium-226, approach but do not exceed these limits.

The ore body contains 12 million metric tonnes of economically mineable ore at 0.2% U_3O_8 that is expected to yield about 23,000 metric tons of uranium. This ore will be mined and transported to a mill in the vicinity where 95 per cent of the uranium is recovered; the tailings are deposited near there in appropriate disposal consistent with this standard.

The Reference Natural Uranium Ore Body is located in the semi-arid region of the Western United States (annual precipitation averages 30 cm/yr) where the land is used for general ranching and farming. The immediate area around the surface above the ore body is grazed by wildlife and domestic livestock. The total population with 80 km of the ore body is 100,000. A community of 5,000 is located 20 kilometers from the site, and a larger community of 50,000 is located 80 kilometers from the site.

Terrestrial background radiation is 75 mrem/yr. Cosmic ray background contributes an additional 115 mrem whole body doses per year. Radon concentrations in the air measure 1000 pCi/m^3 when the wind is calm or less than 5 km/hr.

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[a] The characteristics of the reference natural uranium ore body and the region surrounding it are representative of known existing uranium ore deposits some of which are well described in the following documents.

<u>New Mexico</u>

1. Uranium in the San Juan Basin-An Overview, William L. Chenoweth, GJV open file report TM-108, May 1977.

2. Final Environmental Statement, Dalton pass Uranium Mine, Tennessee Valley Authority, April 1978.

<u>Utah</u>

3. Environmental Report, Shootering Canyon Uranium Project Plateau Resources Limited, May 1978.

4. Environmental Report, White Mesa Uranium Project, Energy Fuels Nuclear, Inc., January 1978.

<u>Wyoming</u>

5. Final Environmental Statement, Highland Uranium Solution Mining Project, Exxon Mineral Company, U.S.A., NUREG-0489, November, 1978

6. Final Environmental Statement, Sweetwater Uranium Project, Minerals Exploration Company, NUREG-0505 December 1978.

7. Final Environmental Statement, Morton Ranch Uranium Mining, Tennessee Valley Authority, January 1976.

8. Environmental Report, Morton Ranch, Wyoming Uranium Mill, United Nuclear Corp. 1976.

<u>References</u>

1. H. O. Haug, Production, Disposals, and Relative Toxicity of Longlived Fission Products and Actinides in the Radioactive Wastes from the Nuclear Fuel Cycle. ORNL-TR-4302, Oak Ridge National Laboratory, Oak Ridge, TN, translation of KFK-2022, 1977.

2. K. A. Tonnesson and J. J. Cohen, Survey of Naturally Occurring Hazardous Materials in Deep Geologic Formations: A Perspective on the Relative Hazard of Deep Burial of Nuclear Waste, UCRL-52199, January 1977.

A-201

APPENDIX B

CONSIDERATION OF SEISMIC EVENTS

In evaluation of the proposed repository site integrity, the fractures and faults in the vicinity of the site are significant considerations. The potential impact of seismic events on a deep, sealed repository are not expected to be significant unless the fault passes directly through the repository. Consideration should be given to the earthquake hazard regions of the United States in selection of repository sites. Figures B-1 and B-2 show the seismic zones of the United States evaluated as to the expected 50-year hazard for horizontal acceleration and the expected distribution of damaging earthquakes without regard to frequency.

Figure B-1: Earthquake Hazard Map of the United States

Levels of ground shaking for different regions of the U.S. are shown on the map by contour lines which express in percentages of the force of gravity the maximum amount of horizontal acceleration (shaking) likely to occur at least once in a 50-year period. For example, a contour at 10 percent of gravity means that scientists are 90 percent certain that the region in the vicinity of the contour will not experience ground shaking more than 10 percent of the force of gravity.

Contours at 4, 10, 20, 40, and 60 percent of gravity are shown on the map. All contours are expressed at the 90 percent probability level.

Accelerations on the map are those estimated to occur on solid rock. Because the surface materials in many areas of the United States are not solid rock, the maximum acceleration at a particular location may be quite different from that shown on the map. For example, depending upon surface geologic materials, the acceleration may be 2 to 3 times larger, or in a few cases, even slightly lower than the values shown on the map. The HLW repositories will be located in solid rock, therefore no amplification factor is required.

Figure B-2: Seismic Risk Map of the United States

This map is based on the known distribution of damaging earthquakes and the M.M. (Modified Mercalli Intensity Scale) intensities associated with these earthquakes, evidence of strain release, and consideration of major geologic structures and provinces believed to be associated with earthquake activity. The probable frequency of occurrence of damaging earthquakes in each zone was not considered in assigning ratings to the various zones.

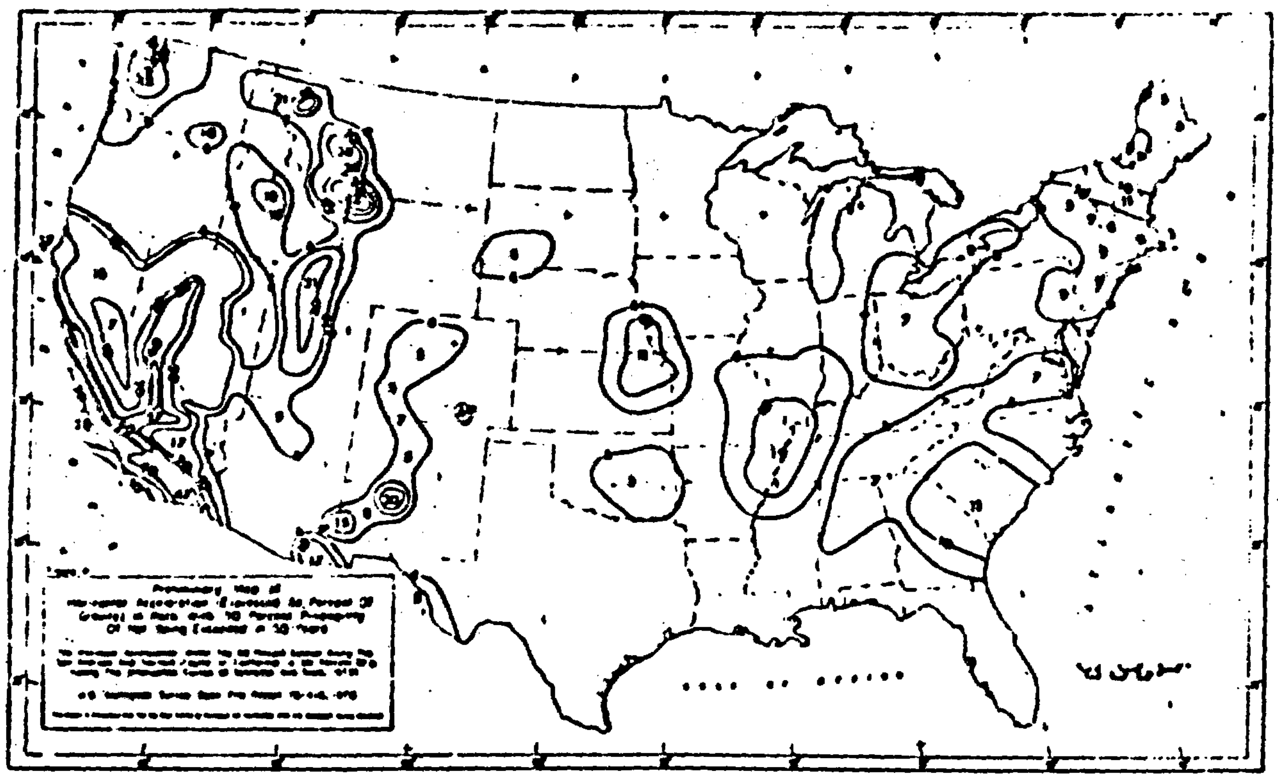


Figure B-1 Earth Quake Hazard Map of the United States.

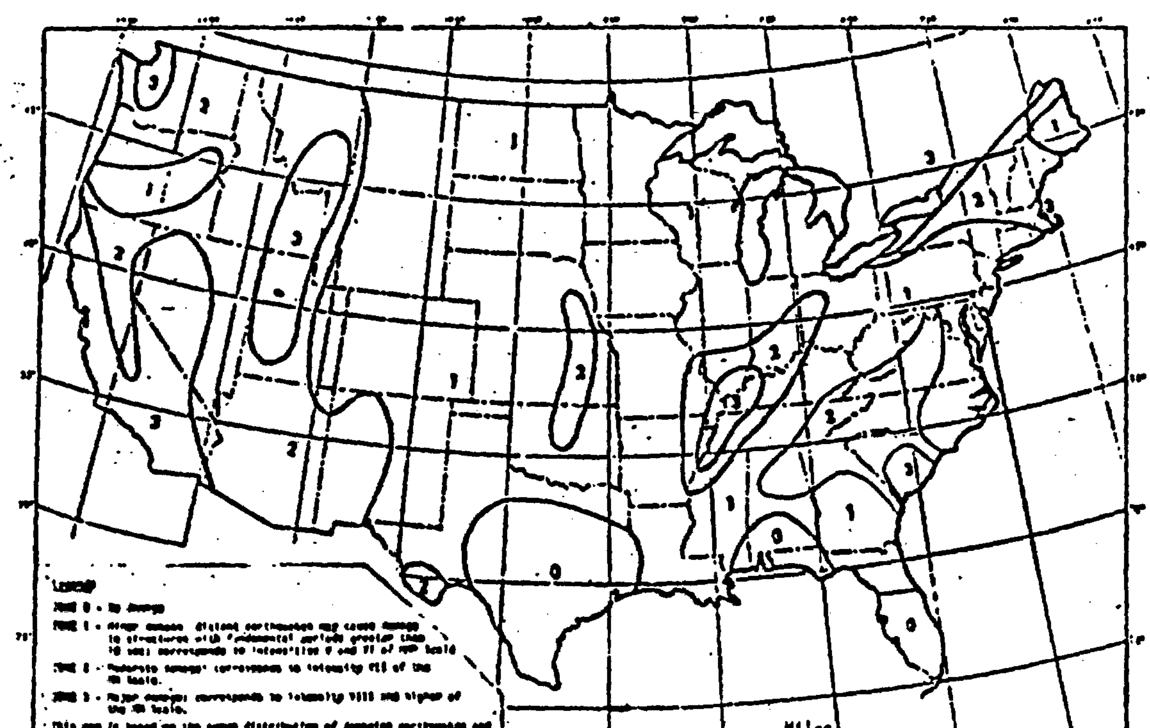


Figure B-2 Seismic Risk Map of the United States.

APPENDIX C

LIMITATION OF RADIATION DOSE TO INDIVIDUALS RESULTING FROM RADIOACTIVE WASTE DISPOSAL

This appendix provides a discussion of radiation exposure limits vs. probabilities of dose. Conformance with these objectives is not required in the selection among waste management alternatives. These objectives are, however, useful guides worthy of consideration in the alternatives evaluation.

APPENDIX C

Limitation of Radiation Dose to Individuals Resulting from Radioactive Waste Disposal[1]

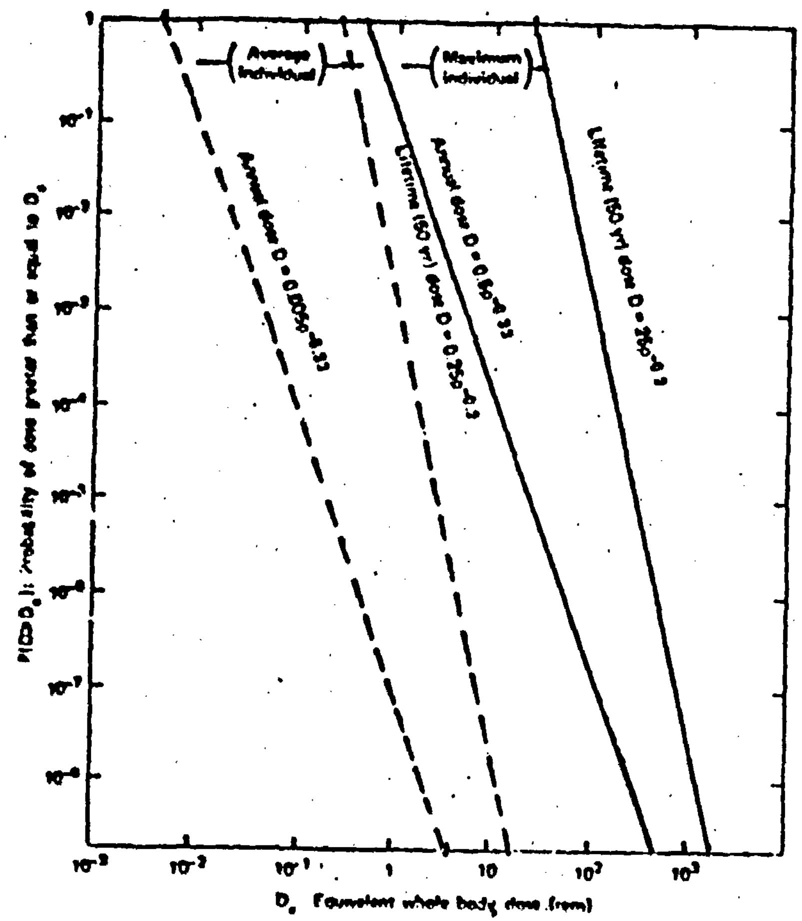
Several models for prediction of individual radiation dose resulting from waste disposal activities have been determined. Such models generally consider the probability for occurrence of initiating events causing the release of radioactive material from the repository as well as pathways to the biosphere and exposure consequences.

Uncertainties in model parameters can be incorporated in model calculations by using the observed or estimated probability distribution function for these parameters.

To determine the acceptability of a proposed waste management system, not only should radiation doses to individuals be considered, but also the probability for their occurrence should be taken into account. The following discussion describes the recommended criteria for determining the acceptability of a waste management system from predicted individual radiation dose.

The limits for exposure to maximum and average individuals are given in Fig. C-1. For preemplacement events, the probability (p) scale may be interpreted as the annual probability that operations will result in an annual dose or lifetime dose equal to or greater than that indicated. For postsealing events, the probability scale pertains to any event or combination of events that will ever result in an annual radiation dose or lifetime individuals dose equal to or greather than that indicated.

Figure C-1 Radiological performance objectives (individual whole-body dose)



The recommended criteria can be summarized by the following equations:

for the "maximum" individual

Lifetime dose (50-y dose) (rem):

$$D = 25\ p^{-0.2}, \qquad (2)$$

Annual dose (rem):

$$D = 0.5\ p^{-0.33}. \qquad (3)$$

The dose to the average individual should be no greater than 1/100 that to the maximum individual. The maximum individual is defined according to the parameters given in NRC Regulatory Guide 1.109. The average individual dose is determined by estimating the population dose (in man-rem) to the total population residing within 80 kilometers of the repository and dividing by the population value.

The recommended dose levels for certain exposure ($p = 1.0$) are consistent with current ICRP standards. Should these standards be changed at some time in the future, the criteria may readily be scaled accordingly.

Reference

1. The discussion in this Appendix is derived largely from material in NUREG/CR-0579, "Suggested Nuclear Waste Management Radiological Performance Objectives."* A more detailed discussion of the criteria and its rationale may be found in this document.

*The referenced document has not been adopted as an NRC position.

APPENDIX D

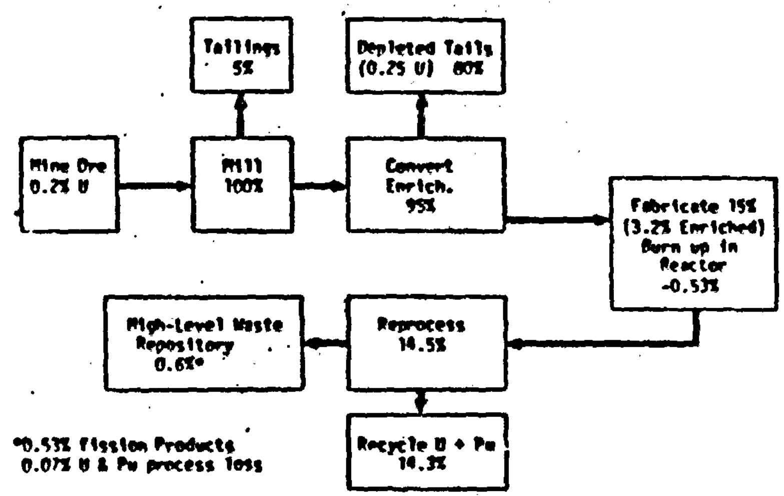
Distribution of Uranium and Related Materials in the Fuel Cycle From the Ore Mines to the Waste Disposal Site

Activities of the nuclear fuel cycle from mining of uranium ore to final disposal of the waste include the removal of a naturally occurring material from its original location in the earth's crust, its distribution to various places throughout the industry, and finally emplacement in the earth's crust of all potentially hazardous product waste materials. For purpose of comparison of the relative potential hazards at various points in the fuel cycle with the undisturbed ore body, it is instructive to review the distribution of these materials. A highly simplified schematic representation of the fuel cycle is shown in Fig. D-1. The approximate mass fraction of the mined uranium or its equivalent mass as Pu or fission products is shown at each point in the cycle. In this analysis, an estimated 5% of the mined uranium is left associated with the mill tailings. All of radium and other decay products that are in equilibrium with the uranium at the time it is mined are also left at the mill. These decay chain products, which occur throughout the earth's crust in association with uranium and thorium, are by far the dominant toxic materials connected with natural uranium and thorium.

The separated yellowcake proceeds through the cycle to the enrichment plant where approximately 80% is left behind as depleted tails. This 80% of the total uranium is very similar to the natural uranium that is primarily ^{238}U. In approximately 10^4 years the ^{226}Ra will build up in this material to the equivalent of that at the mill tailings pile. This estimate includes a factor for accumulation of material in the depleted tails due to the fact that the enrichment plant serves several mines and mills. Eventually the radium in the depleted tails will greatly exceed that at any single mill site.

Proceeding through the cycle, the fabricated fuel after burnup in the reactor is reprocessed; the majority of the uranium and plutonium are recovered and

Figure D-1 Simplified Block Diagram of Uranium Flow Through The Fuel Cycle. Figures given are percentages of Uranium Mined.



required. The fission products in the high level wastes which at the time of separation represent the highest concentration of toxic materials in the fuel cycle, are equivalent to about 0.6% of the mass of the original uranium mined.

A repository will hold different amounts of waste material depending upon the thermal conductivity of the host medium. Repository capacities are given in DOE/EIS-0046 for conceptual repositories in salt, shale, granite, and basalt. For solidified high-level wastes, these loading capacities vary over a factor of about 2.5 depending on the host rock thermal conductivity. Any high level waste repository will contain the solidified waste resulting from the mining and milling of the ore from a number of uranium ore deposits.

The requirement that the repository provide protection equivalent to or better than that of the reference natural uranium ore body necessitiates that the relative concentrations of material between dispersed ore bodies and the final repository be taken into account. As this comparison is made in any of the three approaches to defining adequate safety of the repository, the increased concentration of toxic materials at the repository must be accommodated through relative nondispersibility in proportion to the relative toxicity of the waste repository and the ore bodies. This relative concentration factor is to be established by comparison between reference natural uranium ore body (Appendix A) and the proposed repository.

The final evaluation of the integrity of the repository must show that the waste repository is better than the reference natural uranium ore bodies at all times. The three-stage ore body comparison requires that at each stage the repository self-containment factors be better than the natural uranium ore body. The absolute degree of relative containment will be defined by comparison of the reference natural uranium ore body with the proposed repository.

APPENDIX E

RATIONALE

This standard addresses an activity that is subject to both technical factors and individual and institutional perceptions of risk. Accordingly the ANS 40.12 Writing Group endeavored to take into account such perceptions along with the technical aspects of waste disposal. This Appendix sets forth, as a background to the standards, some of the considerations of the Group. They are not expressions of the ANS, nor are they necessarily a unanimous expression of the Group.

No human activity is entirely free of risk. Man engages in various activities presumably because the perceived benefit is greater than the perceived costs, including risk to life and health. When all of the costs are incurred by the individuals who decide what risks to take, and they are well informed, there is little or no need for government intervention. The more typical case, however, is that costs and risks are borne by those who do not have much influence in deciding among alternatives. Procedures for achieving a consensus of the affected persons do not currently exist.

In such circumstances it is legitimate and necessary for elected representatives of the public to define, explicitly or implicitly, an acceptable level of risk. As part of this process, the decisionmakers should seek the best available technical information on the nature and magnitude of risks, costs, and benefits, along with any attendant uncertainties, but it should be recognized at the outset that the decision itself is not, nor should it be, solely the product of an analytical process. There is, for example, no objective way of establishing what society should be willing to pay to avoid the statistical occurrence of an injury or premature death. The best that the analyst can do on this question is to inform the decisionmaker of the valuation implied by a series of past individual and social decisions and what values are implied by the alternatives in the present design. Such information might possibly, though not necessarily, promote a degree of consistency.

The factors to be weighed are even more complex than is implied by the above. Some people are more averse to risk than others. They would not, for example, think of engaging in a high-risk occupation, nor would they, because of the perceived risk, choose to partake in many activities that most people would regard as routine. Should the decisionmaker be influenced more by the norm than by those at either extremes of risk aversion? The decision is not an obvious one, especially when dealing with the category of involuntary risks.

Even more basically, some members of society are uncomfortable in dealing with the concept of an acceptable level of statistical risk. One of our core beliefs is the sanctity of human life. This belief helps hold together the social fabric. We generally approve when enormous costs are incurred to save specific individuals who are in danger. Even here, however, the reality is different from the ideal. A naval task force, for example, might search for a week or two to locate survivors from a sunken ship. It would not do so for a year. The decisionmaker will state that "no hope remains" that unlocated survivors exist, but the usual truth is that there is a finite though perhaps extremely small possibility that they do.

A further distinction is appropriate between decisions which are reversible and those which are not. If reversible actions are found to be more hazardous than at first believed, or if society's level of risk aversion increases, the damage can be undone or at least limited. Irreversible actions do not offer such escape valves, so a more conservative approach in dealing with them is warranted. (Radioactive waste involves both types of decisions: irreversible, in the production of long-lived waste products and reversible disposal options if waste repositories are designed for possible retrieval of wastes.)

Still another complication is that benefits and costs may not be confined to the generation involved in the decision. Future generations do not "vote" in current markets or political processes. The use of a discount rate to calculate the present worth of future costs and benefits is of arguable validity when effects transcend the generations. Further it is proper to include positive as well as negative impacts on future generations in any analysis of the question. This is not always done.

One approach to resolving this dilemma is to ask whether, on balance, future generations will be better or worse off as a result of the chosen action than if no action had been taken. The technological optimist will assert (with much supporting evidence) that a broadened body of knowledge and reservoir of usable resources will more than compensate for most risks. Indeed, life spans have increased even while new risks have been introduced. The pessimist will point to the dangers of that increased knowledge, most notably that of the design and production of weapons of mass destruction, to allege that the safety and security of future generations has been diminished. In any event, the risks being evaluated with respect to the disposal of radioactive wastes (assuming only a rudimentary degree of care) pale into insignificance when compared with the probabilities and consequences of nuclear warfare. Conversely, a policy which results in marginally reducing the risk of nuclear war will provide an overall reduction in risk even if it should result in a significant increase in conventional risk.

Another approach is to compare the new risks to qualitatively similar, routine risks in the natural environment. That is the approach taken in this standard. The risks from the waste depository are compared to the risks of a typical reference natural uranium ore body. Though not a perfect answer to all the questions raised, this comparison serves to put the hazard in perspective with natural risks over which man cannot exert control in any practical manner. There is little doubt that this approach, properly implemented, will not significantly increase net risks to present and future generations. Moreover, any increase in risk, should it indeed occur, will be orders of magnitude below risks that are now accepted as routine. Reduction of risk to this level should relieve the concerns of all but the most risk averse members of society.

To perform an analysis of the risk of the waste disposal sites versus a natural uranium ore body, or naturally occurring hazardous materials, it is necessary to describe the understood behavior of both the repository and the naturally occurring system. These descriptions must be represented by mathematical models which will then predict the behavior of both systems. The characterization of the condition of the natural system and the performance of that system and that of the waste repository, depends upon knowledge of the physical and chemical properties of both systems. Because these physical properties have variabilities and there is some uncertainty in their values, there is uncertainty in the predicted performance of both systems.

If the analysis of most probable behavior does not show the performance of the repository to equal its natural counterpart, and where uncertainty exists, a degree of conservatism in the location and design of the repository should be applied to compensate for predicted performance and to allow for those uncertainties. This conservatism is applied through changes in the containment properties of the waste and disposal system which contribute most significantly to the containment of the waste material.

It is expected that the performance of the system will become more uncertain with time. The desired degree of containment of the wastes in the repository can be achieved by more stringent specification of those parameters that are most cost effective in enhancing containment. Then, even with the greater uncertainty, the degree of containment will be acceptable even over a long time.

The intrinsic risk from the wastes, in relation to those of the natural uranium ore body, will decrease with time. Thus the fact that it is difficult to predict performance far into the future is not necessarily a source of great concern, since the increase in uncertainty may occur at a slower rate than the decrease in relative risk.

Prior to development of the specific criteria, the group reviewed concerns that have been expressed about the risks of radioactive waste disposal to establish the parameters which were amenable to quantitative control. It may be useful to review the main issues to see how the approach of comparing the risks of proposed disposal alternatives with those of naturally occurring counterparts can satisfy those concerns.

One concern is that there be no demonstratable increase in radiation effects or risk to current and future generations. This test will be met by the proposed standard, since the risks will be no greater than from the typical natural uranium ore bodies from which the wastes were generated. Although the specific activity (toxicity) of the waste may be much greater than that of the ore which has been removed from the earth's crust, its accessibility (solubility) can be made proportionately lower, so that the

product of toxicity and accessibility is no greater. This product is, in effect, a source term for a rather long pathway of occurrences necessary for harm to be done. These occurrences can be made to have a lower probability for the waste repository than for the ore body. In the case of high level wastes, for example, the repository can be located in a more geologically stable region, further from aquifers, and deeper underground than is the case for most mined ore bodies.

In addressing the potential exposure of an individual versus the general population, early drafts of the standard set an exposure limit on the individual of ten times the population exposure. However, as the natural ore body is the radiation reference for the population it is felt that it could serve equally as a reference for the individual; therefore, the factor of ten has been deleted.

A second concern is that any costs be borne by those individuals and generations who benefit from the waste-generating activity, and that no large costs be passed on to others. A related concern is that the disposal activity not rely on the longevity of social institutions for it to succeed. Even ignoring the possible indirect benefit to future generations referred to earlier, the proposed standard meets this test. No maintenance would be required after the initial period of emplacement of wastes. The eventual decay of the radioactive wastes leads to the result that the risks to future generations would be less than if the uranium mining and power generation had never taken place.

Consideration was given to defining a "period of concern," during which time the wastes would be considered to be hazardous and therefore require attention, and after which time they would not. The question becomes most salient when the high level waste repository is compared with the reference natural uranium ore body. Similarly the argument holds for low level waste compared to naturally occurring toxic materials. This comparison should be done for all future times. The risk from the waste repository soon after emplacement of the wastes will be no greater than that from the ore body, such will almost certainly continue to be the case in later years, since most wastes will contain a greater portion of relatively short-lived radioactive species than will the ore body. Even should this not be true in a specific instance, the important factor is the comparison of risks rather than the selection of a period of concern that is likely to be at least somewhat arbitrary.

A third concern is that human intrusion, either intentional or unintentional, might occur. The proposed standard minimizes this possibility. In the case of high level wastes this would be done by first removing elements (such as plutonium) of potentially high economic value, and then locating the repository deep below the surface in a formation of common occurrence and of little significant economic value. There is, moreover, logic in assuming that an intruder with the technology to reach the wastes would be aware of the potential risks, either by means of historical records or by measurements made during the course of intrusion. Since the hazard to the intruder is greater than to the general public, this knowledge may be sufficient in itself to prevent intrusion.

A fourth concern is that the costs of disposal not be unreasonably high. The proposed standard, though producing a result much more protective of health than most of man's routine activities, should also meet this test. For high level wastes, the key to modest cost is the conversion of wastes to forms that are insoluble enough to assure adequate integrity of this form enough during the period of highest toxicity of the wastes. The relatively small volume of high level wastes also helps keep costs low. For low level wastes generated at various points in the fuel cycle, the availability of volume reduction techniques will contribute to keeping the disposal costs down. The more difficult problem is probably that of mill tailings, because of their large volume. Even for tailings, however, costs should be manageable when proper methods are applied at the beginning.

The application of an "as low as is reasonably achievable" (ALARA) criterion for risk reduction is required for the commercial nuclear fuel cycle and other nuclear operations. It provides for further reasonable reduction in risk, even after all other criteria are met, if such reduction provides benefits to public health and safety and of a societal and socio-economic nature greater than the added cost. Because of the widespread use of ALARA in the nuclear industry, and its intended avoidance of added costs when they are greater than the perceived added benefits, it is included in this standard.

Other concerns have been raised: that wastes with various toxicities be properly characterized, so that suitable disposal criteria and techniques can be applied to each; that solely technical questions be dealt with in a technical and not a political manner; and that the initial choice of a waste disposal technology not preclude the later adoption of a different technology for future wastes should such seem to offer advantages. The proposed standard would promote, or at least not significantly interfere in meeting these objectives.

There have been a number of attempts made to classify or categorize radioactive wastes. These have been based on activity level, physical and/or chemical form, packaging, etc., alone or in various combinations. In this standard, three classes are given. It will be necessary that each waste type, at each disposal site and for each method of disposal, be demonstrated to present a lower hazard than that of the natural reference material or comparable societal activities. (This may be done by simple comparison to another formerly demonstrated waste, site, and disposal method.) Such a demonstration would include the effects of waste form (solubility, half-life, reactivity, heat release, package, other engineered barriers, possible interaction with other materials, etc.) and site characteristics (hydrology, geology, demography, depth of burial, excavation and back-fill methods, etc.). Thus, the value of a more detailed classification scheme diminishes except as an after-the-fact tool for defining wastes coupled to sites.

In summary, the proposed standard would protect the health and safety of present and future generations. Despite its extraordinary stringency it should not give rise to excessive economic costs.

EXXON NUCLEAR COMPANY, Inc.
RESEARCH AND TECHNOLOGY CENTER
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OFFICE OF SECRETARY
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BRANCH

November 4, 1981

(58)

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch

Dear Sir:

Subject: Comments on 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories", (Federal Register, July 8, 1981)

Exxon Nuclear Company has participated in a working group of the Atomic Industrial Forum that was formed to prepare comments on the criteria being proposed by the Commission in this rulemaking. We endorse the AIF comments.

We wish to comment separately, however, on one of the major issues, that of alternative approaches, since we consider this a very important issue in this portion of the rulemaking.

In our comment letter of July 11, 1980, on the Advance Notice of Proposed Rulemaking on this subject, we stated that "the approach taken by the NRC does not appear to be consistent with the systems approach recommended by the IRG". We continue to support the view that the NRC should establish appropriate criteria and standards for the performance of the overall system rather than defining specific performance values for individual components.

It is encouraging to note that the NRC has now agreed to consider three alternative approaches in which alternative 1 is consistent with our earlier recommendation. Alternative 2, which appears to be a hybrid between the overall approach alternative 1, and the data led approach alternative 3, seems to be now preferred by the NRC as offering a reasonable and practical compromise. It is also consistent with the approach proposed in the rule governing disposal of low level waste, 10 CFR 61. However, after careful consideration of the Commission's comments and logic supporting their preference for alternative 2, we continue to support the overall approach represented by alternative 1 for the following reasons:

11/16/81 emp

1. If the minimum performance standards cannot be met for one of the major components of the system, no allowance is provided to compensate for this by exceeding the standard in another major component in a manner which preserves the overall performance.

2. Site specific characteristics cannot be used to advantage in designing the waste package or underground facility.

3. The ultimate requirement in the performance objective approach is the meeting of EPA's generally applicable environmental standards during all times that the overall system must protect the environment and public health and safety. How this is accomplished by combining the major components should be left to the designer to balance the considerations of cost and system effectiveness.

The NRC states that alternative 2 substantially enhances their confidence that the overall standards will be met. It is not stated how this confidence is enhanced. Any degree of confidence could be specified by establishing a requisite confidence level in the overall performance standard. This is not an uncommon approach in designing other systems which have risks. In addition, the Commission would be able to review the designer's values for each component, including technical bases and uncertainties, and with that information be assured that the overall performance objectives are met.

With the above approach, the individual performance standards can be retained as guides for the designer with departures properly justified by engineering analyses.

We appreciate the opportunity to comment on this very important rulemaking.

Very truly yours,

R. Wilson

R. Wilson, Manager
Corporate Licensing

RW:elr

Union of
CONCERNED
SCIENTISTS

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BRANCH

4th November, 1981

Secretary
Nuclear Regulatory Commission
Washington
DC 20555

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

59

Attention: Docketing and Service Branch

Dear Secretary

Re: Comments of the Union of Concerned Scientists on the NRC's Proposed Rule (10 CFR Part 60) on Disposal of High-Level Radioactive Wastes in Geologic Repositories

1. Introduction

These comments fall into two categories; those addressing specific questions posed by the NRC, and the remainder.

The proposed rule is in many respects adequate to its purpose. These comments specifically endorse parts of the rule and also point out some of its deficiencies.

2. Questions Posed by the NRC

(a) Is the proposed retrieval schedule satisfactory? (p 10)

The proposed schedule is satisfactory. It should not be shortened.

Requirements for retrieval may have a significant effect on the thermal and mechanical design of a repository, particularly one located in salt. Nevertheless, the advantages of the proposed retrieval schedule are such that it should be retained.

Section 60.21 (Content of Application) should stipulate the information on retrieval which should be included in DOE's application.

11/16/81 emp

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(b) Should minimum performance standards for major elements be combined with an overall EPA standard? (p 15)

The combination proposed by the NRC (Alternative 2) is satisfactory. However, some of the proposed performance standards should be altered (see comments below).

As a sequence of two engineered barriers and a natural barrier is required in the proposed rule, it is appropriate to set standards for each barrier in addition to standards for the overall combination of barriers.

(c) Should population-related siting requirements be included? (p 19)

Prior to closure of the repository, such siting requirements would reduce the risk to the public arising from transportation and other accidents.

Both prior to and after closure, such siting requirements would reduce the risk to the public arising from failure of the repository. It is likely that appropriate requirements would be effective in separating the repository from large populations for several centuries, during which period the radiation and heat loading of the repository would decline. The risk of repository failure would decline correspondingly.

Therefore, population-related siting requirements should be formulated.

(d) Should the design and construction requirements (sections 60.130 through 60.134) be abbreviated? (p 20)

These requirements should not be abbreviated.

Furthermore, these requirements should address the monuments which are called for under section 60.51.

(e) Should ALARA be applied to performance requirements dealing with containment and releases? (p 40)

These requirements should use ALARA wording as outlined in the footnote on p. 40, together with quantitative minimum criteria such as those now in the proposed rule.

The ALARA approach is consistent with the requirement in (c) (3) of section 60.21 that the safety analysis shall include a comparative evaluation of design alternatives. There may be several design alternatives at a given site which each meet the quantitative minimum criteria.

NRC
4th November 1981
page 3

As in other regulatory areas, there is likely to be an association of higher costs with the pursuit of higher standards. ALARA is appropriate to this situation.

3. Comments not Specifically Requested by the NRC

(a) Safety analysis and performance confirmation

The proposed rule calls upon DOE to be the sole body responsible for the safety analysis preceding a license application and for the program of performance confirmation which is to be continued until permanent closure. However, it is admitted by the NRC (section 60.101) that long-term performance of the repository is subject to great uncertainty. Additional review of DOE's work is therefore needed.

An independent body should be set up to review DOE's safety analysis and performance confirmation programs. This body should have the power to require tests and investigations beyond those conducted by DOE. Membership of this body should include representatives of other federal agencies, relevant state agencies (those from states affected by repository) and the National Academy of Sciences.

(b) Control of releases

The performance objectives governing control of releases (paragraph (b) (2) (ii) of section 60.111) do not specifically stipulate that the underground facility should be assumed to be saturated. That stipulation should be included.

Release requirements should be applied to all radionuclides. The proposed exemption for radionuclides contributing less than 0.1% of annual release should be removed.

The proposed release objectives do not address the capacity of the underground facility to inhibit releases if waste packages fail during the first 1,000 years. Requirements for inhibition of such releases should be included in this rule.

NRC
4th November 1981
page 4

(c) Required characteristics of the geologic setting

These requirements now stipulate ((c) of section 60.112) that pre-waste emplacement groundwater travel times be at least 1,000 years. This stipulation should instead demand that estimated post-waste emplacement travel times be at least 1,000 years.

At present, minimum repository depth (300 m) is merely one of the favorable conditions listed in section 60.122. Minimum depth should be a required characteristic.

Thank you for your attention.

Sincerely,

G. R. Thompson

Gordon Thompson PhD
Staff Scientist

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60

PROPOSED RULE PR-60
(46FR 35280)

November 3, 1981

Secretary of the Nuclear Regulatory Commission,
Attention: Docketing and Service Branch,
WASHINGTON, DC 20555.

Dear Sir,

10CFR Part 60 - Proposed Technical Criteria

I should like to draw the attention of the NRC to one section of the Technical Criteria of 10CFR Part 60, as issued for public comment July 8, 1981.

Under §60.132 the following statements appear:

> (h) Subsurface Ventilation: The Ventilation system shall be designed to:
>
> (2) Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure.

The implication is that all excavations would have to be ventilated sufficiently that free access would be practical at any time during the repository construction or operation. Even preliminary calculations of the total volume of air required to meet this condition suggest that there would be serious practical implications if this condition had to be satisfied.

Large quantities of ventilating air would be required to provide even minimal conditions in every emplacement room or corridor. This could be provided by recirculating air within a panel, but such practice might not be considered acceptable if the primary function of the subsurface ventilation is to control the transport of radioactive particulates and gases. The alternative of providing "fresh" air to all openings would necessitate the use of very large diameter shafts and ventilation corridors, if the air velocity is to be kept within a normally accepted range. Excavating of such large openings would be inconsistent with minimising the disturbance of the host rock mass within which the repository is sited.

Quite apart from the practical problems of ventilating all openings, it is not clear that ventilation of emplacement rooms would be of any practical benefit. It is inconceivable that instant access to any emplacement room would be required or that a period of up to a few days to reventilate and cool an emplacement room would be unacceptable. If "as required" ventilation was considered acceptable then the ventilation system could be designed to have sufficient capacity to permit simultaneous occupancy of several but not all emplacement rooms.

11/16/81 emg

A-213

Based on these comments I recommend that the sentence I quoted be amended to read:

> Permit continuous occupancy of all parts of the repository in which development or waste handling is active and selected portions of the repository already prepared for waste emplacement or in which waste emplacement activities have been completed.

Alternatively, the term normal operations could be clarified.

I would be happy to discuss this issue with the NRC if appropriate.

Yours faithfully,

Christopher St John

Christopher St. John
Vice-President

C.St.J/pd

Penberthy Electromelt International, Inc.

631 South 96th Street

Seattle, Washington 98108, U.S.A.

Nuclear Waste Division

3 November 1981

Secretary, Nuclear Regulatory Commission
Attention: Docketing & Service Branch
Nuclear Regulatory Commission
Washington, D.C. 20555

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61

DOCKET NUMBER PR-60
PROPOSED RULE (46FR35280)

Comments on Proposed 10 CPR-60

Dear Sir:

I wish to comment as follows:

Retrievability

If the Commission really wants to have retrievability, then the concept of "deep geologic" for a repository should be abandoned in favor of repositories above the flood plain. This kind of repository was proposed by Winograd (1974). There are many advantages over the deep mined repositories.

A repository of this kind can be made by a tunnel boring machine at a cost much lower than is expected for deep repositories. Such a tunnel might be 12 to 20 feet in diameter, entering the side of a mountain, mesa, butte or hill about 100 feet above the surrounding flood plain. The tunnel is bored slightly uphill, so that the repository is self draining. Concrete sleds are placed in the tunnel to form a platform for storage and a passageway underneath for drainage if any. The tunnel itself is lined with reinforced concrete.

In use, the canisters of glassified waste are simply stacked on the concrete platform. If the wastes are high enough in self-heating, a chimney can be provided for cooling by escape of heated air.

A chimney of sufficient diameter 100 feet high will remove a great deal of heat. In this way, the selected limitation of 100 kw of self-heating for a sealed deep repository can be avoided. Instead of canisters 12 feet on centers they can be placed fairly close to each other.

The concept of putting canisters in sockets in a tunnel should be discarded. Not only is there extra expense for boring the sockets in the floor, there is added expense for making a drift (tunnel) which is high enough to accept the drilling machine.

11/16/81 emp

The concept of retrievability must necessarily include the factor of economics. Certainly repository actions can be reversed, but not necessarily at an expense affordable to society.

One of the reasons for considering retrievability is to be able to reprocess the waste in case the first packaging system is not good enough. I believe this is a false objective. Alumino-silicate glass used as a radwaste host has centuries of successful history which makes prediction for the future completely reasonable. Glass objects have been recovered in good condition after several thousand years in tombs and after 2,000 years from immersion in the Aegean Sea.

An advanced waste form is available which has a cladding say 6 mm thick on the outside which is made of totally inert glass. Thus, any alteration of the surface will take place on the inert glass for some thousands of years, even under total immersion conditions.

Another argument for retrievability is the recovery of the resource of the wastes themselves. If heavy stainless steel canisters are used, the metal may be valuable a thousand years hence. But it won't be economic to recover it if the repository is very deep and the backfill has solidified and the repository is flooded. We should not make a conscious, collective societal decision to thwart the future recovery of the wastes, including the canisters. The residual uranium and plutonium may be valuable at a future time.

The alumino-silicate glass as made is very resistant to leaching due to the low soda and high alumina content. However, they can be rendered soluble in the future by remelting the glass with 20% added soda. This will not be costly if the overall activity has decayed nearly to background.

Interim Storage

10 CFR-60 should allow for interim storage for say 90 years as an integral part of the tunnel repository plan. The waste will have decayed in 90 years to a self-heating level only one-eighth as high as when made. This can make the repository only one-eighth as big, with considerable saving in capital costs.

This is discussed by Sen (1980).

MULTIPLE BARRIERS

The nation cannot afford too many multiples of barriers. Three are justified but not more. The first barrier is the use of a high durability alumino-silicate glass as the radwaste host. The glass composition should be similar to the Atomic Energy of Canada Ltd compositions buried in the soil in 1960 with monitored excellent results. Alumino-silicate glasses of this type form a protective skin after 100-200 days of leaching, and show distinctly superior resistance to performance when compared with the soft borosilicates previously planned (Penberthy 1981).

The next justifiable barrier is to have the waste glass annealed to a monolith rather than allowing it to shatter by uncontrolled cooling. Savannah River Laboratory is planning to allow their glass castings to shatter, which has the disadvantage of increasing the surface area available for leaching by a factor of 100 to 1000. Retention of the monolithic shape is easy and reasonable in cost to attain, and there is no reason why this should not be done.

I realize that the NRC in 10 CFR-60 is working to a perceived objective rather than to particulars such as monolithic versus shattering, but annealing to a monolithic block is in simple accordance with the as-good-as-reasonably-achievable principle.

Another barrier that can be applied reasonably is to cast the radwaste glass while molten into an inert glass container so that the inert glass serves as a cladding.

The only other barrier which should be contemplated is physical isolation. This can be accomplished quite adequately without going 1000 feet down. A tunnel bored into a rocky structure where the inner end of the tunnel is say 100 feet below the rock surface is a formidable barrier against intrusion. The heavy concrete portal and concrete plug at the entrance provide a sufficient barrier against accidental intrusion.

With the above system, the canister is used only for processing and transportation. It can be made of mild carbon steel rather than an alloy steel. It is easy to coat the steel with a rust preventative coating such as zinc or nickel, but it can be remembered that carbon steel does not rust when its temperature is significantly above the dew point.

In the event there is no significant hill at the place where the wastes are glassified, then the storage can be in a seismic boat. This seismic boat is a concrete building resting on a concrete slab with a one-inch layer of sand between the slab and the floor of the boat. In the event of an earthquake, the earthquake forces cannot be transmitted to the boat through the sand slip layer.

LEVEL OF DETAIL FOR THE PERFORMANCE CRITERIA

I prefer alternative 2 which prescribes minimum performance standards for each of the major elements, as long as there are only two major elements. The waste package element includes a top quality waste form, monolithic shape, with inert glass cladding. The other element is the physical barrier such as 100 feet of dirt or rock or two feet of seismic boat wall topped with ten feet of dirt.

Depth

There is no reason at all to require a minimum depth of 300 meters (1000 feet). A host rock thickness of 100 feet between the repository and the surface is quite sufficient to prevent casual entry into the repository.

Performance Objectives

Column 1 on page 60-15 refers to permanent closure with the restriction that the repository must perform so that releases are within the limits prescribed. It should be kept in mind that releases depend on a transport mechanism. If the repository is built in such a way that the waste is kept dry, a lot of problems are completely avoided. This performance objective is met by such a system because there is no transport mechanism.

TECTONIC PROCESSES

The foregoing system of packaging the radwaste in a glass of high integrity and clad with an inert glass makes it quite unimportant whether there is collapse of the tunnel due to an earthquake. Nothing will happen to the waste.

GROUND WATER TRAVEL TIME

The restriction on page 60-20 for travel time of ground water through the far field to the accessible environment of at least 1000 years is a quite unnecessary restriction. This will interfere with the drain repository concept, whereby the flooding of the nuclear waste package is avoided. When the waste is kept dry, we don't care whether there is a trickle of water along the bottom of the repository tunnel.

MULTIPLE BARRIER AGAIN

There has been discussion of backfilling of a powdery material around the waste canisters. This is exactly a wrong move, because powdered materials are insulators. They will prevent the active cooling of the waste and thus possibly induce devitrification which is adverse to leaching resistance, and they will set up the temperature conditions which are also adverse to leaching resistance.

The canisters should be open to the surrounding tunnel so that their heat can be either removed by ventilation or can be removed by radiation and air convection to the entire interior surface of the tunnel.

Fire Alarms

The requirement for explosion and fire detection alarm systems is completely unnecessary if the waste form is glass cast into steel containers. There isn't anything in the repository which could either burn or explode.

<u>References</u>

Penberthy, L., The Structure of Glass as A Host for Radwaste, or Why we Need a Glass Better Than "Borosilicate", Waste Management-81, Proceedings of ANS Symposium at Tucson, Arizona, February 23-26, 1981, Vol. 1, page 227.

Winograd, I.J., Radioactive Waste Storage in the Arid Zone, EOS Transactions, American Geophysical Union, Vol. 55, No. 10, October 1974, page 884.

Bon, R., Dedicated-site, Interim Storage of High-Level Nuclear Waste as Part of the Management System, Proceedings National Academy of Science, USA, Vol. 77, No 11, pp. 6269-6271, November 1980.

Yours truly,

PENBERTHY ELECTROMELT INTERNATIONAL, INC.

Larry Penberthy

Larry Penberthy

LP/ne

STATE OF CALIFORNIA — RESOURCES AGENCY

EDMUND G. BROWN JR., Governor

DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
DIVISION OF OIL AND GAS

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DOC

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OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

emp

62

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

November 5, 1981

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Docketing and Service Branch

Dear Mr. Secretary:

Nuclear Regulatory Commission 10 CFR 60.
Proposed Rules for Disposal of High-Level Radioactive Wastes
in Geologic Repositories (Federal Register
Vol. 46, No. 130, Pages 35280 - 35296,
<u>Wednesday, July 8, 1981</u>)*

The California Department of Conservation (CDC) has reviewed the subject document and has the following general and specific comments on the proposed rules. The subjects under general comments include EPA standards, inadvertent human intrusion, alternative approaches to performance standards, population-related siting requirements, and ALARA principle.

CDC's specific comments relate to site characterization and performance objectives in Sections 60.10 and 60.111, respectively. In those discussions, CDC makes specific recommendations on proposed rules.

<u>General Comments</u>

1. <u>EPA Standard</u>

The section on <u>Authority</u> (FR p. 35281), states 'Although no EPA standards for disposal of HLW yet exist, these proposed technical criteria for regulating geologic disposal of HLW have been developed to be compatible with a generally applicable environmental standard. Specifically, the performance objectives and criteria speak to the functional elements of geologic disposal of HLW and the analysis required to give confidence that these functional elements will perform as intended.' CDC is concerned both with toxicity and radioactivity of the radionuclides emplaced as HLW,

*Referred to in this review as "FR p. 35283", etc.

11/16/81 emp

and which may later be released into the environment. At such time as the EPA standards have been prepared, we recommend that the proposed rules be reevaluated to make sure that the performance criteria will indeed provide the calculations necessary to assure that repositories meet EPA standards.

2. <u>Inadvertent Human Intrusion</u>

The proposed rules in Section 60.123 <u>Potentially adverse conditions</u> (FR p. 35290) do not clearly address the issue of potential resources in the repository area which should be considered before siting the repository, to avoid future inadvertent intrusion into the facility. That section states "(3) Resources that have either greater growth value, net value, or commercial potential than the average for other representative areas of similar size that are representative of and located in the geologic setting."

CDC recommends an addition to this section, to read "Studies of mineral resources should be made to determine whether or not such minerals exist at the site, and if so, whether they may have strategic value during the life of the repository. If such resources were found, their presence should be considered an adverse condition in locating a HLW repository at the site."

3. <u>Alternative Approach</u>

CDC has considered the Commission's specific request (FR p. 35283) for comment as to the level of detail in which the performance criteria for a geological HLW repository should be prescribed. The three alternative approaches listed, range from 1) Single overall performance standard -- to EPA standard, 2) Overall EPA standard, plus minimum performance standards for each of the major elements, and 3) Detailed numerical criteria for critical engineering attributes of the repository system.

CDC believes the principal issues on which to base a choice, among this continuum of alternatives which range from very simple to very complex data requirement, are 1) The general public confidence engendered, and 2) The practicality of providing and of evaluating the alternate levels of detail that would be required. Further, this issue must be considered in the light of present unavailability of the EPA standards on which alternatives 1 and 2 would be based, as well as the procedural fact that a lesser level of detail is acceptable in this set of technical criteria than will be required at the future stage of site- and design-specific data, when license applications are prepared for each specific proposed disposal site.

CDC's position is that maximum practical detail of performance criteria is valuable, for confidence in the overall safety of any proposed site, but that as long as detailed numerical criteria are mandatory in each license application, the compromise alternative ("2. Prescribe minimum performance standards for each of the major elements, in addition to requiring the overall system to meet the EPA standards.") is appropriate for the purpose of this proposed rule-making. In endorsing this approach, we understand the "major elements" are the engineered barriers (waste package and underground facility), and the natural barrier provided by the geological setting. Further, as we discussed below under "Performance Objectives" and "ALARA Principle", we believe that the criteria for each of those elements should be made as numerically specific as practical, by incorporation of the requirement of probabilistic analysis, based on the worst-case scenario.

4. <u>Population-Related Siting Requirements</u>

The Commission invited (FR 35284) commentary on whether population-related siting requirements should be included in the final rule, and if so, how. CDC feels this is a significant issue which needs further review. At a minimum, we suggest inclusion of the following criteria: "That the distance from the repository site to a point of human intrusion be based on the radius of contamination due to accidental release of radioactive material during the deposition of the HLW waste material."

5. <u>ALARA Principle</u>

The Commission has requested (FR p. 35289) comments on the ALARA principle, which as it relates to containment, reads, "...as <u>long</u> as reasonably achievable," and as it relates to releases "...as <u>low</u> as reasonably achievable." CDC recognizes that unavoidable uncertainties are inherent in the engineering design, and in human prediction and control of future geologic processes, and on their impacts on the engineered systems. However, CDC believes strongly that all evaluations of HLW containment and releases should be based on probabilistic data which uses the worst-case scenario in failure analysis.

In application to the ALARA principle, CDC's concern is that any process of determining what degree of containment or release is "reasonably achievable" be required to follow a rigorous procedure that applies probabilistic, worst-case reasoning.

Secretary of the Commission.
Page Four
November 5, 1981

Specific Comments

1. **Site Characterization**

Section 60.10, Site Characterization, subpart (b), states "Unless the Commission determines with respect to the site described in the application that it is not necessary, site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced."

No explanation is offered as to any set of conditions under which NRC would consider deleting the requirement of a thorough program of on-site exploration and testing for every potential HLW site. Even if a proposed site were in a geologic setting considered to be similar to a previously approved site, the site-specific conditions and their comparability with the approved site would still need to be tested to verify that the proposed site could indeed meet prescribed performance criteria. CDC believes strongly that in situ testing of geological conditions must be a mandatory element in any set of procedures required for selecting HLW sites, with no exception.

We recommend that subpart (b) of Section 60.10 be revised to unconditionally require an on-site exploration and testing program for every proposed potential site, as follows:

Section 60.10 Site Characterization

"(b) Unless the Commission determines with respect to the site described in the application that it is not necessary, Site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced."

2. **Performance Objectives**

The general proposed performance objective for all HLW disposal sites is to provide an engineered waste package system (including waste form, container, and overpacks) which will retain all the radionuclides during a 1,000-year containment period following permanent closure. After this period, the general performance objective would allow the engineered system to release the radionuclides at a maximum prescribed rate to the geologic setting.

A weakness in the performance objectives is their apparent reliance on the geologic setting to protect against possible failure of engineered systems during the 1,000-year containment period, but at the same time, having no rational way to specify the maximum expectable releases of radionuclides, heat, and radiation from the engineered system, if it should fail during that period.

Secretary of the Commission
Page Five
November 5, 1981

CDC recommends additional tightening of the performance objectives in Subsection 60.111, to emphasize the importance of stringent criteria for the geologic setting, to assure its reliability under all failure conditions, to be able to mitigate a possible maximum level of radionuclide releases from the engineered system. As we discussed under General Comments, above, under the ALARA principle, CDC believes it is important that the engineering and geologic containment criteria be expressed in as definite and stringent manner as is feasible in the context of the Rules for Disposal. We believe that specific reference to the need to apply probabilistic failure analysis, and the worst-case scenario will provide a significant degree of additional assurance of safety, in the redundant systems.

CDC recommends the following changes to the proposed rules:

1. **Subsection 60.111 (b) (2) (ii) (A): Control of releases**

"(A) For HLW, the engineered system shall be designed with sufficient redundancies and with probabilistic failure analysis using the worst-case scenario so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is will be at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure..."

2. **Subsection 60.111 (b) (3) (i) Containment Period**

"(i) Containment period. During the containment period, the geologic setting shall mitigate the impacts of the worst-case scenario including a complete premature failure of the containment barriers provided by the engineered system. The ability of the geologic setting to isolate wastes during the isolation period, in accordance with paragraph (b) (3) (ii) of this section, shall be deemed to satisfy this requirement."

CDC recommends NRC's consideration and adoption of these changes to the proposed rules, in order to assure the safest possible disposal of high-level radioactive wastes.

Sincerely,

Brian A. Sway

Brian H. Sway
Deputy Director

cc: P. Greenberg
G. Veronini
J. Ward
J. Davis
P. Amiboto

[illegible]

DEPARTMENT OF NATURAL RESOURCES
OFFICE OF ENVIRONMENTAL AFFAIRS
NUCLEAR ENERGY DIVISION

[illegible]

DOCKETED
USNRC

November 5, 1981

'81 NOV 10 P12:55

Secretary of the Nuclear Regulatory Commission
Washington, D.C. 20555

63

Attention: Docketing and Service Branch

PR-60
(46 FR 35280)

Dear Sir:

Re: 10CFR, Part 60

Enclosed please find comments on the referenced proposed rule submitted by a member of the Louisiana State Review Panel on Radioactive Waste Management. Any additional state comments received will be forwarded to your office as received.

Sincerely,

/s/ L. H. Bohlinger

L. Hall Bohlinger, Sc.D.
Assistant Administrator
Nuclear Energy Division

LHB:mg

Enclosure

Ackn.d 11/16/81

[illegible]

Capital-Area Groundwater Conservation Commission

P.O. Box 64526
Baton Rouge Louisiana 70896
Telephone (504) 924-7420

October 19, 1981

Dr. L. Hall Bohlinger
Dept. of Natural Resources
Nuclear Waste Dept.
Postoffice Box 14690
Baton Rouge, LA 70898

Ref: Proposed Technical Rule 10CFR60-Federal Register, July 8, 1981

Dear Dr. Bohlinger:

The proposed regulations have two major weaknesses, that were and are also prevalent in ongoing radwaste studies of salt domes.

GENERAL COMMENTS

1. The regulations for radwaste should require for each State an "oversight interdisciplinary group" that would serve as a State Review panel to the prime contractors, to State officials, and the involved Federal agencies. Its function would not include the review of contracts nor the control of activities. The creation of such a group would assure the data-collection and interpretive multidisciplinary studies are not fragmented, assure that the assigned task are accomplished with the State's needs in mind, provide input and information to the executive and legislative branches of the State government; and serve as a "route" for information to governmental agencies and to the concerned public.

2. The regulations and the ongoing studies are oriented primarily toward geology and do not place hydrology in the proper perspective. Geology includes structure, stratigraphy and lithology and provides knowledge of the framework BUT does not provide the needed hydrologic data required in major hydrologic decisions, such as that required in Section 60.112 (c)--"the predicted travel time of groundwater." The rate and movement of ground water are the most important processes relative to the potential impact on the containment of waste and therefore hydrology should be considered a unique discipline that requires equal emphasis in the regulation and in the studies.

In conformance with the above considerations, following are specific comments and summary.

Dr. L. Hall Bohlinger
October 19, 1981
Page 2

SPECIFIC COMMENTS

<u>Section 60.2 Definitions</u>. Should include definitions of hydrologic terms such as ground water, etc. Excellent sources of definitions are U. S. Geological Survey Water Supply Papers 1988 and 1541 A. U. S. Geological Circular 779 is an excellent "thinking document" when considering radwaste and earth science.

<u>Section 60.10 (b) Site Characterization</u>. I agree with the requirement for <u>in situ parameters</u>—a prime requirement for the collection of hydrologic data.

<u>Section 60.10 (d)</u>. The suggestion to limit adverse effects by limiting the number of subsurface "penetrations," indicates the need for the forementioned "State oversight" group and the interdisciplinary planning of penetrations or test holes for multipurpose data activities--geologic, hydrologic, etc. Current studies have not always been planned with this in mind but have had a "lack of data" syndrome and the need for "more holes" attitude.

<u>Section 60.21 (c) (1)</u>. Data needs should include absorptive and adsorptive properties and other clay properties. It should be recognized that clay is <u>not</u> impermeable.

<u>Section 60.102 (c)</u>. Last sentence should read, ". . . particular attention must be given to the characteristics of host rock, material surrounding the host rock, <u>regional hydrologic setting, and the past, present and predicted future effects of manmade and natural stresses on the hydrologic system</u>." (Underlined material added)

Section 60.112 should be headed "Required characteristics of the geologic and <u>hydrologic</u> setting."

<u>Section 60.112(c)</u>. The requirement of 1000 years for isolation of the "waste package" when considering ground-water travel time cannot be predicted without some uncertainty because of the inability of the scientist to guarantee future hydrologic conditions, the stability and integrity of host rock, and the effects of manmade stresses. Although models may not be capable of giving a <u>single unquestionable</u> answer for 1000 years and changes may occur with time, it should be realized that a model may be able to provide a spectrum of alternatives based on (1) the geology and hydrology (2) the historical stability and integrity of the host rock, (3) the regional and local hydrology of the materials surrounding the host rock, (4) the present and predicted long-term effects of manmade and natural stresses that have some degree of uncertainty, (5) the radwaste form, and (6) degree of accuracy of the in situ hydrologic parameters. In summary, it is satisfactory to assume, with all

Dr. L. Hall Bohlinger
October 19, 1981
Page 3

the uncertainties candidly discussed, that 1000 years predictions for ground water movement can be made but with an ever increasing degree of uncertainity and concern. The inability to predict long-term ground water movement can be offset by the adoption of a philosophy to avoid the possibility of "ground water interaction" by locating sites so that the host rock is not surrounded and overlain by water-saturated material.

<u>Section 60.111 (a) (2)</u>. This section (July 3, 1981 in Federal Register) gives the retrievability time of starting at any time up to 50 years after waste emplacement" not <u>110 years</u> as mentioned in Dr. Heath's memorandum. As I recall a 50-year period is considered to be temporary storage time. Is this intended to be a "safety feature" for a permanent storage facility? Regardless if it is to be permanent radwaste facility, the emplacement should be designed for an infinite period of time.

<u>Section 60.111 (b) (ii) A and B</u>. In regards to a 1 to 10^5 part release rate, the fallibility of man and the unpredictability of nature and man's activities may consider this release rate to be unacceptable. However, if nuclear physicists can assure that the risk, if any, will be minimal and that the rate of release will not endanger the biosphere and geosphere, then the release should be satisfactory.

SUMMARY

Geology provides information on the "makeup of the container", whereas hydrology quantifies the hydrodynamics of the system. Thus, geologic studies alone do not provide information required to estimate the movement of fluids and answer questions pertaining to the rate of movement of radionuclides and water especially in areas where the host rock is surrounded by saturated materials. Local and regional hydrologic modeling should be prime prerequisitite during the initial phase of a site study because it not only provides information on the effects of hydrologic stresses but indicates data needs and oftentimes indicates geologic unconformities. Unfortunately, the early stages of studies made in the Gulf Coast areas did not include enough emphasis on hydrologic studies. As a consequence, questions related to the interaction of hydrology to the shear zone, the sheath, the fissures in the caprock, the salt, and to the rate and direction of ground-water movement cannot be answered with a slight degree of confidence at this time and probably for some time into the future. Thus NRC proposed regulations should place equal importance on hydrologic studies to prevent omissions during the data-collection phase and provide for multidiscipline activities. Final determinations as to the suitability of a salt dome for radwaste storage will be unnecessarily delayed until the proper hydrologic data are collected and regional and local hydrologic models are started, calibrated, verified, and accepted.

Other subjects that need early consideration in the licensing processes are socioeconomics, archeological, and wildlife.

Very truly yours,

A. R. Turcan, Jr.
Director

ART/sbo
cc: Charles Grant
George H. Cromer
Kai Hodbou

VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

'81 NOV 10 P2:55

November 5, 1981

W. N. Thomas
Vice President
Fuel Resources

Secretory
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attn: Docketing and Service Branch

(64)

Re: Notice of Proposed Rulemaking; 10 CFR Part 60
Disposal of High-Level Radioactive Wastes in
Geologic Repositories (Technical Criteria)
46 Fed. Reg. 35,280

-60
(46 FR 35280)

Dear Sir:

The Utility Nuclear Waste Management Group (UNWMG), of which Vepco is a member, has prepared and submitted comments concerning the Nuclear Regulatory Commission's (NRC) proposed rule, 10 CFR Part 60 - Disposal of High Level Radioactive Wastes in Geologic Repositories. Vepco supports the position taken by the UNWMG and feels that incorporation of their comments into the rule will permit the design, construction and operation of a repository as effective as one under the current form of the proposed rule in a more timely and less costly manner.

The key points in the proposed rule that Vepco and the UNWMG take exception to are summarized below:

1. Systems Approach vs. Barrier Performance Objectives (46 Fed. Reg. 35,283-84)

The major concern with the NRC's proposed rule is the use of specific barrier performance objectives for repository components rather than the use of overall system performance objectives. The selection of the current barrier performance standards, i.e., 1,000 year waste package life and 1,000 year water travel time to the accessible environment, appear to be an imposition of arbitrary standards without scientific or technical support. The use of individual performance standards is also at odds with an important factor of sound repository design and operation; the interaction of individual components to achieve, on a combined basis, the required level of repository system performance. Use of an overall system performance standard would focus attention on total repository performance while permitting appropriate design flexibility to take advantage of new developments and permit the use of specific characteristics for individual sites.

2. Retrievability (46 Fed. Reg. 35,282)

The requirement to maintain retrievability for a period of up to 110 years is excessive, without any adequate support, and could unnecessarily delay the final closure of the repository. A more reasonable approach might be to base design requirements for retrievability, if any, on the period of repository operation. Assuming that the first waste packages will have been in place for about 30 years before the repository becomes filled and allowing another 30 years (the same times as for original construction and emplacement)

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for retrieval, would result in a design requirement of 60 years. This time period is reasonable because any problems involved with the storage will probably become apparent quickly.

3. Design and Construction Criteria (46 Fed. Reg. 35,285)

The level of detail required for design and construction of the repository is excessive and should be reduced. This comment is based on the desirability to maintain flexibility with respect to design and construction wherever possible and minimize unnecessary cost.

By formulating a well defined and workable set of rules now, future problems will hopefully be avoided. Vepco believes that the proposed changes will result in a more effective rule and provide for the more timely and less costly design and construction of a repository. We understand similar recommendations supporting these changes have been submitted to the NRC by other groups including the American Nuclear Society and the United Kingdom's Department of the Environment.

Should you have any questions regarding our comments, we would be glad to discuss them with you.

Very truly yours,

W. R. Thomas

cc: Mr. T. Lough, Virginia State
Corporation Commission
Mr. R. R. L. Stanford,
Project Manager - [illegible]

DOCKETED

DEPARTMENT OF ENERGY & TRANSPORTATION
Watkins Building, 510 George Street
Jackson, Mississippi 39202
601 / 961-4733

'81 NOV 10 P4:22

emp

November 6, 1981

65

PR-60
(46 FR 35280)

Mr. Ed O'Donnell
Division of Health, Siting
and Waste Management
Office of Nuclear Reactor Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. O'Donnell:

Enclosed are the comments which you have requested on proposed 10 CFR Part 60 technical rule. I have been in contact with the Mississippi State Board of Health concerning their comments. Due to the fact that they have been involved in a critiqued emergency response exercise for the past several weeks, they presented two oral comments which are as follows:

1. There is no mention in the rule of population and/or proximity to population. Since the life of a repository could well exceed the institutional lifetime of the nation, and as such the issue of population is critical and should be included in the technical rule.

2. Attention to the protection of fresh water is necessary, especially since water is perhaps Mississippi's most valuable natural resource.

We are hopeful these comments can be utilized in a manner that will assist the national effort toward achieving a comprehensive nuclear waste management plan and its regulation.

Sincerely yours,

John W. Green, Jr.

John W. Green, Jr., Manager
Nuclear Waste Program

11/16/81 emp

MISSISSIPPI DEPARTMENT OF NATURAL RESOURCES
Bureau of Geology
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P. O. Box 5348
Jackson, Mississippi 39216
(601) 354-6228

October 30, 1981

'81 NOV 10 P4:32
emf

...-60
(46 FR 35280)

Mr. Ron Forsythe
Nuclear Waste Program
Department of Energy and Transportation
510 George Street, 300 Watkins Bldg.
Jackson, Mississippi

Dear Ron:

The Bureau of Geology is pleased to deliver to you the accompanying report, "Comments on Proposed Rules of the Nuclear Regulatory Commission Regarding Disposal of High-Level Radioactive Wastes in Geologic Repositories, 10 CFR Part 60, Subparts E-H (as published in Federal Register July 8, 1981)." We sincerely hope that the NRC will view our comments as constructive criticism and utilize them in their revision of the proposed technical rule.

Sincerely,

Michael B. E. Bograd

Michael B. E. Bograd
Geologist

MBEB/ss

Enclosure

RECEIVED
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A-221

COMMENTS ON PROPOSED RULES OF THE NUCLEAR REGULATORY
COMMISSION REGARDING DISPOSAL OF HIGH-LEVEL
RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

10 CFR Part 60, Subparts E-H

(as published in Federal Register July 8, 1981)

Mississippi Department of Natural Resources

Bureau of Geology

October 1981

Comments on NRC Proposed Technical Rule
10 CFR Part 60, Subparts E, F, G, and H

by

Mississippi Department of Natural Resources
Bureau of Geology

PREFACE

This report was prepared by staff geologists Michael B. E. Bograd, S. Mark Smith, and Curtis W. Stover. It represents the position, opinions, and concerns of the Mississippi Bureau of Geology.

Alvin R. Bicker, Jr.
Director, Bureau of Geology

INTRODUCTION

These comments are addressed to the Nuclear Regulatory Commission (NRC) and pertain to the proposed technical rule regarding Disposal of High-Level Radioactive Wastes in Geologic Repositories, 10 CFR Part 60, Subparts E, F, G, and H, as published in the Federal Register on July 8, 1981. Included are comments on revised Section 60.2, Definitions. In a letter from Robert J. Wright to Alvin R. Bicker, Jr., dated October 7, 1981, the NRC specifically invited comments on: (1) retrievability, (2) selection of regulatory approach - three alternatives, (3) consideration of population density or proximity, (4) construction design, and (5) performance requirements.

The Mississippi Bureau of Geology is vitally interested in all aspects of the federal program to develop a permanent repository for high-level radioactive waste for two reasons: (1) the method of permanent disposal most likely to be developed is a deep geologic repository(ies), and (2) Mississippi is a potential repository host state. We hope these comments will be helpful in making improvements to the rules proposed by the NRC on Jul. 8, 1981.

GENERAL COMMENTS

In our reviews to date of work done by the U.S. Department of Energy (DOE) and Battelle's Office of Nuclear Waste Isolation (ONWI) in the National Waste Terminal Storage (NWTS) Program, the Bureau of Geology has been concerned constantly with the lack of specific guidelines and criteria for studies being done. Existing guidelines and criteria for the NWTS Program are so vague and generalized, and written using so many ambiguous or undefined terms, as to be almost worthless. Our experience with NWTS reports in Mississippi has been that widely differing interpretations of the significance of certain geologic findings can be made under existing criteria. These differing interpretations have been such that ONWI may find that a site satisfactorily meets a certain criterion as a suitable repository site, while the Bureau of Geology may have a different interpretation of the criterion and argue that the site is unsuitable based on the same data. Despite pleas for the promulgation of specific criteria, the NWTS Program continues with only vague and general rules available. We have found even that DOE's interpretation of the criteria, or at least the weight put on different criteria, changes with time.

The Bureau of Geology has looked to the NRC, as the repository licensing agency, for a definitive description of the geologic parameters of a suitable repository site, including a description of geologic features that would make a site unsuitable. We do not find such descriptions in the proposed rules for 10 CFR Part 60, Subparts E-H. Our primary complaint is with the lack of specificity. The rules are a good outline or list of goals to be achieved, but we need more definition of how these goals are to be achieved. We suspect that some of the goals cannot be met with present technology.

It is difficult to comment on these proposed rules for several reasons, but primarily because they are very general and in many cases not as specific as criteria outlined in ONWI-33(2). Difficulty also arises in differentiating the respective roles of DOE, NRC, and EPA. DOE is charged with the responsibility of siting, constructing, and operating a repository. EPA is responsible for developing performance standards with respect to radionuclide releases from a repository. NRC is responsible for developing rules by which they will receive and rule on license applications from DOE. If NRC rules become too rigid, they could in effect dictate exploration, design, and construction criteria for DOE. If the rules are too general, they become meaningless and would allow DOE to replace NRC licensing rules with their own criteria. The NRC rules are also dependent upon EPA standards which do not exist. It is possible that DOE and NRC could jointly dictate the EPA standards.

Although we find that the proposed rules are too generalized and non-specific, the Bureau of Geology has no complaints about the topics or subjects covered in the rules, except where mentioned below. We make no recommendations of sections to be deleted or additional topics to be added. We only request that the "skeleton" of the proposed rules be given some "flesh".

SPECIFIC COMMENTS

Page 35282, Column 3

Conservative practice requires that choices of options, specifically including retrieval, should be maintained as long as possible. However, NRC should be more specific on the objectives of maintaining the retrievability option. For example, there is no list of those possible conditions under which retrieval would be initiated.

Page 35283, Columns 1 and 2

We agree that site selection should be directed toward sites of little resource value or scientific interest and for which there is no attraction for future societies. If this criterion is to be followed, then this would tend to eliminate salt domes since they are potential sites for: solution mining of salt, storage of hydrocarbons, gases, or pumped air; sulfur extraction; oil and gas exploration; and geothermal energy activities. It would seem that bedded salt would better fit the requirement. Although we cannot offer any alternative approaches to the Human Intrusion question, we do not believe that the resource potential of the Mississippi salt domes has been adequately assessed in the NWTS Program to date. We have reason to believe that oil and gas resources may exist that have not been explored for yet.

Page 35283, Column 3

We agree with NRC's selection of alternative #2 regarding the detail of performance criteria. The design and construction should be based on existing knowledge and technology and should not depend on future breakthroughs.

Page 35284, Column 3

Population density and proximity to population centers should be given consideration since safe disposal should be the primary objective of the NWTS Program. Common sense should dictate that HLW be disposed of in a remote area with as low a population density as possible. Primary consideration should be given to the safety of the general population in the vicinity of the surface facility of the repository since that is where spent fuel and HLW will be processed for encapsulation into canisters and placed in the repository. Since the spent fuel and HLW will become progressively less hazardous with time, it would seem more logical to site the repository with more consideration given to present safety than to the safety of a repository at some future time.

Section 60.2

The definition of "accessible environment" needs to be refined and clarified. It is defined as "those portions of the environment directly in contact with or readily available for use by human beings." With present technology boreholes and shafts can and do penetrate to repository depth. The whole repository can be considered to be in the accessible environment. Previous publications have maintained that waste needs to be isolated from the biosphere, which is said to be the base of fresh water. There seems to be a conflict between the two criteria. The ambiguity of the present definition will cause problems in interpretation of several sections in Subpart E.

Page 35289, Column 2, Footnote 3

An ALARA principle should be applied to the performance requirements dealing with the containment and control of releases since post-closure data may not be available to confirm whether or not the requirements are being met. Setting given values for containment and releases would not be verifiable. Implementation of an ALARA principle based on state-of-the-art technologies and materials would be more appropriate, as long as the utmost care is taken.

Section 60.112

This section is good, but not specific. How are the stabilities required in paragraphs (a) and (b) defined? Perhaps in paragraph (c) the 1000-year groundwater travel times required at a site should be specified for both pre- and post-waste emplacement.

Section 60.122

This section is no more specific than Section 60.112, unfortunately. Again, in paragraph (f)(6) pre-waste emplacement should perhaps be changed to include post-waste emplacement conditions. What is the meaning or significance of paragraph (j)?

Section 60.123

Parts of this important section also need clarification, including but not limited to the following. In the case of a salt dome, the 2 km distance in paragraph (b), if sufficient, should be from the boundaries of the dome. In (b)(3), what would "representative areas" be at a salt dome site? In (b)(4), what is "extreme" erosion? Does (b)(5) apply to salt domes, all of which exhibit evidence of dissolutioning of soluble rocks? What is the definition of "complex engineering measures" in (b)(16)?

Section 60.132

This section is particularly vague and general. As one example, what is the meaning of "control of groundwater movement" in (a)(2)?

Section 60.133

Paragraph (b)(2) requires that "at the time of permanent closure sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass." Is this possible with existing technology? And if it is possible, can we expect the seals to remain effective for 1000 years or longer? The rule should specify what methods or materials would have to be used to meet this requirement.

Subpart F - Performance Confirmation

The contents of Subpart F do not specify what agency is to be responsible for performance confirmation. Some of the monitoring functions should be conducted by an agency independent of DOE, perhaps.

[illegible] and [illegible].

The proposed technical rule makes no mention of post-closure monitoring of the geologic environment in the vicinity of the waste packages. Such monitoring may be desirable for years following closure of the repository; it could be accomplished if provided for prior to closure. In situ monitoring should continue as long as possible after closure to detect any significant rises in temperature, deformation of the underground facility, condition of shaft and borehole seals, or any release of radioactivity from individual waste packages or from certain areas of the repository. Monitoring devices could be emplaced prior to permanent closure and be monitored as long as they function. Monitoring would provide down-hole information on the conditions in the repository and the condition of the canisters, which would be useful if consideration were being given to re-entering the repository. Paragraph 60.143(d) should be revised, at least to delete the phrase "as long as possible."

Warren C. Liebold
44 Roslyn Avenue
Sea Cliff, New York 11579

(66)

Docketing and Service Branch
Secretary, USNRC
Washington, D.C. 20555

Dear Friends,

Enclosed are the comments of the Sierra Club's Nuclear Subcommittee of the National Energy Committee on Proposed 10 CFR Part 60 (46 FR 35280), Disposal of High-level Radioactive Wastes in Geologic Repositories.

Any questions should be directed to Marvin Resnikoff, 14 Cliff Avenue, Yonkers, New York 10705, (212) 691-8550-Work, (914) 968-5248-Home.

Sincerely,

Warren Liebold

cc: Resnikoff, Coan, Conlon

COMMENTS OF THE SIERRA CLUB NUCLEAR SUBCOMMITTEE OF THE NATIONAL ENERGY COMMITTEE ON PROPOSED 10 CFR PART 60 (46 FR 35280): DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

The proposed rule details the performance standards for construction and criteria for siting high-level waste repositories. The proposed rule provides a good general direction for repository siting and regulation of construction. We support the inclusion of detailed design and construction criteria in the rule itself and not in supplementary Regulatory Guides. The proposed rule paints a much more technologically complex picture of waste disposal than the nuclear industry does and if honestly adhered to by the NRC Staff and licensing Boards will go a long way toward restoring public confidence in the federal agencies and the process of siting a waste repository.

While we are in general agreement with the rule, we believe it should be strengthened in several significant ways because it does not yet meet citizen concerns in important respects. In general the degree of proof called for by the NRC is "reasonable confidence" that the public health is protected whereas the Sierra Club would wish a "high degree of confidence". The Proposed rule still allows for a large amount of radioactivity to enter the environment and therefore a large number of cancers to be caused per kwh of electricity produced. We believe there should be a limit. The proposed rule does not provide for an environmental impact statement before test radioactive wastes are placed in the ground, only an environmental assessment. The Sierra Club considers this test placement of radioactive wastes "a major federal action significantly affecting the environment", requiring an EIS. The proposed rule has no retrievability criteria, i.e. conditions which specify when buried wastes would be retrieved. Finally, certain technical and procedural details regarding human intrusion, long-term controls, population criteria etc. need strengthening and are mentioned specifically in the comments below.

Reasonable Assurance

The proposed rule indicates (60.101) that complete assurance concerning protection of the public health can never be met and that the Commission will only require "reasonable assurance" based on the record. Instead, the Club believes that under conservative assumptions, there should be "high confidence" that concentrations of radionuclides in waste materials should not be allowed to appear in the Earth's biosphere before they have decayed to innocuous levels.

Limit to radiation releases

The limits to yearly radiation releases are specified in 60.111(b)(2). According to the proposed rule, within the first 1,000 years following closure, the waste package must contain all radionuclides. Following this initial period, the annual release rate can be no more than one part in 100,000 of the radionuclides present at 1,000 years following closure, excluding radionuclides which are present in small quantities. Certain of these excluded radionuclides will produce the largest number of health effects in the long term. They include technetium-99, neptunium-237 and iodine-129. Further, it is not clear, without detailed calculations at specific sites, that this regulation is sufficiently stringent to protect the public health, or whether it would lead to a large number of cancers.

Human Intrusion

The most likely long term threat to the integrity of a high-level waste repository is human intrusion. As an example, a DOE funded study has shown that 29 million deaths could be caused by solution mining for table salt (PNL-2955). Just the drilling for resources, and not even the removal of those materials, could undermine the integrity of a waste repository. It is therefore important not to locate a repository near perceived resources, where humans are likely to drill. We therefore propose the following wording:

> The geologic medium and the site selected for geologic disposal should be chosen to minimize the possibility of future human intrusion during periods after which the permanence of records can no longer be relied upon. Hence, neither the medium should be a valuble resource, nor should the site be located in an area where other valuble resources have been suspected or are likely to be mined.

Rather than reflect this view of perceived resources, the regulations only require an assessment of present resources near a proposed repository. Under 60.21, the application must include

> "an identification and evaluation of the natural resources at the site, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the site to isolate radioactive wastes. Undiscovered deposits..."

While we agree that present resources or potential resources should be estimated, there should also be an assessment of past resources and drilling activities.

The region as a whole must be assessed for past drilling activity and not just the immediate site. E.g., of 162 salt domes in the Gulf Coast region potentially usable for a Federal repository, 95 of these have already been drilled (Y/OWI/SUB-7414/1,p.174)... This indicates that for the Gulf Coast region as a whole, there is a high probability that a salt dome will be drilled. Thus, in 60.123, a potentially adverse human activity that significantly affects the hydrogeology is drilling holes and this must be assessed in 60.124.

Long term controls

Not enough thought has been given, in the proposed rules, to long term controls and whether such controls are possible for the time periods during which the materials in the repository remain extremely hazardous and have high heat content. Further NRC guidance and EPA standards are needed here. If effective and specific long term controls for 1,000 years cannot be exercised, then sites must be chosen with this knowledge in mind.

Population criteria

Population density criteria must be included as part of the proposed rule. They are not included now. The Commission believes that the issue has been adressed indirectly through a consideration of resources in the geologic setting. The Commission believes that this is a more realistic approach over the long periods of time involved.

We disagree and believe there should be population density criteria. As the proposed rules now stand, a high-level waste repository could be located in the South Bronx.

Resources apply to dollar value of goods and not human health effects. Any EIS, in a consideration of alternative sites, must weigh the resources in dollars and the human health effects separately in concluding where a repository should be located. The preferred site must minimize the total number of health effects.

We disagree with the Staff's reasoning on this point. The Staff claims that because of the long-lived nature of the wastes, population predictions are uncertain and thus an area which is sparsely populated today might not be so in the future. However, the greatest hazard from high-level wastes occurs during the first few hundred years. Highly populated areas, or those which are reasonably projected to be so, should be avoided in the times periods during which the high-level waste is most hazardous.

Retrievability

We concur with the comment of the ACRS on this point, that

> the NRC should indicate the conditions under which retrieval would need to be performed, perhaps by postulating illustrative circumstances. The type of waste to be inserted could influence the retrievability requirements as well as the performance of the repository.

Without knowing under what conditions the high-level waste would be retrieved, we oppose the insertion of high-level wastes in a reposibory, even for test purposes. The promise of retrievability gives local citizens a false sense of security. Citizens feel that if there is a problem at the repository, the wastes will be retrieved and they will be protected. However, in our experience, the worse the situation, the less likely that wastes would be removed. Why? Because a balancing would take place: the environmental impact of leaking radionuclides would be weighed against occupational exposures incurred in removing the waste materials. Because it is more difficult to predict future health effects compared to health effects to workers involved in a retrieval operation, the result can be predicted now: DOE would do nothing. This scenario has already occurred with the West Valley burial ground. Thus there is a need to produce guidlines for retrieval, demonstrate the capability for retrieval and estimate the occupational dose which could be incurred during retrieval.

Again, this issue is well illustrated by the burial ground at West Valley. A radiation finger now extends 1½ miles from the reprocessing plant/burial ground complex due to migration of radionuclides along a sand lens underground. Material is buried at the NRC-licensed burial ground in 50-foot deep holes which, we believe, have pierced a sand strata. The sand strata is cut by Cattaraugus gorge. Cattaraugus Creek empties into Lake Erie, the water supply for 1.8 million people! In spite of this danger to the health of the general population, there is tremendous resistance to exhume the burial ground and to place the material in above ground bunkers. The arguments center on whether the occupational exposures plus the economic costs are greater than the number of health effects which coul. . caused by the leakage of the radionuclides into drinking water. Of course, had the information concerning this potential leakage appeared in an initial safety analysis report, perhaps the wastes would not have been located at West Valley in the first place, with no leakage taking place into Cattaraugus Creek

EIS at Site Characterization Stage

We feel strongly that an environmental impact statement should be prepared before a site is characterized. The EIS must include an evaluation of the testing and site characterization activities on the integrity of the potential repository. For example, if drill holes are used to characterize salt, how many drill holes will there be and what will be the effect? If drill holes are made in granite, what effect will that have? How much waste material placed in the proposed repository is necessary to characterize the site? How will that nuclear waste material be removed?

The placement of radioactive wastes in a proposed repository should be licensed by the NRC and there should be a limit on the amount of radioactive wastes permitted during the site characterization stage. If this is not done, the testing stage could lead directly to an unlicensed repository. The proposed rule does not explicitly limit the amount of wastes for testing purposes, does not call for an EIS at the site characterization stage, and does not require the licensing of wastes placed in a repository for testing purposes.

Chicken and Egg Problem

The wastes and the geologic setting, as an integrated system, are intended to prevent radionuclides from reaching the environment. However, the NRC, according to legislation which has passed Congress, will not license all waste forms. At West Valley, as an example, the DOE will be creating a waste form without regard for the eventual geologic medium. If any specific waste form is produced and is later found to be incompatible with a salt repository or other medium, will those solidified wastes not have a permanent home? Will the NRC Staff perform separate analyses for each type of waste form which may be placed in a repository? The proposed rule should deal with the problem of waste forms being created first, before a repository is sited [illegible] more human and [illegible]. public relief [illegible]

[illegible] more human kind conclusions protecting public health safety in peace now here. Command public vote for eternal recovery conversion from archaic nuclear waste to renewable energies including technical economic concepts in the best interests of public health safety in peace now here

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PR-60
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OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

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(46 FR 35280)

NOV 16 1981

OFFICE OF
THE ADMINISTRATOR

Mr. Samuel Chilk
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch '81 NOV 16 A10:56

Dear Mr. Chilk:

emp

SECRETARY
& SERVICE
BRANCH

In accordance with Section 309 of the Clean Air Act, as amended, the U.S. Environmental Protection Agency (EPA) has reviewed the technical criteria for Disposal of High-level Radioactive Wastes in Geologic Repositories (10 CFR 60). These proposed rules were published in the Federal Register July 8, 1981 (46 FR 35280). We earlier provided you with comments on the advance notice of proposed rulemaking for this regulation (45 FR 31393).

EPA endorses the proposed use of mutiple barriers for these repositories. This is an approach that will be incorporated in EPA's own forthcoming standards for high-level nuclear waste disposal. As we commented earlier, we are concerned that the emphasis of the proposed rule is on engineered barriers rather than on favorable geology. The proposal presents specific numerical requirements for the waste package, the leachibility of the waste, and the travel time of water from the repository to the accessible environment. We think that you should consider guidelines relating to such geological properties as sorption. We urge the Commission to extend the multiple barrier approach to the geology and geochemistry of the disposal site.

Although we strongly support the multiple barrier approach, we think that the 1000 year waste package requirement may be excessive. Studies published by the Electric Power Research Institute (EPRI) and confirmed by EPA indicate that in almost all situations improvements in canister life are less important for reducing long-term risks than improvements in waste form or careful selection of site characteristics. If the waste package lasted only a few hundred years, it would guard against uncertainties during the period of greatest heat generation; however, the 1000-year-life requirement for the waste package could necessitate the use of very expensive or exotic materials (such as titanium) for waste canisters. The supporting documentation for the rule does not consider the potential cost of this requirement. In light of the relatively small benefits and possible high cost, we believe the Commission should reexamine this requirement.

We do not understand why your proposed section 10 CFR 60.123 (b)(3) includes the caveat that resources are to be compared with others "that are representative of and located in the geologic setting". We suggest that the resources also be compared with resources in other areas in different geological settings.

The language regarding explosive, pyrophoric, and chemically reactive materials in Section 60.135(c)(1) seems too vague to be enforceable. We suggest that it be quantified through a "worst case" analysis as was done for free liquids [Section 60.135(c)(2)].

EPA is, as you know, developing standards for the disposal of high-level nuclear waste, and we hope to propose them early in 1982. Close coordination between the NRC and EPA will be necessary to ensure that our respective regulations are compatible, including definitions of such terms as "retrievability," "storage," "accessible environment," "barrier," and "disposal."

If you have any questions about our comments or if we can assist you any further, please call Mr. Dan Egan (557-8610) of EPA's Office of Radiation Programs or Dr. W. Alexander Williams (755-0790) of my staff.

Sincerely yours,

Paul C Cahill

Paul C. Cahill
Director
Office of Federal Activities

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STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

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November 5, 1981

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PR-60
(46 FR 35280)

Mr. Samuel J. Chilk
Secretary
Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Chilk:

Thank you for this opportunity to offer comments on the Nuclear Regulatory Commission's Proposed Rule 10 CFR Part 60, "Disposal of High-Level Radioactive Waste in Geologic Repositories.".

After consultation with our State Geologist in the Department of Environmental Protection, we offer the following comments regarding this proposed rule.

The Rule provides acceptable geologic standards for the disposal of high-level radioactive waste in geologic repositories. Though we believe the Rule to be generic in nature, it does address the major requirements and criteria for such a facility. It should be stressed however, that each specific site should be considered on the specifics of the location and any circumstances which are unique to the area, town or state.

We do have concerns that the Proposed Rule has not included any siting requirements which directly deal with population density or proximity to population centers. We believe this area should be considered in the overall siting requirement of a repository. In a state the size of Connecticut, population density would be a crucial factor in the siting of any facility for radioactive waste disposal. Our state made extensive comments regarding this issue to the Department of Energy on their study "Crystalline Intrusives in the United States and Regional Geologic Characteristics Important to Storage of Radioactive Waste." (copy attached)

Thank you for this opportunity to offer our views.

Sincerely,

William A. O'Neill
WILLIAM A. O'NEILL
Governor

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

March 3, 1981

Mr. J. O. Neff
Program Manager
National Waste Terminal Storage Program Office
United States Department of Energy
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Neff:

This letter is our state's long overdue response to the report "Crystalline Intrusives in the United States and Regional Geologic Characteristics Important for Storage of Radioactive Waste." We apologize for the delay in formulating this correspondence.

I have consulted with the various state agencies involved in radioactive waste disposal, with particular review by our State Geologist and Director of our Natural Resources Center of the Department of Environmental Protection.

Based on our evaluation, it seems clear that Connecticut is being considered as a site for further exploration only because we are located in the region which the study calls "Northern Appalachians". If the regional criteria used by the contracted Office of Nuclear Waste Isolation study were applied specifically to Connecticut, it would be concluded that our state is totally unsatisfactory for such a siting. It is our belief that while some regional exploration might prove worthwhile, serious investigations of Connecticut for a high-level waste disposal site would be a waste of professional time and public funds.

Connecticut's population density is such that siting would be nearly impossible. Our state currently has a population of 3 million people, living on 3,205,760 acres. Although not [illegible] evenly distributed, population centers do cover the entire state, leaving [illegible] a few, very small isolated areas of low density. These areas do [illegible] ide with the geographic distribution of those geologic units [illegible] preliminary consideration in the study. If the report had used th[illegible] criterion as the first screen, Connecticut could not have [illegible] considered.

studied for its surface water/ground water quality classification and standards. This program, which annunciates a state policy on existing and future water use is based on our knowledge of the ground water flow systems and their boundaries. Since so many of the residents throughout the state are dependent on ground water and since we have an adopted policy to encourage ground water development as a priority over other sources. we have taken a very strict and conservative position on waste disposal into these ground water systems. Not only are the conditions adverse relative to the report criteria, such an action would be in violation of adopted state policy. Again, the report rates the Northern Appalachians as unknown (0) for this criteria. We rate Connecticut as poor or unacceptable (1).

1.3.4. - Tectonic Stability and Erosion Rates

In this section, the report discusses such items as "away from tectonic boundaries" and "regional uplift and/or subsidence". The degree of generalization in the evaluation of this criteria is difficult to comprehend. Connecticut, containing only 5,009 miles, is severely segmented by major tectonic boundaries; including the taconics in the west and the Connecticut Basin in the central third of the state. Major faults and lineaments prevail throughout the state. Post-glacial isostatic rebounds can be documented and current sea-level changes are being monitored for 15 years along the coast. Under this criteria the report rates the Northern Appalachians as good (3). Our rating of Connecticut is poor (1) or fair (2) at best.

1.3.5. - Fault, Lineament and Joint Concentration

The criteria used in the report indicates that faults should not exist at the site and locations having high concentration of lineaments and joints are to be avoided. During the past three years, Connecticut has done considerable work in this area along with detailed geologic field mapping which supplies ample data that our state is a massive array of bedrock features and lineaments. The report rates the Northern Appalachians as fair (2) under this criteria. Our rating of Connecticut is very poor (1).

1.3.6. - Mineral and Energy Resources

The report suggests that the site should be unattractive as practical for future exploration and land development. Their evaluation is based on past and present mining activity. Connecticut's mining activity is currently limited to the pegmatites and trap rock in central Connecticut and the carbonates in the western portion of the state. At the present time,

The following analysis is the result of work done utilizing the criteria of the study by our Natural Resources Center. I stand by the expertise in this review and think it points out the major reasons why Connecticut is not a feasible choice for further study. Our analysis follows the format of the study.

1.3.1. - Depth, Thickness and Land Requirements

The criteria in the report calls for minimum depths of about 1400 feet and a minimum area of 40 square miles. The "crystalline" bodies (as defined in the report) in Connecticut are relatively small localized features. They include in the report "Triassic intrusives in the Connecticut Basin". These bodies are relatively thin, highly fractured, and have a shallow regional dip making them quite unsuitable. In cooperation with the Geologic Division of the U.S. Geological Survey, Connecticut has mapped the bedrock geology in the 100 quadrangles which cover the state, at a scale of one inch to 2,000 feet over the past 25 years. The "crystalline" rocks referred to in this report contain only small portions of these maps. None of them can be found in areas where as much as several square miles of land is available, let alone 40 square miles. The report rates the Northern Appalachians as good (3) for this criteria. Our analysis concludes that Connecticut is very poor (1) under this criteria.

1.3.2. - Mechanical, Thermal and Chemical Properties

The basic criteria relates to low permeability, porosity and water content and their near surface location for observation of these properties. Connecticut has a very high water table condition. Inland wetlands are nearly uniformly distributed across the state and make up 20-25% of the land surface. Documentation of this material is available from our inland wetland regulation program and the detailed soils mapping conducted by the U.S. Soil Conservation Service. Groundwater sources serve approximately 40% of our population throughout the state. Although there are occasions when rock wells have very low yields, in most cases, a second well nearby will produce the average of 3-5 gallons per minute for private residential needs. Finally, the detailed field mapping of all rocks in Connecticut would indicate that multiple tectonism throughout the geologic history of Connecticut has severely fractured these rocks. Under this criteria the report rates the Northern Appalachians as unknown (0). Our rating for Connecticut is poor (1).

1.3.3. - Hydrology

Ground water movement is considered as a vital evaluation of a site in this report. Through our cooperative program with the Water Resources Division of the U.S. Geological Survey, every basin in the state has been

Mr. J.C. Neff

March 3, 1981
Page 4

however, we do not rule out any area for future drilling exploration. The report rates the Northern Appalachians as good (3). Under this criteria, our rating is poor (1) or fair (2) at best.

1.3.10 - Flooding and Surface Hydrology

The report considers both reoccurring riverine and coastal flood-proneness as well as rise in sea level as the result of ice cap melting. Connecticut has three major riverine systems (Connecticut, Thames and Housatonic) which account for most of the 8400 miles of rivers and streams and 253 miles of coastline. For the size of the state, flooding problems are ubiquitous and frequent. However, when you also consider the concern for sea level rise up to 500 feet in the event of ice cap melting, Connecticut would be over 50% under water. The report rates the Northern Appalachians as fair (2). We rate Connecticut as very poor or unacceptable (1).

In conclusion, we believe that when the same criterion used in the report are applied to Connecticut alone, there is no rationale to continue considering Connecticut as a potential site for the storage of radioactive waste in crystalline intrusives. Population density, endangered species, natural areas and other environmental and land use factors have not been considered as criteria. Our state geologist, biologist and hydrologist stand ready to document their findings regarding the report.

Since our state has been actively involved in the work of the State Planning Council on Radioactive Waste Management, we have been following the development of waste disposal plans in the Department of Energy. Though additional briefings on the program might prove informative for our state officials, any serious consideration of Connecticut as a possible site would not be productive.

We hope this information and analysis is helpful to the Department as they continue their search for adequate long term and permanent storage for high-level radioactive waste.

Sincerely,

William A. O'Neill

WILLIAM A. O'NEILL
Governor

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON D C 20555

'81 NOV 16 P1:39

emp

WMHT 3106.1

NOV 13 1981

70

R-60
(46 FR 35280)

Mr. Norman K. Olson
State Geologist
S.C. Geological Survey
Columbia, S.C. 29210

Dear Mr. Olson:

We have received your November 4, 1981 comments on Subpart E of 10 CFR 60.

By copy of this letter, I am transmitting the comments to the Secretary of the Nuclear Regulatory Commission for docketing.

Your interest in the proposed rule is appreciated.

Very truly yours,

Robert J. Wright

Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management

cc: Secretary of the Nuclear Regulatory Commission, with Olson's memo to Wright dated 11/4/81 and Copy of Wright's letter to Olson dated 10/20/81

TO: Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

FROM: Norman K. Olson
State Geologist
S. C. Geological Survey
Columbia, S. C. 29210

DATE: November 4, 1981

Reference comments to Subpart E of 10 CFR Part 60, NRC Proposed Rule, Federal Register, vol. 46, no. 130, July 8, 1981.

Para 60.121, subpara (a), p. 35280

Some mention should be made concerning special legal considerations for State Water Rights in applicable states. This would show cognizance of a vital issue.

Para 60. 122, subpara (a) and (b), p. 35280

"Tectonic processes" in (a) should be considered adequate as covering "structural processes" in (b), thereby eliminating the need for subpara (b).

Para 60.122, subpara (a) through (e), p. 35280

For clarity, suggest changing "would not affect or would favorably affect" to "would n• affect or would not decrease."

Para 60.122, subpara (f), p. 35280

Suggest adding an additional ground-water characteristic. "(5) ground-water flow paths leading away from the geologic setting."

Para 60.122, subpara (i)

Suggest for geodetic accuracy changing "deemed to be the elevation of the lowest point" to "deemed to be the altitude above mean sea level of the lowest point."

Para 60.123, subpara (a) (5)

Last words, "that is less than the smallest dimension of the fault rupture surface" are somewhat confusing and too permissive. Compare with subpara (b)(8) which follows. Suggest rephrasing to avoid ambiguity.

OCT 20

Mr. Norman K. Olson
State Geologist
Harbison Forest Road
Columbia, South Carolina 29210

Dear Mr. Olson:

At the suggestion of Dr. William Hambleton, I am sending to you, and other members of the State Geologists Technical Review Group, a copy of my October 7 communication to Dr. William Fisher with attachments.

If you have any questions about this material, or wish to discuss it, please telephone me at (301) 427-4177.

Sincerely,

ORIGINAL SIGNED BY

Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management

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UNITED STATES
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WASHINGTON, D.C. 20555

'81 NOV 16 P1:39

WMHT 3106.1

NOV 13 1981

EMD

71

PROPOSED RULE PR-60
(46 FR 35280)

Dr. Thomas C. Gustavson
Project Director
West Texas Waste Isolation
Texas Bureau of Economic Geology
The University of Texas at Austin
University Station Box X
Austin, Texas 78712-7508

Dear Dr. Gustavson:

We have received your November 2, 1981 memorandum and comments on Subpart E of 10 CFR 60. By copy of this letter, I am transmitting the entire communication to the Secretary of the Nuclear Regulatory Commission for docketing.

Your interest in the proposed rule is appreciated.

Very truly yours,

Robert J. Wright

Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management

cc: Secretary of the Nuclear
Regulatory Commission, with
Gustavson's memo to Wright
dated 11/2/81 with/enclosure and
Wright's letter to Fisher dated 10/7/81

THE UNIVERSITY OF TEXAS AT AUSTIN
BUREAU OF ECONOMIC GEOLOGY
AUSTIN TEXAS 78712

University Station, Box X
Phone 512-471-1534
471-7721

November 2, 1981

MEMORANDUM

TO Dr. Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

FROM: Dr. Thomas C. Gustavson
Project Director, West Texas Waste Isolation
Texas Bureau of Economic Geology
The University of Texas at Austin
University Station Box X
Austin, Texas 78712-7508

Attached are review comments on the proposed rule 10CFR, part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories." These comments were prepared by our scientific staff actively involved in nuclear waste isolation investigations and are submitted in response to your request of October 7, 1981.

Our response includes specific comments and a review. A marked copy of the proposed rule is attached.

TCG:gp
Attachments

cc: W. L. Fisher
E. G. Wermund
L. F. Brown, Jr.
Wilton Holloway, Dir. TENRAC

4-23

The performance objectives and site criteria outlined in Subpart E-Technical Criteria are very generalized. Because it is generalized, it is highly inclusive and there are no pertinent issues that have not been mentioned. The proposed rule, however, is so nonspecific that the objectives and criteria of site-characterization work are not well-defined.

Phrases such as ". . . description and assessment of . . . ," ". . . characteristics of . . . ," "hydrogeologic properties of . . . ," ". . . analysis of . . . ," "potentially adverse conditions . . . ," etc. are so ill-defined that almost anything could be done and still satisfy the guidelines.

In addition to being ambiguous, some requirements for the site (geologic setting) are phrased in such general terms so as to probably eliminate all known geologic settings. For example, Section 60.123 (p. 35290) indicates that "evidence of dissolutioning of soluble rocks" in the disturbed zone may "compromise site suitability." It is clear that in most geologic settings, some dissolution, in addition to salt dissolution (sometimes followed by reprecipitation) is to be expected especially in carbonates. Is the presence of dissolution of these "soluble rocks" really to be an important screening criteria? If so, a great deal more work will have to be done to determine the magnitude of this process.

On page 88 (Concepts, 60.102, Area Adjacent to the Geologic Repository, Operations Area) the statement is made that - Within the geologic setting, particular attention must be given to the characteristics of the Host Rock as well as any rock units surrounding the host rock. On page 90 (Favorable Conditions, 60.122) the statement is that "the host rock should provide the following ground-water characteristics: (1) low ground-water content, (2) inhibition of ground-water movement in the host rock, (3) inhibition of ground-water flow between hydrologic units or along shafts, drifts, and boreholes, and (4) ground-water travel times under pre-waste emplacement conditions between the underground facility and the accessible environment that substantially exceeds 1,000 years." With the exception of number 4, the Technical Rule is nonspecific with respect to characteristics of the host rock. The Technical Rule should detail the properties that a host rock (and bounding units) should possess, for example: composition, texture, bedding characteristics, moisture content, impurities and inclusion, physical integrity. The characteristics of the host rock may inhibit flow between hydrogeologic units (see segment 3 above), but it will never inhibit flow or in any manner affect flow along shafts, drifts or boreholes.

The proposed rule contains vague and frequently unrealistic criteria pertaining to structural stability. For example:

SS 60.112

a) "The geologic setting shall have exhibited structural and tectonic stability . . ."; neither the geologic setting nor the phrase "structural and tectonic stability" are defined. Rigidly enforced, this would make both the Hanford Reservation and the Nevada test site unsuitable.

SS 60.122

". . . appropriate combination of these conditions . . ."; who is to determine what is and is not appropriate?

a) Reference is made to the rates of tectonic processes. This is essentially undeterminable for 99% of the regions under consideration.

(SS 60.122 - continued)

9) Similarly for structural processes.

SS 60.123

a) 4) Reference is made to the historical earthquake record. In the midcontinent, where seismicity is diffuse and the historical record is so short as to be statistically non-existent, this criteria is not valid.

5) Fault activity is not defined.

b) This criteria requires investigation to 500 m below the repository level, yet the drill holes necessary for these investigations compromise the repository integrity.

6) "Fault activity" is not defined.

8) This criteria requires dating of fractures, which are certain to be present. This is undeterminable in 99.99% of the cases.

The proposed rule contains vague and unrealistic criteria pertaining to hydrogeologic and geomorphic stability. For example:

SS 60.112

b) "The geologic setting shall have exhibited hydrogeologic, geochemical, and geomorphic stability since the start of the Quaternary Period." What constitutes hydrogeology, geochemical and/or geomorphic stability is not defined.

SS 60.122

a-e) "The nature and rates of tectonic, structural, hydrogeologic, geochemical and geomorphic processes that have occurred since the start of the Quaternary period are such that, when projected, they would not affect, or would favorably affect the ability of the geologic repository to isolate waste." To make this determination a period of time over which the rate projection is to be made must be provided. A specific time period is not provided in section 60.111 Performance Objective and so the requirements of section 60.122 (a-e) cannot be attained.

On p. 35283, column 2, paragraph 2, the statement is made that "The proposed technical criteria are written to direct site selection towards selection of sites of little resource value and for which there does not appear to be any attraction for future societies." This is probably the best approach to take to attempt to minimize human intrusion. Section 60.123 (b) (3), however, states that an adverse condition exists only when the disturbed zone has resources that have a greater value than the average value for other areas of similar size located in the geologic setting. The intent of these two statements is not parallel. The first statement says to avoid areas of potential resources. The second says only that one adverse condition exists if the disturbed area can be shown to contain substantial mineral resources.

SS 60.123

c) If the assessment of natural resources is limited only to a depth of 500 m below the repository, this will exclude recognition of most hydrocarbon resources in sedimentary basins. This excludes consideration of resources below 1500 m (5,000 ft) and most hydrocarbons are found at this depth or greater depths.

To conclude, the concepts and scope of the proposed rule are satisfactory, but the rule is vague and nonspecific in many areas. Because of the lack of specific or detailed requirements, the rule may not achieve its proposed objective, namely assurance that a waste repository does not become a safety and health hazard.

BEG
11/3/81

Wright

3103.4/RJW/10/05/81/0

- 1 -

OCT 07 1981

WMHT 3103

Dr. W. L. Fisher
Director, Bureau of Economic
  Geology
University Station, Box X
Austin, TX 78712

Dear Bill:

You may recall that in September, 1980 and again in May of this year, visits were made to the Bureau by myself and a technical group from the Nuclear Regulatory Commission. The visits were part of a review of the investigations in Texas being done by the Department of Energy in connection with a possible repository for high-level radioactive waste.

Since the last visit, further progress has been made by the Commission in formulating the regulations under which a repository would be licensed. I am writing to describe this activity.

The regulations will form part 60 of title 10 in the code of federal regulations (10 CFR 60). On February 25, 1981 subparts A, B, C and D of 10 CFR 60 were published in final form. These cover the licensing procedures. On July 8, 1981 subparts E, F, G and H were published as a proposed rule. These cover, among other things, the proposed geoscience criteria by which the suitability of a repository site would be determined.

Copies of both documents are enclosed, along with a technical rationale for subpart E.

I particularly wish to invite your attention to the proposed rule of July 8, which is open for written comments or suggestions by the public until November 5. You may find special interest in Subpart E-Technical Criteria. Here a number of geologic, hydrologic, geochemical and seismic requirements and conditions are presented.

It might also be noted that the Commission requests comments on certain topics in the proposed rule, as mentioned in the following portions of the text:

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3103.4/RJW/10/05/81/0

- 2 -

OCT 07 1981

Page No.	Column No.	Paragraph No.
35282	3	1 (incomplete)
35283	2	1
35284	3	2
35285	1	3
35289	2	Footnote 3

If there are any questions on this matter, please write or telephone me (301-427-4177).

The assistance of the Bureau in connection with the NRC visits to Texas is greatly appreciated.

Sincerely,

ORIGINAL SIGNED BY
Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
  Development Branch
Division of Waste Management

cc: Dr. Milton Holloway, Director
    Texas Energy & Natural Resources

Distribution
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A-247

NUCLEAR REGULATORY COMMISSION

10 CFR Part 60

Disposal of High-Level Radioactive Wastes in Geologic Repositories

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The NRC is publishing proposed amendments which specify technical criteria for disposal of high-level radioactive wastes (HLW) in geologic repositories. The proposed criteria address siting, design, and performance of a geologic repository, and the design and performance of the package which contains the waste within the geologic repository. Also included are criteria for monitoring and testing programs, performance confirmation, quality assurance, and personnel training and certification. The proposed criteria are necessary for the NRC to fulfill its statutory obligations concerning the licensing and regulating of facilities used for the receipt and storage of high-level radioactive waste.

DATE: Comments received after November 5, 1981 will be considered if it is practical to do so, but assurance of consideration cannot be given except for comments received on or before this date.

ADDRESSES: Written comments or suggestions on the proposed amendments should be sent to the Secretary of the Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. Copies of comments may be examined at the U.S. Nuclear Regulatory Commission Public Document Room, 1717 H Street NW., Washington, D.C. Comments may also be delivered to Room 1121, 1717 H Street NW., Washington, D.C., between 8:15 a.m. and 5:00 p.m.

FOR FURTHER INFORMATION CONTACT: Frank J. Arsenault, Director of the Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone (301) 427-4350.

SUPPLEMENTARY INFORMATION:

Background

On December 6, 1979 the Nuclear Regulatory Commission (Commission or NRC) published for comment proposed procedures for licensing geologic disposal of high-level radioactive wastes. The licensing procedures were published in final form on February 25, 1981 (46 FR 13971). On May 13, 1980 (45 FR 31393) the Commission published for comment an Advance Notice of Proposed Rulemaking (ANPR) concerning technical criteria for regulating disposal of high-level radioactive wastes (HLW) in geologic repositories. Included with the advance notice was a draft of the technical criteria under development by the staff. The public was asked to provide comment on several issues discussed in the advance notice and to reflect on the draft technical criteria in light of that discussion. The comments received were numerous and covered the full range of issues related to the technical criteria. The technical criteria being proposed here are the culmination of a number of drafts, and were developed in light of the comments received on the ANPR. It is the Commission's belief that the regulation proposed here is one which is both practical for licensing and that notice provides a flexible vehicle for accommodating comments in that it points out alternatives and calls for comment in a number of critical places. The Commission has prepared an analysis of the comments which explains the changes made from the ANPR, and intends to publish soon the comments and the analysis as a NUREG document. A draft of this NUREG has been placed in the Commission's Public Document Room for review. In addition, the staff has begun a program to develop guidance as to the methods that it regards as satisfactory for demonstrating compliance with the requirements of the proposed rule.

The technical criteria being set forth here as proposed rulemaking are a result of the Commission's further effort in regulating geologic disposal of HLW by the Department of Energy (DOE). The rationale for the performance objectives and the Environmental Impact Assessment supporting this rulemaking, are now being published separately and are available free of charge upon written request to Frank Arsenault at the above address. In developing these criteria we have not reconsidered DOE's programmatic choice of disposal technology resulting from its Generic Environmental Impact Statement, inasmuch as the Commission has expressly reserved until a later time possible consideration of matters within the scope of that generic statement (44 FR 70408). Accordingly, the technical criteria apply only to disposal in geologic repositories and do not address other possible or potential disposal methods. Similarly, as that DOE's current plans call for disposal at sufficient depth to be in the area termed the saturated zone, these criteria were developed for disposal in saturated media. Additional or alternative criteria may need to be developed for regulating disposal in the unsaturated or vadose zone.

Authority

Sections 202 (3) and (4) of the Energy Reorganization Act of 1974, as amended, provide the Commission with licensing and regulatory authority regarding DOE facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under the Atomic Energy Act and certain other long-term HLW storage facilities of DOE. Pursuant to that authority, the Commission is developing criteria appropriate to regulating geologic disposal of HLW by DOE. The requirements and criteria contained in this proposed rule are a result of that effort.

Relation to Generally Applicable Standards for Radiation in the Environment Established by the Environmental Protection Agency

The Environmental Protection Agency (EPA) has the authority and responsibility for setting generally applicable standards for radiation in the environment. It is the responsibility of the NRC to implement those standards in its licensing actions and ensure that public health and safety are protected. Although an EPA standard for disposal of HLW yet exists, these proposed technical criteria for regulating geologic disposal of HLW have been developed to be compatible with a generally applicable environmental standard. Specifically, the performance objectives and criteria speak to the functional elements of geologic disposal of HLW and the analyses required to give confidence that these functional elements will perform as intended.

Disruptive Processes and Events

The NRC's implementing regulations assume that licensing decisions will be based, in part, on the results of analysis of the consequences of processes and events which potentially could disrupt a repository. Thus, throughout the criteria are requirements that the design basis take into account processes and events with the potential to disrupt a geologic repository. If the process or event is anticipated, i.e., likely, then the design basis requires barriers which would not fail in a way that would result in the repository not meeting the performance objectives. Anticipated processes and events would include such items as waste/rock interactions that result from emplacement of the wastes or the gradual deterioration of borehole seals. If the process or event is unlikely, then the overall system must still limit the release of radionuclides consistent with the EPA standard as applied to such events. An example of an unlikely event would be reactivation of a fault within the geologic setting which had not exhibited movement since the start of the Quaternary Period. In general, both likely and unlikely processes and events are expected to be site and design specific and would be identified by DOE in its license application.

Multiple Barriers

The proposed technical criteria were developed not only with the understanding that EPA's generally applicable environmental standard would need to be implemented, at least in part, by performing calculations to predict performance, but also with the knowledge that some of these calculations would be complex and uncertain. Natural systems are difficult to characterize and any understanding of the site will have significant limitations and uncertainties. Those properties which pertain to isolation of HLW are difficult to measure and the measurements which are made will be subject to several sources of error and uncertainty. The physical and chemical processes which isolate the wastes are themselves varied and complex. Further, these processes are especially difficult to understand in the area close to the emplaced wastes because that area is physically and chemically disturbed by the heat generated by these wastes.

However, a geologic repository consists of engineered features as well as the natural geologic environment. Any evaluation of repository performance, therefore, will consider the waste form and other engineering features which are elemental to the performance of the repository as a system. By partitioning the engineered system into two major barriers, the waste package and the underground facility, and establishing performance objectives for each, the Commission has sought to exploit the ability to design the engineered features to meet specific performance objectives as a means of reducing some of the uncertainties in the calculation of overall repository performance.

In addition, the requirements for containment, controlled release rate, and 1,000-year groundwater transit time are three criteria which act independently of the overall repository performance to provide confidence that the wastes will be isolated at least for as long as they are most hazardous.

Containment and Isolation

During the first several hundred years following emplacement of the wastes, both the radiation from and the heat generated by the wastes are attributable mainly to the decay of the shorter-lived nuclides, primarily fission products. At about 1,000 years after emplacement both the radiation from and heat generated by decay of the wastes have diminished by about 3 orders of magnitude. As the decay of the longer-lived nuclides, primarily actinides, begins to dominate, both the radiation from and thermal output of the wastes continue to fall until almost 100,000 to 1,000,000 years after emplacement. By that time both have diminished by about 5 orders of magnitude and both heat and radiation become roughly constant due to the ingrowth of daughter nuclides, primarily Ra-226, Ra-229 and their decay products.

The technical criteria would require the engineered system to be designed so that the wastes are contained within the waste package for the first thousand years following emplacement. Following this period, containment is no longer assumed and the function of the waste package and underground facility is to control the release of radionuclides from the underground facility. By requiring containment during the period when the thermal conditions around the waste packages are most severe, evaluation of repository performance is greatly simplified to considerations of the degree of conservatism in the containment design relative to events and processes that might affect the performance during the containment period.

Although both the radiation from and heat generated by the decay of the wastes have diminished about 3 orders of magnitude during the containment period, the area surrounding the emplaced wastes will not return to temperatures near those before the wastes were emplaced until after about 10,000 years. As mentioned earlier, the thermal disturbance of the area near the emplaced wastes adds significantly to the uncertainties in the calculation of the transport of the radionuclides through the geologic environment. The technical criteria are intended to compensate for uncertainties by imposing further design requirements on the waste package and underground facility, thereby limiting the source term by controlling the release rate.

Role of the Site

The Commission neither intends nor expects either containment to be lost completely at 1,000 years following emplacement or the engineered system's contribution to the control of the release of wastes to cease abruptly at some later time. However, the Commission recognizes that at some point [illegible]

Retrievability

The licensing procedures of 10 CFR Part 60 were written assuming that there would be a program of testing and measurement of the thermal, mechanical, and chemical properties of the major engineered barriers to confirm their expected performance. The Commission would like to tie the requirement for retrievability of the wastes to the expected time needed to complete the performance confirmation program. However, at present it appears to the Commission that neither the specific nature nor the period needed for completion of the performance confirmation program will be certain until construction of the repository is substantially complete, that is, until the actual licensing to receive wastes at a geologic repository. Hence it is difficult at this time to use the performance confirmation program as a basis for establishing a period of retrievability. [illegible]

[illegible]

Human Intrusion

[illegible]

information transfer over time. There are numerous examples of knowledge, including complex information, being preserved for thousands of years. This has occurred even in the absence of printing and modern information transfer and storage systems. Furthermore, this information transfer has survived disruptive events, such as wars, cultural dispersion, and dramatic changes in the social and political fabric of societies. The combination of the historical record of information transfer, provisions for a well-marked and extensively documented site location, and the scale and technology of the operations needed to drill deeply enough to penetrate a geologic repository argue strongly that inadvertent intrusion as described above is highly improbable, at least for the first several hundred years during which time the wastes are most hazardous. Selecting a site for a repository which is unattractive with respect to both resource value and scientific interest further adds to the improbability of inadvertent human intrusion. It is also logical to assume that any future generation possessing the technical capability to locate and explore for resources at the depth of a repository would also possess the capability to assess the nature of the material discovered, to mitigate consequences of the breach and to reestablish administrative control over the area if needed. Finally, it is unreasonable to assume the scientific and technical capability to identify and explore an anomalous heat source several hundred meters beneath the Earth's surface and not assume that those exploring would have some idea of either what might be the cause of the anomaly or what steps to take to mitigate any untoward consequences of that exploration.

The above arguments do not apply to the case of deliberate intrusion. The repository itself could be attractive and invite intrusion simply because of the resource potential of the wastes themselves. Intrusion to recover the wastes demands (1) knowledge of the existence and nature of the repository, and (2) effort of the same magnitude as that undertaken to emplace the wastes. Human intrusion of this sort can only be the result of a conscious, collective societal decision to recover the wastes.

Intrusion for the purpose of sabotage or terrorism has also been mentioned as a possibility. However, due to the nature of geologic disposal, there seems to be very little possibility that terrorists or saboteurs could breach a repository. Breach of the repository would require extensive use of machinery for drilling and excavating over a considerable period of time. It is highly improbable that a terrorist group could accomplish this covertly.

In light of the above, the Commission adopted the position that [illegible] that everything that is reasonable be done to discourage people from intruding into the repository. Thus, the proposed technical criteria are written to direct site selection towards selection of areas of little resource value and for which there does not appear to be any attraction for future intrusion. Further the proposed criteria would require reliable documentation of the existence and location of the repository and the nature of the wastes emplaced therein, including marking the site with the most permanent markers practical. However, once the site is selected, marked, and documented, it does no one [illegible] to argue over whether these measures will be adequate in the future, or to speculate on the virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard. Of course, the Commission recognizes that there are alternative approaches to the Human Intrusion question. Accordingly, comment on this and alternative approaches is welcome.

Relation to Other Parts of NRC Regulations

The proposed rule contemplates that DOE activities at a geologic repository operations area may be appropriate cases to be licensed under other parts of NRC regulations and would then not be governed by these technical criteria. We note, in this connection, that the scope section of the procedural rule specifically provides that Part 60 shall not apply to any activity licensed under another part. This allows an independent spent fuel storage installation to be licensed under Part 72, even though located at a geologic repository operations area (provided, of course, it is sufficiently separate to be classified as "independent"). Other DOE activities of the geologic repository operations area could be licensed under Parts 30 or 70 if an exemption from Part 60 is determined to be appropriate.

Alternative Approach

In the course of the Commission's deliberations, it became evident that in order to have confidence in the ability of a geological repository to contain and isolate the wastes for an extended period of time, the repository must consist of multiple barriers. In view of the uncertainties that attach to reliance on the geologic setting alone, the Commission believes that a repository should consist of two major engineered barriers: waste packages and underground facility, in addition to the natural barrier provided by the geologic setting. The Commission [illegible] emphasizing these elements to take advantage of the [illegible] greater confidence [illegible] were. Having reached these conclusions the Commission considered next whether or not and to what extent detail the performance criteria for a geological repository should be prescribed. In this regard, the Commission considers the following alternatives:[1]

1. Prescribe a single overall performance standard that must be met. The standard in this case would be the EPA standard;

2. Prescribe minimum performance standards for each of the major elements, in addition to requiring the overall system to meet the EPA standards; and

3. Prescribe detailed numerical criteria on critical engineering attributes of the repository system.

Alternative 3 is considered overly restrictive on the design flexibility and judged to be inappropriate at this stage of technological development. Therefore, this alternative is quickly eliminated as a viable regulatory approach.

Alternative 1 has as its principal advantage the fact that it provides maximum flexibility in apportioning credit [illegible] the several elements of the repository. It also allows the designer to incorporate and apply new technological developments and knowledge from the site characterization phase to the repository design. Notwithstanding some concern over its practicality as a regulatory framework, the Commission cannot at this time eliminate it from further consideration. The Commission is, therefore, specifically requesting the general public, particularly those from the technical communities, to comment on this point. In addition, the Commission requests commentors espousing this alternative to address specifically ways in which the Commission might find reasonable assurance that the ultimate standards

[1] Detailed discussion on the advantages and disadvantages of each of these alternatives are given in Appendix [illegible] to Commission Paper SECY-[illegible], April [illegible], 1981, "Rationale for Performance Objectives and Required Characteristics of the Geologic System." [illegible] Commission's Public Document Room, 1717 H St. NW, Washington, D.C. [illegible]

[illegible]

4. *Design and Construction.* In addition to the requirements on designing for natural phenomena, criticality control, radiation protection, and effluent control, the proposed technical criteria require the design of the repository to accommodate potential retrieval of the wastes, the underground facility, and the site. Requirements are also placed upon the design of the equipment to be used for handling the wastes, the performance and purpose of the backfill material, and design and performance of borehole and shaft seals. Further, there are requirements related to the methods of construction. The Commission believes such requirements are necessary to ensure that the ability of the repository to contain and isolate the wastes will not be compromised by the construction of the repository.

The proposed technical criteria would require that the subsurface facility be designed so that it could be constructed and operated in accordance with relevant Federal mining regulations, which specify design requirements for certain items of electrical and mechanical equipment and govern the use of explosives.

These criteria are a blend of general and detailed prescriptive requirements. They have been developed from Commission experience and practice in the licensing of other nuclear facilities such as power plants and fuel cycle facilities. While there are differences in the systems and components addressed by these criteria from those of power plants or fuel cycle facilities, and the criteria have been written to be appropriate for a geologic repository, the proposed criteria represent a common practice based on experience which has shown that the above items need to be regulated. The level of detail of these criteria reflects the Commission's current thinking on how to regulate effectively geologic disposal of HLW. However, the Commission continues to examine other possibilities for promulgating the more detailed of these requirements. Comments are invited on [illegible] for the design and construction criteria in the rule, perhaps in a more concise form; these may be supplemented, of course, with more details in staff guidance documents such as Regulatory Guides.

5. *Waste Package.* The proposed requirements for the design of the waste package emphasize its role as a key component of the overall engineered system. Besides being required to contribute to the engineered system's meeting containment and controlled release performance objectives, both compatibility with the underground facility and the site and a method of unique identification are required of the waste package. Included in the section of the proposed technical criteria which deals with the waste package are requirements that the waste form itself [illegible] within the package be consolidated and noncombustible.

6. *Performance Confirmation.* The proposed technical criteria include requirements for a program of testing and measurement (Subpart F). The main purpose of this program is to confirm the assumptions, data, and analyses which led to the findings that permitted construction of the repository and subsequent emplacement of the wastes. Further, the performance confirmation program includes requirements for monitoring of key geologic and hydrologic parameters throughout site characterization, construction, and emplacement to detect any significant changes in the conditions which supported the above findings during, or due to operations at the site. Also included in the program would be tests of the effectiveness of borehole and shaft seals and of backfill placement procedures.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Commission hereby certifies that this rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. This proposed rule affects only the Department of Energy, and does not fall within the purview of the Act.

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, the National Environmental Policy Act of 1969, as amended, and sections 552 and 553 of title 5 of the United States Code, notice is hereby given that adoption of the following amendments to Title 10, Chapter I, Code of Federal Regulations is contemplated.

PART 60—DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

1. The authority citation for Part 60 reads as follows:

Authority: Secs. [illegible], U.S.C. [illegible]; Pub. L. [illegible]

2. Section 60.2 is revised to read as follows:

§ 60.2 Definitions.

For the purposes of this Part—

"Accessible Environment" means those portions of the environment directly in contact with or readily available for use by human beings.

"Anticipated Processes and Events" means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Candidate area" means a geologic and hydrologic system within which a geologic repository may be located.

"Commencement of construction" means clearing of land, surface or subsurface excavation, or other substantial action that would adversely affect the environment of a site, but does not include changes desirable for the temporary use of the land for public recreational uses, site characterization activities, other preconstruction monitoring and investigation necessary to establish background information related to the suitability of a site or to the protection of environmental values, or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Decommissioning" or "permanent closure" means final backfilling of subsurface facilities, sealing of shafts, and decontamination and dismantlement of surface facilities.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the biosphere.

"Disturbed zone" means that portion of the geologic setting that is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered system" means the waste packages and the underground facility.

"Far field" means the portion of the geologic setting that lies beyond the disturbed zone.

[illegible]

"Waste package" means the [illegible] sealed [illegible] the waste form and any [illegible] including shielding [illegible] and overpacks.

3. Section [illegible] is revised to read as follows:

§ [illegible]

(a) Prior to [illegible] of an application for a license to be issued under this part the DOE shall conduct a program of site characterization with respect to the site to be described in such application.

(b) Unless the Commission [illegible] with respect to the site described in the [illegible]

[illegible]

(c) The Safety Analysis Report shall include

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect [illegible] design and performance. The description of the site shall identify the [illegible] of the [illegible] with respect to the [illegible] of the geologic repository operations area.

(i) The description of the site shall also include the following information regarding subsurface conditions [illegible] vicinity of the proposed underground facility—

(A) The orientation, distribution, [illegible]

[illegible]

[illegible] changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

* * * * *

5. Paragraph [illegible] of § [illegible] is revised to read as follows:

§ [illegible] Construction authorization.

* * * * *

(a) * * *

(2) The site and design comply with the criteria contained in Subpart E.

* * * * *

6. Paragraph [illegible] of § [illegible] is revised to read as follows:

§ [illegible] License amendment to decommission.

(a) * * *

(2) a detailed description of the measures to be employed—such as land use controls, construction of [illegible]

[illegible] of the waste in the archives of local and Federal government agencies, and archives elsewhere in the world, that would be likely to be consulted by potential human intruders.

* * * * *

7. New Subpart E, "Technical Criteria," Subpart F "Performance Confirmation," Subpart G, "Quality Assurance" and Subpart H, "Training and Certification of Personnel" are added to 10 CFR Part 60.

Subpart E—Technical Criteria

Sec.

[illegible] Purpose and nature of findings.

[illegible] Concepts.

Performance Objectives

[illegible] Performance objectives.

[illegible] Required characteristics of the geologic setting.

Ownership and Control of the Geologic Repository Operations Area

Sec.
60.121 Requirements for ownership and control [illegible]
[illegible]

[illegible]

§ 60.102 Concepts.

[illegible]

(d) Stages in the licensing process. [illegible]

[illegible]

(e) Containment. Early during the repository life when radiation and thermal levels are high and the uncertainties of events are especially difficult to predict rigorously, [illegible] is placed upon the ability to contain the wastes by waste packages within an engineered system. This is known as the containment period. The engineered system includes the waste packages as well as the underground facility. A waste package includes:

(1) The waste form which consists of the radioactive waste materials and any associated encapsulating or stabilizing materials.

(2) The container which is the first major sealed enclosure that holds the waste form.

(3) Overpacks which consist of any buffer material, receptacle, wrapper, box or other structure, that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

(f) Isolation. Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. Isolation means the act of inhibiting the transport of radioactive material to the accessible environment in amounts and concentrations within limits. The accessible environment means those portions of the environment directly in contact with or readily available for use by human beings.

Performance Objectives

§ 60.111 Performance objectives.

(a) Performance of the geologic repository operations area through permanent closure—(1) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and any generally applicable environmental standards established by the Environmental Protection Agency.

(2) Retrievability of waste. The geologic repository operations area shall be designed so that the entire inventory of waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are complete. A reasonable schedule for retrieval is one that requires no longer than about the same overall period of time than was devoted to the construction of the geologic repository operations area and the emplacement of wastes.

(b) Performance of the geologic repository after permanent closure—(1) Overall system performance. The geologic setting shall be selected and the subsurface facility designed so as to assure that releases of radioactive materials from the geologic repository following permanent closure conform to such generally applicable environmental radiation protection standards as may have been established by the Environmental Protection Agency.

(2) Performance of the engineered system.—(i) Containment of wastes.* The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. The requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW.

(ii) Control of releases.* (A) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the total annual curie release as prescribed by this paragraph.

(B) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.

(3) Performance of the geologic setting.—(i) Containment period. During the containment period, the geologic setting shall mitigate the impacts of premature failure of the engineered system. The ability of the geologic setting to isolate wastes during the containment period, in accordance with paragraph (b)(3)(ii) of this section, shall be deemed to satisfy this requirement.

(ii) Isolation period. Following the containment period, the geologic setting, in conjunction with the engineered system as long as that system is expected to function, and alone thereafter, shall be capable of isolating radioactive waste so that transport of radionuclides to the accessible environment shall be in amounts and concentrations that conform to such generally applicable environmental standards as may have been established by the Environmental Protection Agency. For the purpose of this paragraph, the evaluation of the site shall be based upon the assumption that those processes operating on the site are those which have been operating on it during the Quaternary Period, with perturbations caused by the presence of emplaced radioactive wastes superimposed thereon.

§ 60.112 Required characteristics of the geologic setting.

(a) The geologic setting shall have exhibited structural and tectonic stability since the start of the Quaternary Period.

(b) The geologic setting shall have exhibited hydrogeologic, geochemical, and geomorphic stability since the start of the Quaternary Period.

(c) The geologic repository shall be located so that pre-waste-emplacement groundwater travel times through the far field to the accessible environment are at least 1,000 years.

Ownership and Control of the Geologic Repository Operations Area

§ 60.121 Requirements for ownership and control of the geologic repository operations area.

(a) Ownership of the geologic repository operations area. The geologic repository operations area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use. These lands shall be held free and clear of all encumbrances, if

*The Commission specifically [illegible]

Additional Requirements for the Geologic Setting

§ 60.122 Favorable conditions.

§ 60.123 Potentially adverse conditions.

§ 60.124 Assessment of potentially adverse conditions.

Design and Construction Requirements

§ 60.130 General design requirements for the geologic repository operations area.

protection of personnel during an emergency.

(e) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(f) Safety services.

(1) Each safety service system shall be designed so that essential safety functions can be performed under both normal and emergency conditions.

(2) The safety services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(3) The emergency utility services shall be designed to permit testing of their functional operability and capacity. This will include the full operational sequence of each system when transferring between normal and emergency supply sources, as well as the operation of associated safety systems.

[illegible]

(1) Each module shall be designed to permit isolation from other modules if an accident occurs.

(k) Design for retrieval of waste. The underground facility shall be designed to—

(1) Permit retrieval of waste in accordance with the performance objectives (§ 60.111).

(2) Ensure sufficient structural stability of openings and control of groundwater to permit the safe conduct of waste retrieval operations, and

(3) Allow retrieval of any waste packages that may be damaged or require inspection without compromising the ability of the geologic repository to meet the performance objectives (§ 60.111).

(e) Design of subsurface openings.

(1) Subsurface openings shall be designed to maintain stability throughout the construction and operation periods. If structural support is required for stability, it shall be designed to be compatible with long-term deformation, hydrologic, geochemical, and thermomechanical characteristics of the rock and to allow subsequent placement of backfill.

[illegible]

intrusion, or gas inflow into the underground facility.

(2) Water and gas control systems shall be designed to control the quantity of water or gas flowing into or from the underground facility, monitor the composition of gases, and permit sampling of liquids.

(3) Systems shall be designed to provide control of water and gas in both waste emplacement areas and excavation areas.

(4) Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained.

(5) If the intersection of aquifers or water bearing geologic structures is anticipated during construction, the design of the underground facility shall include plans for cutoff or control of water in advance of the excavation.

(6) If linings are required, the contact between the lining and the rock surrounding subsurface excavations shall be designed so as to avoid the creation of any preferential pathway for groundwater or radionuclide migration.

[illegible]

(i) Backfill placed in the underground facility shall serve the following functions:

(A) It shall provide a barrier to groundwater movement into and from the underground facility.

(B) It shall reduce creep deformation of the host rock that may adversely affect (1) waste package performance or (2) the local hydrogeological system.

(C) It shall reduce and control groundwater movement within the underground facility.

(D) It shall retard radionuclide migration.

(ii) Backfill placed in the underground facility shall be selected to allow for adequate placement and compaction in underground openings.

(j) Waste handling and emplacement.

(1) The systems used for handling, transporting, and emplacing radioactive wastes shall be designed to have positive, fail-safe design, to protect workers and to prevent damage to waste packages.

(2) The handling systems for emplacement and retrieval operations shall be designed to minimize the potential for operator error.

(k) Design for thermal loads.

(1) The underground facility shall be designed so that the predicted thermal and thermomechanical response of the rock will not degrade significantly the performance of the repository or the ability of the natural or engineered barriers to retard radionuclide migration.

(2) The design of waste loading and waste spacings shall take into consideration—

(i) Effects of the design of the underground facility on the thermal and thermomechanical response of the host rock and the groundwater system;

(ii) Features of the host rock and geologic setting that affect the thermomechanical response of the underground facility and barriers, including but not limited to, behavior and deformational characteristics of the host rock, the presence of insulating layers, aquifers, faults, orientation of bedding planes, and the presence of discontinuities in the host rock; and

(iii) The extent to which fracturing of the host rock is influenced by cycles of temperature increase and decrease.

§ 60.133 Design of shafts and seals for shafts and boreholes.

(a) Shaft design. Shafts shall be designed so as not to create a preferential pathway for migration of groundwater and so as not to increase the potential for migration through existing pathways.

[illegible]

(b) Shaft and borehole seals. Shaft and borehole seals shall be designed so that: [illegible]

(1) Shafts and boreholes will be sealed as soon as possible after they have served their operational purpose. [illegible]

(2) [illegible]

(3) [illegible]

(4) [illegible]

(c) Shaft conveyances used in radioactive waste handling.

(1) Shaft conveyances used to transport radioactive materials shall be designed to satisfy the requirements set forth in § 60.130 for systems, structures, and components important to safety.

(2) Hoists important to safety shall be designed to preclude cage free fall.

(3) Hoists important to safety shall be designed with a reliable cage location system.

(4) Hoist loading and unloading systems shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(5) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place, grappled, and ready for transfer.

§ 60.134 Construction specifications for surface and subsurface facilities.

(a) General requirements. Specifications for construction shall conform to the objectives and technical requirements of §§ 60.130 through 60.133.

(b) Construction management program. The construction specifications shall facilitate the conduct of a construction management program that will ensure that construction activities do not adversely affect the suitability of the site to ensure the waste or jeopardize the isolation capabilities of the underground facility, boreholes, shafts and seals, and that the underground facility is constructed as designed.

(c) Construction records. The construction specifications shall include requirements for the development of a complete documented history of repository construction. This documented history shall include at least the following—

(1) Surveys of underground excavations and shafts located via [illegible] also surface features or monuments.

(2) Materials encountered.

(3) Geologic maps and geologic cross sections.

(4) Locations and amount of seepage.

(5) Details of equipment, methods, progress, and sequence of work.

(6) Construction problems.

(7) Anomalous conditions encountered.

(8) Instrument locations, readings, and analysis.

(9) Locations and description of structural support systems.

(10) Locations and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

(d) Rock excavation. The methods used for excavation shall be selected to reduce to the extent practicable the potential to create a preferential pathway for groundwater or radioactive waste migration or increase migration through existing pathways.

(e) Control of explosives. If explosives are used, the provisions of 30 CFR 57.6 (Explosives) issued by the Mine Safety and Health Administration, Department of Labor, shall be met, as minimum safety requirements for storage, use and transport of the geologic repository operations area.

(f) Water control. The construction specifications shall provide that water encountered in excavations shall be removed to the surface and recorded in accordance with design requirements for radiation control and monitoring [§ 60.131(e)].

(g) Waste handling and emplacement. The construction specifications shall provide for demonstration of the effectiveness of handling equipment and systems for emplacement and retrieval operations, under operating conditions.

Waste Package Requirements

§ 60.135 Requirements for the waste package and its components.

(a) General requirements of design. The design of the waste package shall include the following criteria:

(1) Effect of the site on the waste package. The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(2) Effect of the waste package on the underground facility and the natural barriers of the geologic setting. The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the performance of the underground facility or the geologic setting. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) Waste form requirements. Radioactive waste that is emplaced in the underground facility shall meet the following requirements:

(1) Solidification. All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) Consolidation. Particulate waste forms shall have been consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) Combustibles. All combustible radioactive wastes must have been reduced to a noncombustible form unless it can be demonstrated that a fire involving a single package will neither compromise the integrity of other packages, nor adversely affect any safety-related structures, systems or components.

(c) Waste package requirements. The waste package design shall meet the following requirements:

(1) Explosive, pyrophoric, and chemically reactive materials. The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials that could interfere with operations at the underground facility or compromise the ability of the geologic repository to satisfy the performance objectives.

(2) Free liquids. The waste package shall not contain free liquids in an amount that could affect the structural integrity of waste package components because of chemical interactions or formation of pressurized vapor or result in leakage and spread of contamination in the event of package perforation.

(3) Handling. Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) Unique identification. A label or other means of identification shall be provided for each package. The identification shall not impair the integrity of the package and shall be applied in such a way that the information shall be legible at least to the end of the retrievable storage period. Each package identification shall be consistent with the package's permanent written records.

Performance Confirmation Requirements

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

Subpart F—Performance Confirmation

§ 60.140 General requirements.

(a) The performance confirmation program shall ascertain whether—

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program will include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The confirmation program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the repository for monitoring the condition of the waste packages. Packages chosen for the program shall be representative of those to be emplaced in the repository.

(b) Consistent with safe operation of the repository, the environment of the waste packages selected for the waste package monitoring program shall be representative of the emplaced wastes.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

Subpart G—Quality Assurance

§ 60.150 Scope.

(a) As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the repository and its subsystems or components will perform satisfactorily in service.

(b) Quality assurance is a multidisciplinary system of management controls which address safety, reliability, maintainability, performance and other technical disciplines.

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety and to activities which would prevent or mitigate events that could cause an undue risk to the health and safety of the public. These activities include: exploring, site selecting, designing, fabricating, purchasing, handling, shipping, storing, cleaning, erecting, installing, emplacing, inspecting, testing [illegible]

[illegible]

Subpart [illegible]—Training and Certification of Personnel

[illegible]

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Department of Energy
Washington, D.C. 20545

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BRANCH

Mr. & Mrs. Don W. Willoughby
1340 Presley Lane
Shingle Springs, California 95682

Dear Mr. & Mrs. Willoughby:

We are pleased to respond to your October 26, 1981 letter concerning the disposal of radioactive waste. The comments made in your letter are evidentally intended for consideration in the development of related Federal rules and regulations.

The Nuclear Regulatory Commission—not the Department of Energy—is the Federal Agency that is now developing such rules. In the enclosed copy of a Federal Register Notice you will note that the Nuclear Regulatory Commission has announced that it is accepting comments on its requirements for licensing the land disposal of radioactive waste and related matters. In view of that development, we are, by copy of this letter, forwarding your letter to the Nuclear Regulatory Commission for consideration.

We appreciate your interest in this matter.

Sincerely,

Carl J. Wahlquist

Earl J. Wahlquist, Acting Director
Office of Resource Management
and Planning
Nuclear Waste Management
and Fuel Cycle Programs
Office of Nuclear Energy

Enclosure

cc: U.S. Nuclear Regulatory Commission,
w/incoming

11/9/81 emp

October 26, 1981

Mullaney

Office of Nuclear Waste Management
U.S. Department of Energy
1000 Independence Avenue
Washington, D.C. 20585

Ladies and Gentlemen:

We understand that you are accepting comments from the public on the proposed rule regarding nuclear waste.

We would like to see the most stringent guidelines imposed on the nuclear power industry as to waste disposal.

We believe your proposal to require nuclear waste to be stored in canisters that should last for at least 1,000 years; the canisters buried in solid, stable and groundwater free rock formations; and the ability to remove the canisters for up to 50 years after storage, is the bare minimum that should be adopted.

In addition, we would like to see the nuclear power industry carry the full cost of its waste disposal.

No amount of regulation regarding safety and health in respect to waste disposal can be too strict as far as we are concerned.

For the sake of our world and all our children's future, please adopt the most safety and health conscious rules possible.

Sincerely yours,

Donald Willoughby, Mary C. Willoughby

Mr. and Mrs. Dc. W. Willoughby
1380 Presley Lane
Shingle Springs, CA 95682

Department of Energy
Washington, D.C. 20545

'81 NOV -6 P1:47

enp

73

PR-60
(46FR 35280)

Mr. & Mrs. Manuel F. Vega
4712 Amber Lane
Sacramento, California 95841

Dear Mr. & Mrs. Vega:

We are pleased to respond to your October 26, 1981 letter concerning the disposal of radioactive waste. The comments made in your letter are evidentally intended for consideration in the development of related Federal rules and regulations.

The Nuclear Regulatory Commission—not the Department of Energy—is the Federal Agency that is now developing such rules. In the enclosed copy of a Federal Register Notice you will note that the Nuclear Regulatory Commission has announced that it is accepting comments on its requirements for licensing the land disposal of radioactive waste and related matters. In view of that development, we are, by copy of this letter, forwarding your letter to the Nuclear Regulatory Commission for consideration.

We appreciate your interest in this matter.

Sincerely,

Earl H. Wahlquist

Earl J. Wahlquist, Acting Director
Office of Resource Management
and Planning
Nuclear Waste Management
and Fuel Cycle Programs
Office of Nuclear Energy

Enclosure

cc: U.S. Nuclear Regulatory Commission,
w/incoming

11/5/81

A-212

October 26, 1981

Mullaney

Office of Nuclear Waste Management
U.S. Department of Energy
1000 Independence Avenue
Washington, D.C. 20585

Ladies and Gentlemen:

We understand that you are accepting comments from the public on the proposed rule regarding nuclear waste.

We would like to see the most stringent guidelines imposed on the nuclear power industry as to waste disposal.

We believe your proposal to require nuclear waste to be stored in canisters that should last for at least 1,000 years; the canisters buried in solid, stable and groundwater free rock formations; and the ability to remove the canisters for up to 50 years after storage, is the bare minimum that should be adopted.

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For the sake of our world and all our children's future, please adopt the most safety and health conscious rules possible.

Sincerely yours,

Manuel F. Vega / [illegible]

Mr. and Mrs. Manuel F. Vega
4712 Amber Lane
Sacramento, CA 95841

Department of Energy
Washington, D.C. 20545

'81 [illegible] 10 P2:56

Mr. & Mrs. [illegible]. Johnson
2733 36th Street
Sacramento, California 95816

-60 74
(46 FR 35280)

Dear Mr. & Mrs. Johnson:

We are pleased to respond to your October 26, 1981 letter concerning the disposal of radioactive waste. The comments made in your letter are evidentally intended for consideration in the development of related Federal rules and regulations.

The Nuclear Regulatory Commission—not the Department of Energy—is the Federal Agency that is now developing such rules. In the enclosed copy of a Federal Register Notice you will note that the Nuclear Regulatory Commission has announced that it is accepting comments on its requirements for licensing the land disposal of radioactive waste and related matters. In view of that development, we are, by copy of this letter, forwarding your letter to the Nuclear Regulatory Commission for consideration.

We appreciate your interest in this matter.

Sincerely,

Earl J. Wahlquist

Earl J. Wahlquist, Acting Director
Office of Resource Management
and Planning
Nuclear Waste Management
and Fuel Cycle Programs
Office of Nuclear Energy

Enclosure

cc: U.S. Nuclear Regulatory Commission,
w/incoming

11/16/81 emp

October 26, 1981

Office of Nuclear Waste Management
U.S. Department of Energy
1000 Independence Avenue
Washington, D.C. 20585

Ladies and Gentlemen:

We understand that you are accepting comments from the public on the proposed rule regarding nuclear waste.

We would like to see the most stringent guidelines imposed on the nuclear power industry as to waste disposal.

We believe your proposal to require nuclear waste to be stored in canisters that should last for at least 1,000 years; the canisters buried in solid, stable and groundwater free rock formations; and the ability to remove the canisters for up to 50 years after storage, is the bare minimum that should be adopted.

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For the sake of our world and all our children's future, please adopt the most safety and health conscious rules possible.

Sincerely yours,

Mr. & Mrs. John M. Johnson

Mr. and Mrs. J. Johnson
2255 38th Street
Sacramento, CA 95816

5728

Proposed Rules

HAMILTON
& ASSOCIATES, INC

'81 NOV 18 P1:00

November 16, 1981

(75)

PR-60
(46 FR 35280)

The Secretary
Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch

Dear Sir:

The enclosed comments on your proposed technical criteria for disposal of high-level radioactive wastes in geologic repositories under 10 CFR Part 60 is submitted on behalf of the Ad Hoc Subcommittee on Nuclear Waste Management of the Government Liaison Committee of The American Ceramic Society.

We would be pleased to expand on any of these comments in writing or in personal discussion with members of your staff. Please let us know if you desire follow-up.

Sincerely,

Betsy Houston

Betsy Houston
Washington Representative,
The American Ceramic Society

American Ceramic Society

Government Liaison Committee

Ad Hoc Committee on Nuclear Waste Management

Statement Submitted to
The Nuclear Regulatory Commission

Comment on
10 CFR Part 60

Disposal of High-Level Radioactive Wastes in
Geological Repositories

Introduction

The American Ceramic Society is an organization of engineers, scientists, and educators who are involved in researching, developing and utilizing ceramic materials for the benefit of mankind. Many members of the Nuclear Division of the Society are actively involved in the areas of nuclear fuel preparation and behavior in reactors, and in developing and evaluating materials for waste disposal. The society has sponsored sections on nuclear waste materials to each of its annual meetings since 1974. It conducted a major symposium in 1979 on, "Ceramics in Nuclear Waste Management."

Members of the ad hoc committee on nuclear waste management have had long-term experience with nuclear waste materials and are dedicated to the problem of nuclear waste disposal in a safe and cost-effective manner. The comments contained herein represent those of the ad hoc committee and have not been endorsed or reviewed by the Society as a whole.

Comments

We wish to commend the Nuclear Regulatory Commission for developing and publishing a proposed rule for nuclear waste disposal. The rule provides guidelines to those involved in waste management so that they may focus their attention and development on specific areas. This rule allows acceptability to be defined and establishes limits on the continually increasing need for "better" performance. The rule is comprehensive in that it addresses all major technical areas.

There are, however, some specific values and requirements which we feel should be modified.

First, the use of a 1000 year requirement for the barrier lifetime. One-thousand-years does not appear to correlate to any significant change in the waste toxicity or other characteristic. There is, however, a major decrease in toxicity as Cs^{137} and Sr^{90} decay in the waste. This is in the 300-500 year time frame and a limit of 500 years would appear to be adequate and more technically defensible. Engineering designs will be conservatively based and may well use a 1000 year basis to meet a 500 year requirement. The requirement for 1000 year containment will greatly increase the cost and complexity of the engineered system.

Multiple barriers provide increased assurance that wastes will be contained during their high toxicity period. There are at least four barriers during this period...the waste form, the engineered package, the hydrology and the geology. This redundancy is more than needed. Most analysis that we have seen have indicated that two barriers are sufficient for considerations other than for a well drilled into the repository. The question then becomes, "how much are we willing to pay in order to reduce a low probability but high risk incident for a few individual(s)?" Since waste packages can be expected to cost $10 to $100K each; and there are about 14 packages (PNL-3838) per reactor per year; and a repository will hold about 4000 reactor years of waste (NUREG-0116); the cost per repository would then be about $0.5 to $5 billion. We feel that this sum of money could be better spent to save many more lives in other areas of society, such as automobile safety. Such trade-offs between cost and safety do not appear to have been sufficiently considered in formulating the regulations.

A requirement of the engineered facility to have a release rate of no greater than one part to 10^5 may have some merit. However, it is not clear, from what we have read (e.g., PNL-3356) that there is a significant difference in risk with low release rate packages to justify the requirement. It will also be technically difficult to demonstrate that after 1000 years of storage a waste package will have the desired behavior.

It also seems technically inappropriate to require that the waste packages have increased durability with time. The increasing durability with time results from the requirement that the release be 10^{-5}/year based on the presence of the isotopes at that time. It would be much easier to demonstrate that the release was 10^{-5}/year based on the amount present at 1000 years (or 500 years). This would allow durability to decrease with radioactivity and provide a constant risk, rather than a declining risk.

The requirement of retrievability of the waste for long periods [60-111 (e) (2)] would appear excessive, except in the case of spent fuel. It seems likely that spent fuel would be retrieved if buried, however the value of reprocessed waste will be much lower and its risk is also lower. Tests will be carried out before normal repository operations are started and should significantly reduce the possibility of retrieval. Short term retrieval, i.e., 10-20 years for the first waste may be wise, but the cost of this requirement should also be reviewed with a view to potential hazards and risks.

The requirement of sealed packages may create future problems. Some potential types of TRU and HLW wastes may, when considering time periods over a 100 year period, generate significant pressures within a container, from helium buildup in the case of LMFBR or recycled wastes, and from radiolysis in the case of water containing (e.g., cast cement) waste forms. Allowing a slow release could be beneficial without compromising integrity.

HARMON & WEISS

'81 NOV 19 P5:19

WASHINGTON, D.C.

November 18, 1981

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

(76)

ATTN: Docketing and Service Branch

PROPOSED RULE PR-60
(46 FR 35280)

Dear Mr. Chilk:

Enclosed please find the COMMENTS OF THE NATURAL RESOURCES DEFENSE COUNCIL, INC. ON PROPOSED RULE FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES.

I was informed by Mr. Arsenault's office that these comments would be considered if sent by November 19, 1981.

Very truly yours,

Ellyn R. Weiss

ERW/rl

Encl.

cc: Frank J. Arsenault
Director of The Division of Health, Siting and Waste Management

Acknowledged by card. 11/20/81 ...

UNITED STATES OF AMERICA

BEFORE THE NUCLEAR REGULATORY COMMISSION

'81 NOV 19 P5:19

Disposal of High-Level Wastes in Geologic Repositories	Proposed Rule, 46 Fed. Reg. 35280

PROPOSED RULE PR-60 (76)
(46 FR 35280)

COMMENTS OF THE NATURAL RESOURCES DEFENSE COUNCIL, INC. ON PROPOSED RULE FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

On July 8, 1981, the NRC published for comment a proposed rule on disposal of high-level radioactive wastes in geologic repositories. 46 Fed. Reg. 35280. This proposal complements and in some cases proposes to alter the final rule on procedures for the licensing of high-level waste repositories published on February 25, 1981. 46 Fed. Reg.13971. These comments are submitted by the Natural Resources Defense Council, Inc. ("NRDC").

The Proposed Rules Contain Neither Site Suitability Criteria Nor Any Mechanism to Ensure that the Sites are Selected on the Basis of Geologic Considerations

While the Commission recognizes that at some point the ability of the engineered systems to contain waste will be lost and virtually complete reliance will have to be placed on the natural characteristics of the site to isolate the waste, (46 Fed. Reg. 35282) the proposed rules contain no definitive or enforceable geologic criteria for site suitability. Nor do the regulations require DOE to demonstrate that the three sites selected for characterization have been chosen on the basis of their geologic characteristics. Thus, there is no mechanism proposed in these rules to ensure that the critical decisions on site characterization and selection will result in the emergence of a site which is even among the best that could be found. Indeed, recent developments strongly suggest that political considerations have overridden rational geologic considerations in the selection of the first few sites to receive serious attention from DOE. The current rule would not prevent licensing of the "best" of three weak sites. At worst, it would allow DOE to characterize two clearly unsuitable sites and squeeze the Commission into accepting a third marginal one.

Section 60.21(c) requires the Safety Analysis Report to contain a description of the geologic characteristics of the site, phrased in the broadest and most general way. In addition, DOE is called upon to "analyze" 1) the degree to which favorable and adverse site conditions may contribute to or detract from isolation 2) the expected performance of the engineered systems that "bear significantly" on site suitability and 3) the expected performance of the engineered systems that "bear significantly" on site suitability. The analyses called for will involve the use of extremely complex and unverifiable models and will necessarily incorporate gross uncertainties, given the acknowledged difficulty inherent in predicting the behavior of the wastes and natural systems over the periods of time required.

These descriptions and analyses do not substitute for definitive site criteria and give NRC no tools by which to enforce the selection of an optimal site (or even one of the best).*/ Neither do they give DOE much useful guidance in conducting its own site selection process. Nor does any other section of the proposed rule provide either the needed guidance to DOE or criteria by which NRC can judge site suitability.

Section 51.40(d) of the procedural rule requires the characterization of three sites, at least one of which is not in salt. This is said by NRC to provide "a workable mechanism by which the DOE will be able to develop a slate of candidate sites that are among the best that can reasonably be found..." 46 Fed. Reg. 13973.**/ While it may be true that the site characterization process is capable of providing such a mechanism, it is at least equally capable of failing to do so. There is certainly nothing in the site characterization process either alone or combined with any other rule which provides any assurance of identifying and selecting a site that is "among the best that can reasonably be found." No rule requires that DOE demonstrate either that the sites

*/The issue of whether the rules should require selection of the "best" site is a red herring; no rule can ensure this. However, the rules should and do not ensure that site selection is based primarily on consideration of geologic factors.

**/Although the "procedural" rules were adopted in final form in February, 1981, a number of sections would be amended by the proposal now under review, in recognition of the interrelated nature of the two sets of rules. Several of the changes which NRDC suggests below would further amend the procedural rules.

characterized or the site ultimately selected are "among the best" nor even that the process by which they were selected was based on geologic considerations. On the contrary, the rules would appear to incorporate an incentive for selecting two unsuitable sites for characterization in order to enhance the prospects for approval of a predetermined third site which has relative advantages only in comparison with the other two.

As noted earlier, it is already clear that political exigencies - most notably the current desire of DOE to show quick "progress" towards a waste disposal solution - have virtually dictated the selection of at least two of the first three sites which will receive serious DOE consideration for storage of commercial high level waste. These are Hanford and the Nevada Test Site. The DOE apparently is also still pursuing the Savannah River Plant (SRP) as a site for high level waste, although this may be for the purpose of storing defense waste only. These DOE sites are being pursued despite the fact that the National Academy of Science in 1966 stated: "Throughout the fabric of the 10-year history of the Committee's deliberations run some continuing threads of purpose and conviction. Prominent among them is the realization that none of the major sites (including Hanford and SRP) at which radioactive wastes are being stored or disposed of is geologically suited for safe disposal of any manner of radioactive wastes other than very dilute, very low-level liquids, with the probable exception of grout injection into fractured shale at Oak Ridge."*/ Those who have closely followed the nuclear waste issue over the past decade know full well that these sites surfaced and have been pursued by DOE because all are on government-owned reservations, pose no problems of site acquisition and are easily accessible to DOE. There can be no serious question that

*/National Academy of Sciences - National Research Council, Committee on Geologic Aspects of Radioactive Waste Disposal, Report to the Division of Reactor Development and Technology, United States Atomic Energy Commission (May 1966).

a site selection process based on geologic considerations would not have identified these three sites for characterization. Yet the proposed NRC rules would be fully satisfied by characterization of these three sites alone. This demonstrates the inadequacy of the proposed rules.

Some mechanism must be created which will do the job which NRC has articulated as a goal: the development of a slate of candidate sites that are among the best that can reasonably be found. Since the Commission has chosen not to adopt definitive site suitability criteria, the only other option that we can see is to impose a requirement that the sites characterized and selected are chosen by a process based on consideration of geologic factors. NRDC recommends a two-stage demonstration. First, at the level of site characterization, DOE should be required to show that the three sites selected were chosen on the basis of geologic factors and therefore represent a slate of sites that are among the best that can reasonably be found. Second, at the stage of construction authorization, a concept similar to ALARA should be employed, requiring a demonstration that the geologic characteristics of the chosen site provide the highest reasonably achievable degree of enhancement of the waste isolation capabilities of the repository. This is consistent with the requirement for consideration of alternatives contained in §60.21(c)(3) and §50.40(c).

The following changes to the rules would achieve these ends.

1. §60.11(a)(5) should be amended to add the following language:

> "In addition, the description of the decision process by which the site was selected for characterization should contain sufficient information to allow the Director to determine (i) that the site was chosen primarily on the basis of consideration of geologic criteria and (ii) that the slate of sites are among the best that can reasonably be found, judged on the basis of geologic criteria."

§60.31 should be amended to add the following:

6. Site Selection

(1) That the site was chosen from among a slate of characterized sites that are among the best that can reasonably be found judged on the basis of geologic criteria.

(2) That among the sites characterized, the chosen site provides the highest reasonably achievable degree of enhancement of the waste isolation capabilities of the repository.

<u>The Proposed Rule Properly Incorporates Specific Performance Criteria for Multiple Engineered Barriers In Addition to an Overall System Performance Criteria</u>

The proposed rule establishes performance standards for each of two major engineered barriers - the waste package and the underground facility - in addition to requirements for containment, controlled release rate and 1,000 year groundwater transit time, all of which act independently of EPA's generally applicable overall system performance criterion. This regulatory scheme is referred to as Alternative 2. (46 <u>Fed</u>. <u>Reg</u>. 35282) NRDC strongly supports the adoption of this alternative approach.*/ Given the difficulty in characterizing and modelling the natural system over the required periods of time to any reasonable degree of precision, the use of multiple engineered barriers, each judged by objective performance criteria, is the only way to find reasonable assurance that the overall system objectives will be met.

We are aware that much of the nuclear industry as well as DOE oppose the use of performance criteria for independent barriers, preferring to rely solely on the EPA overall system objective. This is justified in the name of "flexibility".

*/NRDC believes that suitable geologic site characteristics should be considered as the third "barrier". As noted previously, however, NRDC does not consider the site performance standard — the 1,000 year groundwater transit time — by itself as representing a satisfactory site selection criterion. Furthermore, under the assumption that the other two barriers fail, this groundwater performance standard is inadequate to insure public safety. We urge the Commission to establish site selection criteria that would insure that sites which are in close proximity to acquifers are not selected as candidate sites.

However, the desire for flexibility (or conversely, the resistance to objective criteria) cannot be permitted to override the ultimate purpose of this rulemaking, which is to provide a framework under which DOE can proceed to design a system and NRC can verify with a high level of assurance that the system will successfully contain radioactive waste from the environment until that waste is harmless. Reliance solely on overall system criteria will not provide the certainty and guidance which the designers of the repository should have and will force NRC to make its decision on the basis of highly uncertain assumptions and computer calculations which are essentially unverifiable and in which little real confidence can be placed.

If the NRC discards the approach of independent barriers with independent performance objectives, it will have in essence delegated to the regulated party, DOE, the task of setting limits. It is absolutely predictable that this will result in the following course of events: Not until DOE presents NRC with its application will the Commission learn in any detail the criteria used by DOE to design the engineered system and the means used to verify compliance with those criteria. In all probability, the information provided by DOE will require substantial supplementation and NRC will have many technical questions requiring DOE's response. Meanwhile, DOE and the nuclear industry will begin to exert pressure for an "expedited" decision on the application, either subtly or overtly painting NRC as dilatory or obstructionist. This pressure would be particularly onerous if Congress adopts a version of the waste bills currently under consideration which set extremely tight timetables for the development of a waste repository.

As a practical matter, NRC's ability to re-examine the proposed system and to question DOE's analyses will be nil, given the fact that it is likely to take several years to design the components of the engineered system. Thus, without performance criteria established prior to the design of the system, it is virtually assured that NRC will be forced to accept DOE's proposal, thus forfeiting its role as independent regulator.

Some of the industry commenters have taken the position that Alternative 2 constitutes a rejection of the "systems" approach to design of the repository. These commenters generally misconstrue the meaning of the systems approach which is, contrary to their assertions, not inconsistent with the defense-in-depth concept incorporated in Alternative 2. The systems approach dictates a method of analyzing the capability of each component of the system by taking into account the manner in which it is influenced by other interacting components. For example, in evaluating the performance of the waste cannister, the systems approach calls for consideration of the environment into which it is placed, including the thermal conduction away from the cannister, the pressure upon the cannister, the amount of moisture present, etc. The systems approach is thus in no way inconsistent with the use of objective performance criteria for each major independent barrier; it merely represents a method of analyzing compliance with those criteria.

WRDC urges the Commission to adhere to the judgment reflected in these proposed rules that, considering the enormous uncertainties involved in predicting repository performance over thousands of years, reasonable assurance in the adequacy of the geologic repository as a whole must be based upon independent barriers whose capability is judged according to pre-established and objective performance criteria. Such an approach is neither overly prescriptive nor over-conservative. On the contrary, it represents an appropriately prudent approach to the unique difficulties inherent in licensing for the first time a formidably complex system of engineered and natural components which must be capable of performing successfully over periods of time of unprecedented length.

Conclusion

For the reasons stated above, WRDC urges the Commission to: 1) modify the proposed rules and the procedural rules as suggested herein so as to incorporate the requirements a) that the sites characterized be chosen by a process which considers primarily geologic factors and results in a slate of candidate sites which are among the best that can reasonably be found and b) that the licensed site provides the highest reasonably achievable degree of enhancement of the waste isolation capabilities of the repository.

2) adopt those portions of the proposed rule which require a demonstration of compliance with performance standards for the major separate elements of the engineered system in addition to the overall EPA standard.

Respectfully submitted,

Ellyn R. Weiss

HARMON & WEISS
1725 I Street, N.W.
Suite 506
Washington, D.C. 20006

Counsel for The Natural Resources Defense Council, Inc.

Thomas B. Cochran
Senior Staff Scientist
Natural Resources Defense Council, Inc.

Dated: November 19, 1981

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(77)

DOCKETED

STATE OF WISCONSIN

DIVISION OF EMERGENCY GOVERNMENT

'81 NOV 20 A9:28

DOCKET NUMBER PROPOSED RULE PR-60
(46 FR 35280)

Lee Sherman Dreyfus,
Governor

November 17, 1981

Gentlemen:

We are submitting comments to the Nuclear Regulatory Commission on behalf of the Governor's Ad Hoc Committee on Radioactive Waste Disposal. These comments are in response to 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories.

General Comments

The difficulties in implementing a program of this magnitude are apparent. The disconcerting part is use of terms (i.e., controlled release) that leaves the reader assured of program success.

Since major program approval is located in the Nuclear Regulatory Commission, the responsibility for the final alternative (and its location) is with the NRC. Approval of a final alternative should include a candid discussion of potential impacts plus that approval must guarantee a long-term (at least 1,000 years) monitoring program. Admittedly, it would be difficult to maintain viable system monitoring capability within the repository pathways (i.e., groundwater) must be performed in order that contingency plans could be implemented in case of system failures. A philosophy of providing monitoring for only a "short period" (50-100 years, for example) following repository closure would be inadequate. These materials are hazardous for far too many years to completely rely on an unproven technology.

The following questions raised earlier have still not been answered:

1. It is not clear whether the waste will require thermal cooling for some initial period of time to ensure continued physical stability of the waste within the package. 60.131 and 60.132(k).

2. The relationship of DOE to other federal agencies and to state agencies is unclear, especially if the state agency personnel disagree with DOE evaluations of candidate site geological characteristics.

Specific Comments

Page 35281 - Containment and Isolation, 2nd Paragraph - A requirement providing for a thousand years of waste package containment is commendable, although it may not be feasible. Two recent Science articles indicate that if the waste is incorporated into glass, the leach

Acknowledged by card 11/30/81 amp

rates are likely to increase substantially past 2,000 years due to α-recoil effects (J.C. Dran, M. Maurette and J.C. Petit (1980) Science 209 1520-22). Existing knowledge coupled with computer models cannot accurately predict events for that time period. Thus, technical criteria cannot be required, but can only be established given best estimates of known factors. Either a shorter period of engineered protection or more study is needed.

Page 35282 - Role of Site - It is stated "The commission also recognizes that isolation is, in fact, a controlled release to the environment which could span many thousands of years...". We question the use of the terms "isolation" and "controlled release" within these contexts. Figuratively speaking, use of the word isolation assumes that the material is unavailable. However, isolation in this instance is admittedly only a temporary, and as yet unknown (in terms of time) variable. "Controlled release" presumes a mechanism which governs and regulates the amount of material available for release (ignoring any natural or man-made catastrophe or system failure). Once nuclear materials are emplaced, the engineered systems take over and all the variables that were previously considered in the design phase are now potential impacts. Thus, any unplanned or miscalculated variables may impact the total system. Decisions are being made and implemented based on the best technology and calculated impacts, despite the contention of a "controlled release". Both may or may not react as planned. While one can only design the system to the best of our ability, it should be recognized that a controlled release is not a given.

Page 35282 - Retrievability

Arguments involving human intrusion may well be valid, but within the past 30 years, we have evidence that "substantial continuity of information transfer over time" does not occur. We would cite the problems of Love Canal in New York, in which the toxic nature of the waste was ignored by government authorities in permitting construction of residential and other buildings. In addition, information is very likely to be lost if there are major movements of people due to climate change (migration in past), major wars, or a widespread epidemic (pandemic) that kills a large fraction of the population. Over the next 1,000-2,000 years the probability of one of these events is highly likely. We have strong doubts that information will survive.

Page 35283 Performance standards alternative 2.

Alternative 1 (a single performance standard) may be laudible and provide greatest flexibility, but also alternative 1 becomes too subjective in the evaluation process.

Page 35284, bottom of third column beginning "Nonetheless, the Commission...."

Demographic evaluation should be required in the final licensing process. In particular, the total demographic evaluation should include a risk analysis that reflects the sources of high-level waste (power plants) and proposed routing to the repository. In our opinion, the transportation routing may be the most hazardous part of high-level waste disposal. Certain sites in the continental United States may require such complex or difficult routes, that other sites may offer a better disposal alternative.

Page 35824 - Number 3 Siting Requirements, 1st Paragraph, Last Sentence -

Does a decision to construct a test facility at a given location constitute repository approval? Will a decision to utilize a specific geologic media at a given location (through the use of an experimental drop shaft and tunnel) guarantee that site's use as a repository?

According to the rule, natural adverse conditions will be resolved through scientific engineering. Will experimental repositories receive adequate in-situ testing to enable scientific estimates of suitability? An important question when considering the time frames necessary for waste isolation is what constitutes adequate testing?

Emplacement of high radioactive wastes may cause an adverse condition. Increased use of engineered designs to compensate for natural adverse conditions could lead to complications in long-term predictions of suitable isolation.

Page 35286, Paragraph 60.10 Site Characterization

In previous correspondence, the State of Wisconsin expressed concern that site characterization (which would include shaft sinking and other engineered activities) would not be subject to NRC licensing. We are still concerned that NRC has not reviewed and licensed many of the activities associated with site characterization.

Our particular concern relates to the mining laws of Wisconsin, in which site characterization including shaft sinking and in situ studies would require an environmental evaluation (and probably an environmental impact statement) and licensing. Significant environmental impact in shaft sinking will occur, and we are concerned that great effort can be expended in site characterization. A marginally acceptable site may become the ultimate repository because of the great amount of time, effort and funds expended to characterize and test.

We renew our request that some degree of licensing be imposed on DOE for at least some of the site characterization studies, so that such work would undergo proper regulatory scrutiny.

Page 35287

60.21(c)(1)(i)(B) -- This section assumes that salt deposits will, in fact, be used for disposal.

60.21(c)(1)(i)(D) -- Are these for each subsurface layer or an average over all layers between the surface and the bottom of the repository?

60.21(c)(1)(ii)(E) -- Will models be openly discussed and reviewed so that "acceptable models" are defined in much the way they have been for air pollutant dispersion?

60.21(c)(3)(i) -- Is there a word missing after "normal"?

60.21 (c)(13) -- Evaluation of natural resources will be very difficult for Wisconsin, particularly in areas now receiving intensive minerals exploration.

60.51 (2) -- What is the expected duration of these measures?

Page 35288, second column, "reasonable assurance" and where else it appears in the proposed rule -

"Reasonable assurance" is a non-legal term that has evolved from the Waste Confidence Rulemaking. We are concerned that this phrase is a very subjective value judgement on the part of the Commission. This value judgement is not clearly amenable to review, except in courts by litigation. The competence of the Commission will change with time, and what constitutes "reasonable assurance" thus will also change, and not necessarily to more or less stringent evaluations.

Page 35289

60.111 -- Performance Objectives (b) (1) Containment Period
The last sentence indicates that "the ability of the geologic setting to isolate wastes during the isolation period, in accordance with paragraph (b)(3)(ii) of this section shall be deemed to satisfy this requirement." Assumptions are being made through positive statements that the suitability of a geologic repository is a given fact following final NRC site approval. However, due to limited scientific knowledge on geologic repositories to date, the adequacy and more importantly, the suitability of a proposed repository will be dependent on how well the variables are integrated into the final evaluation.

60.112(a) -- How will tectonic stability be demonstrated? There is no U.S. historical record longer than 200 years?

60.112(c) -- How will groundwater travel time be estimated for cracked and fissured areas?

60.121 -- There is no requirement for present or future population density, nor for transportation access to the site? These issues should affect site suitability.

Page 35290

60.122 & 123 -- If the time scales discussed refer to the isolation rather than the containment period, the time periods should be 10,000 to 100,000 not 1,000 years (especially for 60.123(a)(8) which should include the next Ice Age).

60.122(f)(4) -- Has the ability to characterize groundwater behavior in crystalline rock improved?

60.123(b) -- The distance from the disturbed zone should be determined by rate of groundwater movement instead of 2 km.

60.123(b)(3) -- The exploitability of resources is a value judgment determined by industry. The standards for exploitation vary for each company, its location, the location of its clients, and the salability of the resource. Evaluation of resources should be given an indepth evaluation at any proposed site. The collapse of the salt mine near Lake Peigneur in Louisiana might be related to petroleum exploration nearby.

Page 35291-2

60.131(b) -- What processing is contemplated? How much manipulation will be required at the surface?

60.135(a)(1) -- Discussion of radiological interaction of waste with package and environment should also appear in: general discussion, 60.122(h), 60.132(3)(3), (k -thermal plus radiation loads).

60.140(1) -- What combination of these factors will make a site licensable or not? If adverse conditions are found during construction, will the site acceptability decision be reversed? What criteria will govern such a situation?

David Woodbury, Chairman
Governor's Radioactive Waste
Disposal Committee

Joseph C. LaFleur, Administrator
Division of Emergency Government

[illegible]

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP

[illegible]

'81 NOV 20 P2:22

emp

November 18 1981

(78)

PROPOSED RULE PR-60
(46 FR 35280)

Secretary
Nuclear Regulatory Commission
Washington, DC 20555

The comments of the Environmental Evaluation Group on the proposed rule "Disposal of High-Level Radioactive Wastes in Geologic Repositories," 10CFR 60 are attached. This proposal was published in the Federal Register on July 8, 1981 (46 FR 35280).

Thank you for the opportunity to comment on this proposed rule.

Sincerely yours,

Robert H. Neill
Director

RHN:JKC:lgr

Enclosure

cc: George S. Goldstein, Ph.D., Secretary, Health and Environment Department

Acknowledged by card. 11/24/81 emp

A-285

Comments on

"Disposal of High-Level Radioactive Wastes in Geologic Repositories"

(Proposed Rule, 10CFR 60 45 FR 35280)

by the

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

State of New Mexico

<u>Multiple Barriers Concept</u> (§60.111 and Preamble)

The multiple requirements of: (1) a 1,000 year waste package lifetime; (2) a leach rate of less than 10^{-5} per year from the package and the engineered facility; and (3) a minimum groundwater transit time of 1,000 years to the accessible environment introduce a great deal of conservatism into repository design. We believe the minimum values chosen may be unnecessarily conservative. Alternative 1 on page 35283 ("prescribe a single overall performance standard that must be met.") may be preferable and should be reconsidered. This alternative has the disadvantages of relying completely on the ability to characterize the system as a whole and on requiring no standardization at all between repositories. We suggest a combination of alternative 1 and 2 be considered. For example, the following criteria might be appropriate:

(1) require a minimum waste package lifetime of about 400 years.
(2) require a minimum groundwater travel time of 1,000 years.
(3) require the maximum leach rate to be permitted in the repository to vary from 10^{-4}/y to < 10^{-5}/y dependent on the specific geological conditions and on the degree of uncertainty at a specific site.

The rationale behind this specific suggestion is:

(1) analyses (Cloninger, PNL-3356) indicate that there is little reduction in individual radiation doses received by increasing waste package life from about 400 years to 1,000 (or even 10,000) years. Also, a 1,000 year package would be more expensive (although the amount is uncertain) and would require additional time to develop and verify.

(2) A minimum groundwater travel time of 1,000 years is obtainable at many sites and there appears to be no real need to settle for lower travel times. Also, we believe that caution must be exercised in choosing the appropriate K_d values to use in radionuclide travel time evaluations and that longer groundwater travel times will partially compensate for uncertainty in the K_d values.

(3) This approach would permit the waste package lifetime and leachability to be standardized for all repositories. In the event that a site was obtained with exceptional geological, hydrological, and geochemical characteristics and little uncertainty there would be no need to engineer greater leach resistance into the repository. However, if necessary lower leach rates could be designed into a specific repository.

The following aspects of the performance objective are not precise and should be clarified:

(1) What percentage of waste packages could be predicted to fail in less than 1,000 years and still meet the criteria?

(2) Does the 1,000 year groundwater travel time refer to the average velocity, leading edge of the plume or some other velocity? Also, is the accessible environment considered to be a well drilled just outside the area of DOE control?

The proposed rule, does not indicate the statistical tests that must be met in order to demonstrate compliance with these criteria.

TRU Wastes (§60.111).

Little separate attention is given to transuranic waste in the proposed rule. TRU wastes are treated as a subset of HLW, although they have unique characteristics. There are two fundamental questions that need to be addressed about TRU wastes:

(1) What is the justification for classifying alpha emitting transuranic elements with concentrations greater than 10 nanocuries per gram as TRU wastes, rather than greater than 100 nCi/g (as EPA is considering) or some other number?

(2) Is it necessary to dispose of TRU wastes in deep geological formations; especially where concentrations are in the order of 10-100 nCi/g?

Because of these fundamental concerns we believe consideration should be given to writing separate regulations for TRU waste disposal, either in this rule or in a separate one.

Human Intrusion (§60.51 and preamble).

The coverage of human intrusion is generally well done and complete. We do have two comments:

(1) Deliberate intrusion would not necessarily require a conscious collective societal decision. All that would be required would be the failure or absence of institutional control, plus a group of dedicated and competent persons.

(2) We do not agree with the statement "once the site is selected, marked, and documented, it does no use to argue over whether these measures will be adequate in the future....." Society would always have the ability to continue or to reclaim positive institutional control over a site if the need is indicated. It is noted that no specific time period for control (e.g. the 100 years being suggested by EPA) is mentioned in the proposed rule. We believe it is not necessary at this time to make an arbitrary determination of the length of time that positive institutional control will be maintained over a site. However, before a final decision is made to relinquish control there should be a thorough evaluation of the benefits and costs of continued positive control.

Siting Requirements (§60.122 and preamble).

We see no geologic reason why population related siting requirements should be included. However, transportation routes to the site should be considered in the overall site evaluation because it is possible that an otherwise acceptable site should be ruled out because of transportation considerations (such as inadequate highways or railroads or the necessity of moving wastes through hazardous or heavily populated areas).

No minimum area for DOE control adjacent to the geologic repository operations area is specified in 60.102(c). This should be considered.

Application of ALARA (§60.111).
We believe the ALARA principal should not be applied to containment and control of release performance requirements. The principal reason for this position is the belief that ALARA is best applied to predictable releases and doses, rather than to unlikely accidents whose probability of occurrence is difficult to accurately estimate.

Definitions (§60.2)
The decommissioning definition appears to require dismantlement of all surface facilities at the repository. This may not be necessary, since some buildings might be usable with no adverse health and safety aspects.

The floodplain definition could be more restrictive than a 1% chance of flooding per year since only a few percent of the total land area in a basin is typically inundated by a 100-year flood. Consideration should be given to defining the flood plain as the area inundated by a Standard Project Flood.

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November 13, 1981

'81 NOV 23 A11:28

Mr. Samuel J. Chilk
Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555
Attention: Docketing and Service Branch

Reference: 10CFR Part 60, 46 FR 35280, July 8, 1981.

PR-
(46 FR 35

Gentlemen:

NRC Proposed Rule on Disposal of High-Level Radioactive Wastes in Geologic Repositories

These comments are submitted on behalf of Northeast Nuclear Energy Company (NNECO) and Connecticut Yankee Atomic Power Company (CYAPCO) the operators of the Millstone 1 and 2 and Connecticut Yankee nuclear power plants. We commend the NRC on its effort to address permanent disposal of high-level waste, an issue which is of vital importance to the future of nuclear power development in the United States. However, we have serious concerns with the proposed assignment of specific, quantitative performance requirements for system components. Establishment of performance requirements for the waste repository system as a whole would still maintain system performance while permitting flexibility in the design and construction of system components to effectively utilize site specific characteristics and thereby reduce repository costs.

The following are our comments, as requested in the notice of proposed rulemaking on the following six specific issues contained in the proposed rule.

1. Alternative Approaches; Systems Approach vs. Barrier Performance Objectives

While it is generally agreed that the use of particular nuclide barriers and other features -- such as a reasonably long-lived waste package, a stable waste form and an appropriate geologic setting are integral components of the repository system, the basic consideration is assurance that these barriers and repository system features operate in a way that provides control over the release of radioactive materials to the accessible environment over time.

On this basis, the NRC Barrier performance requirements approach, as contained in the current proposed regulations, appears to be without scientific or technical support. Also, it is unclear that the inclusion of such component requirements increases the ability to show compliance with an overall system performance requirement.

Acknowledged by card. 11/24/81. emp

We strongly believe that overall repository performance should be addressed directly by means of a systems approach. This would provide for appropriate design flexibility to take advantage of new developments as they occur and to effectively utilize the specific site characteristics.

In particular, use of standards such as proposed by EPA in 10 CFR Part 191 would provide a unified, supportable basis for regulation and, would minimize the possibility of conflicting regulatory requirements. Utilization of a systems approach, based on overall system performance standards, would have the additional advantage of being universally applicable to all geologic repositories.

2. <u>Retrievability</u>

We believe that the proposed rule's requirement to maintain retrievability for a period of up to 110 years is unnecessary and without adequate supporting rationale. A design allowing for retrieval for a 50 year period following waste emplacement could motivate extended and unnecessary delay in final repository closure.

A more appropriate approach would be to base design requirements for retrievability on the period of repository <u>operation</u>. Assuming the first waste packages loaded into the repository would be in place for about 30 years before all emplacement was complete, allowing another 30 years for retrieval would lead to a retrievability design requirement of 60 years. Such a period appears reasonable because any problems are likely to manifest themselves within this time frame.

3. <u>Human Intrusion</u>

The treatment of this subject is proper and should be preserved in the final rule. However, we believe that the importance of avoiding natural resources in the siting of a repository is overemphasized.

4. <u>Population Siting Requirement</u>

We agree that population density or the proximity of a site to population centers should not be a siting requirement. Over the periods of time involved, such requirements would be meaningless since population projections are at best speculative. Further, since overall system performance requirements are stated in terms of limitations on the release of radioactive materials, population-related siting requirements are unnecessary.

5. <u>Design and Construction Requirements</u>

We believe that the level of detail required under the proposed rule should be reduced. This comment is based on the desire to maintain flexibility with respect to design and construction and to minimize unnecessary cost. Further, the proposed rule does not identify a design basis accident with the result that it is not possible to identify any repository structure, system or component important to safety in terms of limiting accident doses to the public, such as the 5 rem level prescribed in 10 CFR § 72.68. Accordingly, the need to specify design and construction requirements important to safety, beyond Part 20, needs clarification. Also, the imposition of quality assurance requirements contained in Part 50 Appendix B to systems that prevent or mitigate the consequences of events that cause undue risk to the public is meaningless without defining these events.

6. <u>ALARA</u>

With respect to high-level waste repositories, NU believes that the application of an ALARA principle is superflous. Projected doses are a small fraction of those resulting from variations in natural background radiation and further reductions would be hard to justify. In addition, the inclusion of ALARA would not improve the performance of an individual component or the overall repository system. Thus, application of ALARA does not seem reasonable and could possibly lead to confusion. Accordingly, we believe its use should be avoided.

Thank you for the opportunity to comment on this important issue.

Very truly yours,

W.G. Counsil

W. G. Counsil
Senior Vice President

J.P. Cagnetta

By: J. P. Cagnetta
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November 3, 1981 '81 NOV 27 P3:54

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80

Dr. Nunzio Palladino, Chairman
Nuclear Regulatory Commission
Washington, D. C. 20555

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Dear Dr. Palladino.

I am a member of the Board on Radioactive Waste Management of the National Academy of Sciences but I wish to disassociate myself from the Board's comments on Proposed Rule on "Disposal of High-Level Radioactive Wastes in Geologic Repositories" (submitted separately) because I do not agree with them. The disposal of radioactive waste is an engineering project that requires scientific backup. Engineering remains an art and this engineering project, as any, must be judged as an engineering project utilizing safety factors to trade off for uncertainty. The magnitude of the safety factor will be a function of the risk and the costs associated with additional margins for safety. In addition, there are many instances in engineering practice where a limit is sufficient and we do not need to know an exact answer; we need only bound the problem. That obviously would not be satisfactory to a scientist.

As an example of differences in approach, if we ask in the abstract are there any geologic formations where we can not verify the groundwater travel time (the scientific question), I am sure the answer is "yes." However, that is not the pertinent question. The pertinent question is to what extent can we evaluate the groundwater travel time in a formation that we have chosen to receive radioactive waste (the engineering question)?

Ackd. 12/1/81 ...

For example, would we even consider a formation where we could not place a confidence level on our evaluation of the travel time? As engineers, we would be satisfied with an answer that the travel time is at least "X" number of years (say 1,000), if "X" is a satisfactory length of time. We do not need the exact number.

The purpose of my comments is to indicate how I think the proposed rules could be improved to protect human health and the environment, while still disposing of radioactive waste in an expeditious and economical manner. Because of the large existing inventory of defense-related waste, a practical program for permanent disposal is needed. The question is how to do this in a safe and expeditious manner.

1. Defense in Depth

   As has been no   many studies of the radioactive waste disposal problem, there will always be residual uncertainties. To provide a safety factor to compensate for this uncertainty, a multiple-barrier system has many advantages. Since we cannot answer the global problem and predict every possible combination of circumstances that might cause releases of waste, multiple, independent mechanisms of slowing or limiting the discharge of radioactive materials to the environment are desirable.

2. Timing of Issuance of Regulations

   An issue in the minds of many scientists and engineers is the timing of the regulations. I agree that in the best of all possible worlds, EPA would have issued its standard and NRC's criteria could be based on and responsive to EPA's standard. EPA has been trying for years to issue its standard and with the advent of a new administrator and a new philosophy, we are liable to see still further delays. Yet DOE needs to know what will be required of it in the licensing procedure. NRC has, in my opinion, tried to fill that gap while still requiring that any disposal system must eventually satisfy EPA's standard. NRC has also indicated the procedure it intends to follow to license such a repository. I agree with the Board on Radioactive Waste Management that the precise numbers chosen may not be the best choices, but reasonable numbers can be selected that put upper bounds or limits on the doses to maximally exposed individuals or to populations while still allowing trade offs among the components.

3. Verification

Complete verification, in the usual sense of the word, will not be possible unless we are willing to delay disposal millions of years. That is not an attractive alternative, since the hazard of waste near the surface surely exceeds the hazard of waste buried in favorable sites 500 to 1,000 meters deep. Possibly more important, by issuing the regulations at this time, NRC will have the opportunity to produce Regulatory Guides that will establish protocols for "verification." This "verification" will be an extended procedure and the sooner it commences, the better.

4. Site Specific Criteria

I believe that the regulation should be procedural rather than substantive since we shall license only one to three repositories in this century. Therefore, specific numbers

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will be determined for these few sites, provided they satisfy EPA's standard and NRC's defense in depth criteria. Consequently, though precise numbers are inappropriate at this stage, a range of acceptable numbers would give DOE some understanding of the types of sites that might be licensable.

5. Alternative Performance Criteria

The first question to be answered is which of the three alternatives NRC should adopt - a single overall performance standard that would be equivalent to the EPA standard; minimum performance standards for each of the major elements as well as meeting the EPA standards; or detailed numerical criteria on the critical engineering attributes of the repository system. As is now known, NRC has chosen the second on the basis that this would be easier for it to implement. This route leads to three of the four technical requirements - the thousand-year waste package containment time, the thousand-year groundwater travel time in the undisturbed environment, and 10^{-5} annual release rate.

I think that one of the major failures in the NRC approach is that the three designated numerical criteria relate neither to a curie release to the environment nor to a dose to the population which should be the major objective of the regulation, as indicated in the purpose, Sec. 60.101. According to the simulations by Burkholder, Cloninger, Sutcliff, etc., the use of these three numerical values in modeling schemes gives results that would appear to meet even the most restrictive EPA requirements.

I believe that the NRC route, provided that the rule is amended to allow negotiable performance criteria, is the best route because it allows DOE to proceed now to design waste package systems and repositories. If during the design phase, DOE finds that the costs to meet these criteria are exorbitant, then they can negotiate with NRC. NRC should also include in their rule limits on radioactive control similar to those included in Appendix I to 10 CFR 50. If that $1,000 (or something similar) per man-rem were made part of the regulations, it would facilitate negotiations. The consequences of following the first approach are also clear. The EPA standard is not yet published. There is still opportunity for drastic revision. Are these the numbers toward which DOE should be designing? How do they proceed now? What do they do when they come to the NRC hearings with a single overall measure and each step in the modeling process is challenged and the uncertainty in each of these numbers, the leach rates, the waste package life, the R_Ds, and the water flow times are debated?

If acceptable values or ranges of values for these parameters are negotiated beforehand and protocols for determining them are established, then the licensing process should be far smoother while still protecting the public health and safety.

6. Absolute Magnitude of the Performance Criteria

If one looks at the Rationale Document for the three key performance criteria - package life, leach rate, and water travel time - it becomes obvious that this is what NRC thinks

is the best available technology (BAT"). The two words that are attached to BAT in the EPA water pollution documents are "economically achievable." Such words should be added to the NRC criteria. The fact that NRC thinks this is the "best available technology" can easily be seen in the case of the leach rate for borosilicate glass. Using the data in DOE's Draft Environmental Impact Statement on Management of Commercially Generated Radioactive Waste, Vol. 2, p. J.6, Table J.4, one finds that the characteristics of borosilicate glass are density, 3.0-3.6 gm/cm^3, the leach rate of 10^{-4} to 10^{-7} gm/cm^2-day. Making the necessary transformations, this leads to leach rates of 7×10^{-2} to 6×10^{-5} per year (for a cubic centimeter cube); making the more realistic assumption of a waste package of 0.5 m x 3.0 m and with no selective leaching, leads to a leach rate of 10^{-3} to 8×10^{-7} per year. The lowest leach rate is less than the limit that NRC says is achievable.

Though the dollar amounts are large for the waste package, I think that the overall costs are still relatively small to the nuclear program and a sense of perspective should be maintained. Certainly for the first set of repositories, economic efficiency should not be the primary goal, but rather licensability and the overall safety and confidence of the public.

The Rationale Document states for the waste package: "containment for 1,000 years has the effect of delaying releases until temperatures in the underground facility are past their peak and are decreasing and until thermal gradients in the underground facility and surrounding rock have decreased substantially from the first few hundred years. Lower temperatures and temperature gradients allow release rates and radionuclide migration to be predicted with greater confidence under these conditions" (p. 18). DOE can argue that they can reduce the temperature of the rock formations by increasing the distance between waste packages and/or decreasing the waste content of the packages or by additional aging of the waste. Since mining is likely to be considerably cheaper than the costs of the waste packages, it seems to me that it might be well worth while for DOE to choose extra excavation to achieve lower temperatures. In such case, the formations then would be perturbed thermally by only an insignificant amount and not affect the confidence with which one can predict release rates and nuclide migration. If one can show that this is economically more desirable than going to the higher temperatures, the higher cost packages and the concomitant uncertainty in rock changes, chemical interactions, and water flow, then that requirement should be relaxed.

The thousand-year groundwater travel time in an undisturbed environment is directly related to the thousand-year containment period. The first 1,000 years in the repository are dominated by the fission products. One would like to be certain that, in fact, all the fission products have decayed substantially before releases to man's environment would occur.

The thousand years is not necessary, a shorter time would be adequate for decay. Therefore, the thousand-years travel time is determined by the actinides, as stated in the Rationale Document. The thousand-year travel time is also coupled with assumptions of sorption equilibrium coefficients of 100 ml/g for actinides and other principal nuclides that contribute to dose, which would prevent most of the principal isotopes of concern from reaching the accessible environment. This, of course, does not affect the transport of those materials which are not easily absorbed, such as Iodine 129.

The other key item is the release rate of 10^{-5} per year. Again, according to the Rationale Document, this would result in a "significant reduction in the fraction of several environmentally significant long-lived isotopes" (p. 20). So basically, we see that NRC is using BAT and is slightly "forcing technology" by its requirements. The results seem to be achievable even though the overall safety and costs may be extremely large under the system.

A misleading aspect of the discussion is the reference to the Burkholder and Cloninger papers, which indicate that the maximum individual dose will not be decreased even if the hold-up times are increased up to a million years, rather than 1,000 years. This is based upon the assumption that a dose 50 years from now is equivalent to a dose a million and fifty years from now. I am afraid that neither I nor the general public buy that. It is obvious that discounting dosages as one discounts money is very difficult to do. On the other hand, it is equally obvious that a dose to some unspecified individual a million years from now is very different from a dose to children or grandchildren a hundred years from now, or even a thousand years from now. There are people who can trace their ancestry a thousand years, but a million years seems a little bit beyond most people's comprehension.

7. Validation of Performance Criteria

Statistical criteria need to be provided so that when the regulations say all material must be contained at the 10^{-5} level, it specifies what fraction of the material that is - 95% of the material or 99% of the material - and at what level of confidence. Once that is specified, testing can proceed to indicate whether or not these design goals are reachable. I think, also, that NRC needs to indicate what validation it will accept for these numbers. How will they allow DOE to prove that the package will last for 1,000 years, or that the travel time is 1,000 years, etc.? These items are crucial to planning a waste package and a repository and to obtaining a license.

8. Retrievability

As is pointed out in the Rationale Document, on page 27, "We only require that the design of the repository preserve the option to retrieve the waste for future decision makers. The persons in charge at the time emplacement is complete will have the opportunity to decide whether to decommission and seal up the repository or to continue to monitor its performance.

We only require that the design be such that they will have this option." Consequently, it would be possible to actually backfill and decommission the repository immediately after filling. This statement from the Rationale Document should be included in the rule.

9. TRU Wastes

The minimal references to the TRU wastes only confuse the document. I believe it would be better to remove these references entirely, since the definition of TRU waste is different by a factor of 10 for the NRC and the unpublished draft of EPA rules.

10. Unsaturated Zone

I believe that regulations could apply equally well to the unsaturated zone with only minor changes. One necessary change, of course, is the requirement of the 300 meters of cover.

In closing, I believe that the current NRC approach, in light of no EPA standards, has much to recommend it. It requires defense in depth. It should be amended to indicate a range of acceptable numerical values dependent upon local conditions and manmade barriers. It requires adherence to EPA's as-yet unissued standard. NRC should develop guidelines on "verification" of input data to mathematical models and for the models themselves. NRC should set a reasonable dollar value on expenditures for dose reductions. I believe the criteria reduce but do not eliminate the uncertainty in the licensing procedure.

Sincerely yours,

Frank L. Parker

FLP bl

DOCKETED USNRC

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(64)

DOCKET NUMBER PROPOSED RULE PR-2 et al (46 FR 38081)

November 24, 1981

(81)

DOCKET NUMBER PROPOSED RULE PR-60 (46 FR 35280)

Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Proposed Rulemaking on Land Disposal of Low-Level Radioactive Waste.

In my opinion nuclear wastes, both high and low level, should be permanently disposed of in underground geologic repositories. This problem should not be left for future generations to resolve.

As nuclear worker radiation doses rise, the long term implications are frightening, given the recent estimates of cancer risks associated with low-level radiation exposure. Therefore, efforts should be made to forge a new partnership among federal, state and local officials concerning all decisions of the disposal of radioactive waste.

Sincerely yours,

Julia M. Jensen R.N.

Julia M. Jensen R.N.
Route 1 Box 86A
Grandview, Tennessee 37337

Acknowledged by card. 12/3/81 emp

PGE Portland General Electric Company

Bart D. Withers Vice President

DOCKETED USNRC

'81 DEC 14 P4:42

OFFICE OF SECRETARY DOCKETING & SERVICE BRANCH

December 11, 1981

Trojan Nuclear Plant
Docket 50-344
License NPF-1

(82)

DOCKET NUMBER PROPOSED RULE PR-60 (46 FR 35280)

Secretary of the Nuclear Regulatory Commission
ATTN: Docketing and Service Branch
Washington, DC 20555

Dear Sir:

TROJAN NUCLEAR PLANT
Comments on Proposed 10 CFR 60

Proposed Nuclear Regulatory Commission rule 10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories, has been reviewed by Portland General Electric Company, resulting in the following comments:

1. Alternative 1, the setting of a single performance standard for the entire repository system, is much more desirable than setting performance objectives for each major system element (Alternate 2), or prescribing detailed numerical criteria on critical engineering alternates of the system (Alternate 3). The overall objective of the repository system is to limit radiation exposure to the public through isolation of high-level wastes from the biosphere until such time and in such quantities as to present minimal risk. Multiple barrier performance objectives and prescribed detailed engineering criteria needlessly restrict the designer's flexibility in producing an integrated design to best meet the overall objective.

2. The requirement to be able to retrieve wastes 110 years after emplacement (50 years of operation, 30 years to final decision, 30 years to retrieve) is excessive. The 30-year decision period following cessation of operation and sealing of the shaft is after the maximum thermal output has been reached for the first-placed canisters. It is at this point that problems resulting from exce· .ve heat would manifest themselves. The 30-year perio· · also after the canister-monitoring program in operation during emplacement has been terminated. As geologic and groundwater considerations woul. not allow transport of radionuclides to the biosphere within 30 years of shaft sealing (assuming complete canister

Acknowledged by card. 12/15/81 emp

Portland General Electric Company

Nuclear Regulatory Commission
December 11, 1981
Page two

failure), the 50-year duration period is unnecessary. Retrievability design criteria, if any, should be based on the time of operation of the facility plus the time to remove all waste if a problem in the first canisters were found when the last canister was emplaced, a total of no longer than 80 years.

3. As population estimates for the time periods in question are largely supposition, population considerations should not be made a part of the rule. Any population residing in the vicinity of a disposal facility would already be protected by the original design criteria limiting radioactive material release.

I hope that these comments will be of use in formulating the final rule.

Sincerely,

Bart D. Withers
Vice President
Nuclear

NEW YORK STATE ENERGY OFFICE
ROCKEFELLER PLAZA
ALBANY, NEW YORK 12223
JAMES L. LAROCCA COMMISSIONER

'81 DEC 29 P3:23

December 16, 1981

DOCKET NUMBER
PROPOSED RULE PR-60 (83)
(46 FR 35280)

Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Docketing and Service Section

Gentlemen:

The U.S. Nuclear Regulatory Commission's proposed technical criteria for disposal of high-level radioactive waste in geologic repositories, as published in the Federal Register on July 8, 1981, have been reviewed by cognizant New York State agencies including the NYS Department of Health, the NYS Geological Survey, the NYS Energy Research and Development Authority and this Office. Based on that review, the following comments are offered:

Performance Objectives

In addition to requiring compliance with the yet to be established EPA "generally applicable environmental radiation standard", NRC proposes to prescribe minimum numerical performance standards for each of the major repository elements (i.e., waste package underground facility, and site). NRC indicates that such criteria provide a means of compensating for some of the uncertainty in the assessment of overall repository performance, provide confidence that the wastes will be isolated for the period of greatest hazard, will enhance confidence that the final EPA environmental standard will be met and will simplify the licensing process.

While we sympathize with NRC's desire for quantitative benchmarks to judge the acceptability of a specific proposed geological repository, the establishment of minimum numerical performance standards is at best premature and probably not desirable in a generic sense. In particular, the technical bases of the proposed performance standards and their relationship to the EPA environmental standard have not been demonstrated. At this stage, it is not clear whether meeting the minimum performance standards is either necessary or sufficient to meet the EPA standard. More generally, the wisdom of setting specific numerical standards for such a first-of-its-kind facility is not clear. NRC admits that such criteria will restrict DOE's flexibility in designing a repository and may inhibit the incorporation of new technological developments or knowledge gained during site characterization. Further, it is not clear to what degree DOE would be able to verify its compliance with these criteria or what level of assurance NRC would require.

Acknowledged by card 12/30/81 mdy

Secretary, U.S. NRC
Page Two
December 16, 1981

For the purpose of codifying technical criteria for a geological repository for high-level nuclear waste, New York recommends that NRC utilize the suggested single overall performance standard approach. When a sufficient basis for developing performance criteria for the various major elements of the repository is established, such as when EPA's general environmental standard is finalized and further experience in repository development (i.e., siting, construction, operation) is obtained, such criteria would be most appropriate and useful as design objectives in a Regulatory Guide format.

__Retrievability__

The proposed requirement that the "geologic operations area" be designed to allow retrieval of all wastes for a specified period following completion of emplacement has been addressed by several New York reviewers. While there is general consensus that a retrievability requirement provides needed compensation for the uncertainty that must be accepted in the initial development of a repository, some question has been raised about the admittedly arbitrary "50-year" retrievability period proposed by NRC. New York believes that the period of designed retrievability would be more appropriately determined on a case-by-case basis taking into consideration the specific characteristics of the geological setting and the planned performance confirmation program.

In addition, the overall concept of retrievability requires clarification. Since the ultimate determinants of the retrievability of the waste appear to be the integrity of the waste package and the stability of the geological medium, wastes could conceivably be retrieved (albeit at great expense) for some significant period, possibly two or three hundred years, following closure of the repository. The concept of retrievability should not necessarily preclude backfilling or decommissioning portions of the repository prior to the expiration of the designated retrievability period. NRC should provide further guidance, possibly in the "Regulatory Guide" format, on the meaning and purpose of the retrievability requirement and what NRC would consider acceptable in terms of designed retrievability.

__Quarternary Period__

The New York State Geological Survey advises us that the term "Quarternary Period" should either be replaced by a span of time in years or be specifically defined in the glossary. The survey indicates that there is no general agreement among geologists on its definition.

__Shaft and Borehole Seals__

The requirement that shaft and borehole seals "inhibit the transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass," does not appear to be justified and may be difficult if not impossible to verify. From this requirement it follows that boreholes and shaft seals of repositories in different media would have to meet different criteria. The ability of the seals to inhibit

U. S. NRC
Page Three
December 16, 1981

waste movement would be more appropriately related to compliance with the EPA generally applicable environmental radiation standard when the latter becomes available.

New York appreciates the opportunity to comment on the proposed high-level waste regulations.

Sincerely,

William E. Davis

William E. Davis
Deputy Commissioner
for Operations

WED:mlg

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER 81/1300

JAN 18 1982

84

[illegible] PR-60
46 FR 35280

Secretary
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

This letter is a second supplement to our letter of October 13, 1981, which reviewed the proposed rule for Disposal of High-Level Radioactive Wastes in Geological Repositories (46 FR 35280).

On page 35281 the supplementary information states that in view of Department of Energy's (DOE) current plans, which call for disposal in a repository in the saturated zone, these criteria were developed for disposal in saturated media. Further, it states that additional or alternative criteria may need to be developed for regulating disposal in the unsaturated zone.

We urge that the proposed rule be modified at this time to consider the possibility of a repository in either the saturated or unsaturated zones. There are sound technical reasons for this, the essential one being that under appropriate conditions the unsaturated zone would provide one more natural barrier to the movement of waste radionuclides from the repository to the water table. Another consideration is that there is a good possibility, under the present accelerated schedule for constructing a shaft at each of three potential sites under investigation, that the DOE could consider the unsaturated welded tuff as a suitable host medium at Yucca Mountain on the Nevada Test Site.

In view of the fact that most of the language of the proposed rule is generalized, presumably to allow some flexibility of action on the part of the DOE, it is our opinion that the task of making the appropriate modifications to consider the unsaturated zone would not be difficult or time consuming.

We hope this comment will be helpful to you in the preparation of a final rule.

Sincerely,

Bruce Blanchard

Bruce Blanchard, Director
Environmental Project Review

Acknowledged by card. [illegible]

A-277

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

In Reply Refer To:
EGS-Mail Stop 410

February 22, 1982

cc Justus
Bell
Knapp
[illegible]

PR 60
46 FR 35280

85

[illegible] PR-60
(46 FR 35280)

Robert J. Miller
High-Level Waste Technical Development Branch
Division of Waste Management
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Miller:

We have reviewed the proposed rule (10 CFR 60) which specifies technical criteria for disposal of high-level radioactive wastes (HLW) in geologic repositories, published in the Federal Register of July 8, 1981, regarding modifications that would be desirable to allow consideration of a repository in either the saturated or unsaturated zones. It is our opinion that appropriate modification of the following parts of the proposed rule would enable the technical criteria to apply to unsaturated as well as saturated zones.

Page 35287, Col. 1, part [ii(a)]: Precise determination of the rates and quantities of expected releases from the unsaturated zone via the saturated zone to the accessible environment using differential equations to describe the flow of solutes through fractured rocks in the unsaturated zone currently is not possible. However, in some environments it can be demonstrated qualitatively that the water flux through the unsaturated zone is acceptably small and that water is unlikely to contact the waste canisters for more than brief periods, if at all; therefore such numerical modeling should not be needed to assess the performance of a repository located in that kind of environment.

Page 35289, Col 2, (2): "Performance of the engineered system - (i) containment of wastes" and (ii) control of releases." As presently stated, the first of these items requires that saturation of the repository be assumed in evaluating the potential for long-term containment by the engineered system. One of the advantages of the unsaturated zone is that well-drained rocks within it will never be saturated and thus the goals of long-term containment and very slow release rates become easier to achieve. This advantage is negated; however, with the current wording because the Department of Energy must assume full or partial saturation in its performance assessment. We suggest that the wording proposed in attachment B, pages 22-24, of the memorandum for Mr. Samuel Chilk, Nuclear Regulatory Commission from Sheldon Meyers, Department of Energy, dated November 5, 1981, may be appropriate for both these items.

<u>Page 35290, Col. 2, paragraph 2 - (f) (2) and (3)</u>: A compelling argument for use of the unsaturated zone for a repository for HLW is predicated on the observation that this zone constitutes a major barrier to the contact of ground water with emplaced radioactive wastes. The strategy for locating a repository in the unsaturated zone is to select a repository horizon with high vertical conductivity that will allow the limited amount of recharge water reaching the repository to pass easily through this horizon into underlying units with little or no contact with the canisters of waste. Thus, "inhibition of ground water circulation in the host rock" is an undesirable condition in a repository horizon in the unsaturated zone. In the unsaturated zone, the presence of fractures or faults help to drain the repository horizon, rather than serve as possible short circuits to the biosphere, as would be the case in the saturated zone. Similarly, inhibition of ground-water flow between hydrogeologic units--is not a favorable condition between the repository horizon and underlying units in the unsaturated zone. Indeed, gravel-filled boreholes could be engineered to assure rapid drainage of water from the repository horizon in the unsaturated zone. We suggest the following addition to (f) to follow (3): In unsaturated zone environments by contrast well-drained rocks unlikely to retain perched ground water constitute favorable conditions.

<u>Page 35290, Col. 3, (b) (8)</u>: "The existence of a fault that has been active during the Quaternary Period." This may not necessarily be an adverse condition in the unsaturated zone.

<u>Page 35291, Col. 1, paragraph 5, (13)</u>: "Conditions in the host rock that are not reducing conditions." In the virtual absence of a transporting medium this does not appear to be an adverse condition.

<u>Page 35293, Col. 2, paragraph 16, (1) (3)</u>: "Backfill placed in the underground facility shall be designed as a barrier" and page 35293, Col. 3, (ii), (A) "It shall provide a barrier to ground-water movement into and from the underground facility," and (ii) (c) "It shall reduce and control ground-water movement within the underground facility." In the unsaturated zone, backfill placed in the underground facility should promote ground-water movement and vertical drainage from the repository. It should <u>not</u> provide a barrier to ground-water movement from the repository and it <u>should</u> provide for vertical ground-water movement through and drainage of the underground facility.

<u>Page 35298, Col. 2, 60.134 (f)</u>: In the unsaturated zone, water encountered during excavation is expected to drain through the repository horizon to underlying units. No purpose appears to be served by attempting to move this water to the surface. We suggest the following wording of this part might be appropriate: (f) Water control. The construction specifications shall provide that water encountered in excavations shall be controlled in accordance with design requirements for radiation control and monitoring.

On the enclosed copy of the proposed amendments to 10 CFR 60, I have marked with a felt pen the items referred to in this letter to facilitate their identification.

In summary, it appears that only relatively minor changes in the wording of the proposed rule are necessary to make it applicable to geologic repositories for the disposal of high-level wastes in both the saturated and unsaturated zones.

We shall be happy to discuss with you any questions that may be raised by our comments.

Sincerely yours,

Jack

John B. Robertson
Chief,
Office of Hazardous Waste Hydrology

Enclosure

were reviewed and published as a [illegible] form on March 31, 1980 (45 FR 21[illegible]). In general, the comments were supportive of the agency's efforts.

It was also at this time, March 1980, that Packers and Stockyards [illegible] a [illegible] review [illegible] the [illegible] of a specific [illegible] regulations [illegible] every [illegible] months. [illegible] regulations were considered [illegible] a total time period of approximately [illegible] years. Fourteen specific regulations, [illegible] policy statements and various report forms were selected for review, and comments were again solicited.

In response to the March request, [illegible] additional comments were received concerning the specific areas targeted for review, i.e., [illegible] Certain levels of required bonding; (2) proper [illegible] of custodial accounts; (3) [illegible] promotion [illegible] and (4) [illegible] annual reporting [illegible] agencies and dealers. The agency's third Federal Register publication, dated December [illegible], 1980 (45 FR [illegible]), discussed these comments and detailed specific changes in these target areas designed to be responsive to suggestions by the industry to lessen regulatory burdens on the industry, and to encourage competitive markets within the industry.

Present Activities

The agency has decided to accelerate the regulatory review and reform process which it has already begun. To assist the agency in achieving this end, the Deputy Administrator, Packers and Stockyards, AMS, established an internal task force in January 1981 to review each rule and regulation and to suggest changes therein which would lessen or eliminate any regulatory burden imposed ... [illegible] the agency's ability to enforce the Packers and Stockyards Act. The task force report of [illegible] has been prepared and a final report is expected by the Administrator of Packers and Stockyards Administration on August [illegible], 1981.

Revised Plan

Packers and Stockyards Administration will not follow its previously published plan for regulatory review. [illegible] the agency will review all current effective regulations, policy statements and reporting requirements by the close of fiscal year 1982 (September 30, 1982). As a part of this review, [illegible] will be made to obtain input from the affected industries, [illegible] Department of Agriculture, and other interested persons prior to formal publication of proposals. Proposed changes and deletions will then be published in the Federal Register for comments prior to final adoption. Additionally, by September 30, 1981, the agency will publish, pursuant to the requirements of the Regulatory Flexibility Act, a listing of all rules having a significant economic impact on a substantial number of small business entities which are to be reviewed during the succeeding 12 months. The proposed regulations published December 31, 1980, in the Federal Register will be reconsidered by the agency to incorporate where appropriate the recommendations of the task force and comments filed by the industry, and where necessary, such regulations will be republished for comment.

Done at Washington, D.C. this [illegible] day of July 1981.

James L. Smith,

Acting Administrator, Packers and Stockyards Administration.

[FR Doc. [illegible] Filed [illegible]]

BILLING CODE [illegible]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 60

Disposal of High-Level Radioactive Wastes in Geologic Repositories

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The NRC is publishing proposed amendments which specify technical criteria for disposal of high-level radioactive wastes (HLW) in geologic repositories. The proposed criteria address siting, design, and performance of a geologic repository, and the design and performance of the package which contains the waste within the geologic repository. Also included are criteria for monitoring and testing programs, performance confirmation, quality assurance, and personnel training and certification. The proposed criteria are necessary for the NRC to fulfill its statutory obligations concerning the licensing and regulating of facilities used for the receipt and storage of high-level radioactive waste.

DATE: Comments received after November [illegible], 1981 will be considered if it is practical to do so, but assurance of consideration cannot be given except for comments received on or before this date.

ADDRESSES: Written comments or suggestions on the proposed amendments should be sent to the Secretary of the Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. Copies of comments ... may be examined in the U.S. Nuclear Regulatory Commission Public Document Room, [illegible] H Street NW., Washington, D.C. Comments may also be delivered to Room 1121, 1717 H Street NW., Washington, D.C. between 8:15 a.m. and 5:00 p.m.

FOR FURTHER INFORMATION CONTACT: Frank J. Arsenault, Director of the Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone (301) 427-[illegible].

SUPPLEMENTARY INFORMATION:

Background

On December 6, 1979 the Nuclear Regulatory Commission (Commission or NRC) published for comment proposed procedures for licensing geologic disposal of high-level radioactive wastes. The licensing procedures were published in final form on February [illegible], 1981 (46 FR [illegible]). On May 13, 1980 (45 FR 31393) the Commission published for comment an Advance Notice of Proposed Rulemaking (ANPR) concerning technical criteria for regulating disposal of high-level radioactive wastes (HLW) in geologic repositories. Included with the advance notice was a draft of the technical criteria under development by the staff. The public was asked to provide comment on several issues discussed in the advance notice and to reflect on the draft technical criteria in light of that discussion. The comments received were useful [illegible] the full range of issues related to the technical criteria. The technical criteria being proposed here are the culmination of a number of drafts, and were developed in light of the comments received on the ANPR. It is the Commission's belief that the regulation proposed here is one which is both generic, for licensing, and this notice provides a flexible vehicle for accommodating [illegible] ... points out a [illegible] and calls for comment on a number of critical issues. The Commission has prepared an analysis of the comments which explains the changes made from the ANPR and intends to publish soon the comments and the analysis as a NUREG document. A draft of this NUREG has been placed in the Commission's Public Document Room for review. In addition, the staff has [illegible] a document to [illegible] the [illegible] that is [illegible] ... demonstrating compliance with the requirements of the proposed rule.

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and processes that might affect the performance during the containment period.

Although both the radiation from and heat generated by the decay of the wastes have diminished about 3 orders of magnitude during the containment period, the area surrounding the emplaced wastes will not return to temperatures near those before the wastes were emplaced until after about 10,000 years. As mentioned earlier, the thermal disturbance of the area near the emplaced wastes adds significantly to the uncertainties in the calculation of the transport of the radionuclides through the geologic environment. The technical criteria are intended to compensate for uncertainties by imposing further design requirements on the waste package and underground facility, thereby limiting the source term by controlling the release rate.

Role of the Site

The Commission neither intends nor expects either containment to be lost completely at 1,000 years following emplacement or the engineered system's contribution to the control of the release of wastes to cease abruptly at some later time. However the Commission recognizes that at some point the design capabilities of the engineered system will be lost and that the geologic setting—the groundwater—must provide the isolation of the wastes from the environment, and has translated this requirement into a performance objective for the geologic setting. The Commission also recognizes that isolation is, in fact, a controlled release to the environment which could span many thousands of years, and that the release of radionuclides and the potential exposures to individuals which could result, should be addressed in the evaluation of a repository. A complement to the evaluation of the effects of design basis processes and events which might disrupt the repository is a projection of how the repository, unperturbed by discrete external events, will evolve through the elements as a result of the geologic processes operating at the site. Herein, an amendment is being proposed to that portion of Subpart B of 10 CFR Part 60 which describes the contents of the Safety Analysis Report of DOE's application for geologic disposal of HLW, which would require DOE to project the expected performance of the proposed geologic repository among the rates and quantities of expected releases of radionuclides to the accessible environment as a function of time.

Retrievability

The licensing procedures of 10 CFR Part 60 were written assuming that there would be a program of testing and measurement of the thermal, mechanical, and chemical properties of the waste engineered barriers to confirm their expected performance. The Commission would like to tie the requirement for retrievability of the wastes to the expected time needed to execute the performance confirmation program. However at present it appears to the Commission that neither the specific nature nor the period needed for execution of the performance confirmation program will be certain until construction of the repository is substantially complete, that is, until the actual licensing to receive wastes at a geologic repository. Hence it is difficult at this time to use the performance confirmation program as a basis for establishing a period of retrievability. Nonetheless, DOE is now making critical decisions regarding the design of geologic repositories which will have a direct effect upon how long the option to retrieve wastes can be maintained, and upon the difficulty which will be encountered in exercising that option, should that be necessary for protection of public health and safety. Therefore, to provide a suitable objective in this regard, the proposed rule sets forth a requirement that the engineered system be designed so that the option to retrieve the waste can be preserved for up to fifty years following completion of emplacement. Thus, the waste package and the underground facility would be designed so that the period of retrievability would not be the determinant of when the Commission would decide to permit closure of the repository. Rather, the Commission would be assured of the option to let the conduct of the performance confirmation program indicate when it is appropriate to make such a decision. In particular, the Commission is concerned that the thermo-mechanical design of the underground facility be such that access can be maintained until the Commission either decides to permit permanent closure of the repository or to take corrective action, which may include retrieval.

As it is now structured, the rule would require in effect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years. The components of this total period are as follows: the first waste packages to go in the repository are likely to be in place about thirty years before all wastes are in place; thereafter, a 50 year period is required by the rule; finally, a retrieval schedule is suggested of about the same time as the original construction plus emplacement operations—another 30-odd years. Since it is probably not practical to adjust the retrievability design aspects of the repository according to the order of emplacement of the waste packages, the 110 year requirement will apply to all of the waste. The Commission is particularly interested in comments on the degree to which this requirement will govern the thermal and mechanical design of the repository and on whether some shorter period would be adequate or whether there are other ways than an overall retrievability requirement to preserve options before permanent closure. The Commission does not want to approve construction of a design that will foreclose unnecessary options for future decisionmakers, but it is also concerned that retrievability requirements not unnecessarily complicate or constrain repository design.

The retrievability requirement does not specify the form in which the wastes are to be retrievable or that wastes are "readily retrievable." The requirement is simply that all the wastes be retrievable during a period equal to the period of construction and emplacement. DOE's plans for retrieval are specifically requested as part of the License application and the practicability of its proposal will be considered by the Commission. Waste may be retrieved upon NRC approval of a DOE application or upon order by NRC, or otherwise, where authorized by DOE's license.

Human Intrusion

Some concern has been raised on the issue of human intrusion into a geologic repository. Human intrusion could conceivably occur either inadvertently or deliberately. Inadvertent intrusion is the accidental breaching of the repository in the course of some activity unrelated to the existence of the repository, e.g., exploration for or development of resources. For inadvertent intrusion to occur, the institutional controls, site markers, public records, and societal memory of the repository's existence must have been ineffective or have ceased to exist. Deliberate or intentional intrusion, on the other hand, assumes a conscious decision to breach the repository, for example, in order to recover the high-level waste itself, or to exploit a mineral associated with the site.

Historical evidence indicates that there is substantial continuity of

[illegible]

"Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands and including at a minimum that area subject to a one percent or greater chance of flooding in any given year.

"Geologic repository" means a system for the disposal of radioactive waste in excavated geologic media. A geologic repository includes (1) the geologic repository operations area, and (2) the geologic setting.

"Geologic repository operations area" means an HLW facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" or "site" is the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste.

"High-level radioactive waste" or "HLW" means (1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

"HLW facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat. 1244).

"Host rock" means the geologic medium in which the waste is emplaced.

"Important to safety," with reference to structures, systems, and components, means those structures, systems, and components that provide reasonable assurance that [illegible] can be [illegible] without undue risk to the health and safety of the public.

"Indian Tribe" means an Indian tribe as defined in the Indian Self-Determination and Education Assistance Act [illegible]

[illegible]

"Medium" or "geologic medium" is a body of rock characterized by [illegible] homogeneity.

"Overpack" means any buffer material, receptacle, wrapper, box or other structure that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

"Public Document Room" means the place at 1717 H Street NW., Washington, D.C., at which records of the Commission will ordinarily be made available for public inspection and any other place, the location of which has been published in the Federal Register, at which public records of the Commission pertaining to a particular geologic repository are made available for public inspection.

"Radioactive waste" or "waste" means HLW and any other radioactive materials other than HLW that are received for emplacement in a geologic repository.

"Site" means the geologic setting.

"Site characterization" means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic repository, but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken.

"Stability" means that the nature and rates of natural processes such as erosion and faulting have been or are projected to be such that their effects will not jeopardize isolation of the radioactive waste.

"Subsurface facility" means the underground portion of the geologic repository operations area [illegible]

[illegible]

[illegible] shafts, boreholes, and their seals.

"Unrestricted area" means any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

"Waste form" means the radioactive waste materials and any encapsulating or stabilizing materials, exclusive of containers.

"Waste package" means the airtight, watertight, sealed container which includes the waste form and any anchors, enclosures, including shielding, discrete backfill and overpacks.

3. Section 60.10 is revised to read as follows:

§ 60.10 Site characterization.

(a) Prior to submittal of an application for a license to be issued under this part the DOE shall conduct a program of site characterization with respect to the site to be described in such application.

(b) Unless the Commission determines with respect to the site described in the application that it is not necessary, site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced.

(c) As provided in § 51.40 of this chapter, DOE is also required to conduct a program of site characterization, including in situ testing at depth, with respect to alternative sites.

(d) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

(2) As a means [illegible], the location of exploratory boreholes and shafts shall be selected so as to limit the total number of subsurface penetrations above and around the underground facility.

(3) To the extent practical [illegible]

[illegible]

[illegible]

[illegible] such as (1) [illegible] mining [illegible] (2) [illegible] rights of way, and (3) all other rights [illegible] under lease rights of [illegible] good [illegible] mortgage, [illegible] or otherwise.

(2) *Establishment of controls.* Appropriate controls shall be established outside of the geologic repository operations area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the site or engineered system's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

Additional Requirements for the Geologic Setting

§ 60.122 Favorable conditions.

Each of the following conditions may contribute to the ability of the geologic setting to meet the performance objectives relating to isolation of the waste. In addition to meeting the mandatory requirements of § 60.112, a geologic setting shall exhibit an appropriate combination of these conditions so that, together with the engineered system, the favorable conditions present are sufficient to provide reasonable assurance that such performance objectives will be met.

(a) The nature and rates of tectonic processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(b) The nature and rates of structural processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(c) The nature and rates of hydrogeological processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(e) The nature and rates of geomorphic processes that have occurred since the start of the Quaternary period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(f) A host rock that provides the following groundwater characteristics—(1) low groundwater content, (2) inhibition of groundwater circulation in the host rock, (3) inhibition of groundwater flow between hydrogeologic units or along shafts, drifts, and boreholes, and (4) groundwater travel times, under pre-waste emplacement conditions, between the underground facility and the accessible environment that substantially exceed 1,000 years.

(g) Geochemical conditions that (1) promote precipitation or sorption of radionuclides, (2) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides, and (3) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(h) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having increased capacity to inhibit radionuclide migration.

(i) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(j) Any local condition of the disturbed zone that contributes to isolation.

§ 60.123 Potentially adverse conditions.

The following are potentially adverse conditions. The presence of any such conditions may compromise site suitability and will require careful analysis and such measures as are necessary to compensate for them adequately pursuant to § 60.124.

(a) *Adverse conditions in the geologic setting.*

(1) Potential for failure of existing or planned man-made surface water impoundments that could cause flooding of the geologic repository operations area.

(2) Potential, based on existing geologic and hydrologic conditions, that planned construction of large-scale surface water impoundments may significantly affect the geologic repository through changes in the regional groundwater flow system.

(3) Potential for human activity to affect significantly the geologic repository through changes in the hydrogeology. This activity includes, but is not limited to planned groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage facilities, or underground military activity.

(4) Earthquakes which have occurred historically that if they were to be repeated could affect the geologic repository significantly.

(5) A fault in the geologic setting that has been active since the start of the Quaternary Period and which is within a distance of the disturbed zone that is less than the smallest dimension of the fault rupture surface.

(6) Potential for adverse impacts on the geologic repository resulting from the occupancy and modification of floodplains.

(7) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could affect the performance of the geologic repository through changes in the regional groundwater flow.

(8) Expected climatic changes that would have an adverse effect on the geologic, geochemical, or hydrologic characteristics.

(b) *Adverse conditions in the disturbed zone.* For the purpose of determining the presence of the following conditions within the disturbed zone, investigations should extend to the greater of either the calculated extent or a horizontal distance of 2 km from the limits of the underground facility and from the surface to a depth of 300 meters below the limits of the repository excavation.

(1) Evidence of subsurface mining for resources.

(2) Evidence of drilling for any purpose.

(3) Resources that have either greater gross value, net value, or commercial potential than the average for other representative areas of similar size that are representative of and located in the geologic setting.

(4) Evidence of extreme erosion during the Quaternary Period.

(5) Evidence of dissolutioning of soluble rocks.

(6) The existence of a fault that has been active during the Quaternary Period.

(7) Potential for creating new pathways for radionuclide migration due to presence of a fault or fracture zone irrespective of the age of last movement.

(8) Structural deformation such as uplift, subsidence, folding, and fracturing during the Quaternary Period.

(9) More frequent occurrence of earthquakes or earthquakes of higher

[illegible] personnel during an emergency.

[illegible] The [illegible] shall be designed to [illegible] so that [illegible] response to emergency conditions and that facilitate the use of [illegible] services such as [illegible] and ambulance service [illegible] from emergencies.

[illegible] services.

[illegible] Each [illegible] service system shall be designed so that essential safety functions can be performed under both normal and emergency conditions.

[illegible] The [illegible] services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

[illegible] The emergency utility services shall be designed to permit testing of their functional operability and capacity. This shall include the full operational sequence of each system when transferring between normal and emergency supply sources as well as the operation of associated safety systems.

[illegible] Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and [illegible] emergency power is provided to instruments, utility service systems and operating systems, including alarm systems. This emergency power shall be sufficient to allow safe conditions to be maintained. All systems important to safety shall be designed to permit them to be maintained at all times in a functional mode.

(7) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance as necessary, to ensure their continued functioning and readiness.

(8) *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and [illegible] of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor [illegible] must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(9) *Instrumentation and control systems.* Instrumentation and control systems shall be designed to monitor and control the behavior of engineered systems important to safety over anticipated ranges for normal operation and for accident conditions. The systems shall be designed with sufficient redundancy to ensure that adequate margins of safety are maintained.

(10) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

§ 60.131 Additional design requirements for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the site, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility. The surface facilities shall be designed so as to permit inspection, repair, and decontamination of such wastes and their containers. Surface storage capacity is not required for all emplaced waste.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111.

(c) *Radiation control and monitoring.*—(1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal and emergency operations. The facilities shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111.

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decommissioning.

§ 60.132 Additional design requirements for the underground facility.

(a) *General criteria for the underground facility.*

(1) The underground facility shall be designed so as to perform its safety functions assuming interactions among the geologic setting, the underground facility, and the waste package.

(2) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of § 60.111.

(3) The orientation, geometry, layout and depth of the underground facility and the design of any engineered barriers that are part of the underground facility shall enhance containment and isolation of radionuclides to the extent practicable at the site.

(4) The underground facility shall be designed so that the effects of disruptive events such as intrusions of gas or water, or explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments, where necessary, to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Separation of excavation and waste emplacement (mining concurrent).* If concurrent excavation and emplacement of wastes are planned, then:

(1) The design shall provide for such separation of activities into discrete areas (modules) as may be necessary to assure that excavation does not impair waste emplacement or retrieval operations.

(2) *Shaft and borehole seals.* Shaft and borehole seals shall be designed so that:

(1) Shafts and boreholes will be sealed as soon as possible after they have served their operational purpose.

(2) At the time of permanent closure, sealed shafts and boreholes will inhibit transport of radionuclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. In the case of soluble rocks, the borehole and shaft seals shall also be designed to prevent groundwater circulation that would result in dissolution.

(3) Contact between shaft and borehole seals and the adjacent rock does not become a preferential pathway for water.

(4) Shaft and borehole seals can accommodate potential variations of stress, temperature, and moisture.

(5) The materials used to construct the seals are appropriate in view of the geochemistry of the rock and groundwater system, anticipated deformations of the rock, and other in situ conditions.

(e) *Shaft conveyances used in radioactive waste handling.*

(1) Shaft conveyances used to transport radioactive materials shall be designed to satisfy the requirements as set forth in § 60.130 for structures and components important to safety.

(2) Hoists important to safety shall be designed to preclude cage free fall.

(3) Hoists important to safety shall be designed with a reliable cage location system.

(4) Hoist loading and unloading systems shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(5) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place, grappled, and ready for transfer.

§ 60.134 Construction specifications for surface and subsurface facilities.

(a) *General requirements.* Specifications for construction shall conform to the objectives and technical requirements of §§ 60.130 through 60.133.

(b) *Construction management program.* The construction specifications shall facilitate the conduct of a construction management program that will ensure that construction activities do not adversely affect the suitability of the site to isolate the waste or jeopardize the isolation capabilities of the underground facility, boreholes, shafts and seals, and that the underground facility is constructed as designed.

(c) *Construction records.* The construction specifications shall include requirements for the development of a complete documented history of repository construction. This documented history shall include at least the following—

(1) Surveys of underground excavations and shafts located via readily identifiable surface features or monuments.

(2) Materials encountered.

(3) Geologic maps and geologic cross sections.

(4) Locations and amount of seepage.

(5) Details of equipment, methods, progress, and sequence of work.

(6) Construction problems.

(7) Anomalous conditions encountered.

(8) Instrument locations, readings, and analyses.

(9) Location and description of structural support systems.

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

(d) *Rock excavation.* The methods used for excavation shall be selected to reduce to the extent practicable the potential to create a preferential pathway for groundwater or radioactive waste migration or increase migration through existing pathways.

(e) *Control of explosives.* If explosives are used, the provisions of 30 CFR 57.6 (Explosives) issued by the Mine Safety and Health Administration, Department of Labor, shall be met as minimum safety requirements for storage, use and transport at the geologic repository operations area.

(f) *Water control.* The construction specifications shall provide that water encountered in excavations shall be removed to the surface and controlled in accordance with design requirements for radiation control and monitoring (§ 60.131(c)).

(g) *Waste handling and emplacement.* The construction specifications shall provide for demonstration of the effectiveness of handling equipment and systems for emplacement and retrieval operations under operating conditions.

Waste Package Requirements

§ 60.135 Requirements for the waste package and its components.

(a) *General requirements of design.* The design of the waste package shall include the following elements:

(1) *Effect of the site on the waste package.* The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(2) *Effect of the waste package on the underground facility and the natural barriers of the geologic setting.* The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the performance of the underground facility or the geologic setting. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) *Waste form requirements.* Radioactive waste that is emplaced in the underground facility shall meet the following requirements:

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall have been consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) *Combustibles.* All combustible radioactive wastes must have been reduced to a noncombustible form unless it can be demonstrated that a fire involving a single package will neither compromise the integrity of other packages nor adversely affect any safety-related structures, systems, or components.

(c) *Waste package requirements.* The waste package design shall meet the following requirements:

(1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials that could interfere with operations in the underground facility or compromise the ability of the geologic [illegible] to satisfy the [illegible] objectives.

[illegible]

CONSUMER PRODUCT SAFETY COMMISSION

16 CFR Part 1700

Human Prescription Drugs in Oral Dosage Forms; Proposed Exemption From Child-Resistant Packaging of All Unit Dose Forms of Potassium Supplements Containing Not More Than 50 Milliequivalents of Potassium Per Unit-Dose

AGENCY: Consumer Product Safety Commission.

ACTION: Proposed rule.

[illegible]

Subpart H—Training and Certification of Personnel

[illegible]

DOCKET NUMBER PR-[illegible]
PROPOSED RULE (46 FR 35280)

(87)

'82 [illegible] -8 [illegible]

Acknowledged by card... [illegible] 4/9/82

April 1, 1982

Dear Director of the
Nuclear Regulatory Commission,

I am very opposed to the opening, finishing, licensing, creating of any nuclear power plant anywhere. We do not want radioactive materials produced. We do not want radioactive waste produced. We do not want nuclear weapons. We want healthy children, healthy water, healthy earth and soil, healthy food. Only help to bless the world with peace.

God bless you & help all the countries of the world to have a nuclear freeze. All the countries should stop where they are at a certain date, ceasing production of nuclear radioactive materials in power plants etc.

Very sincerely,
[illegible] P. Wing
for me and my children and all people I know who are opposed.

DOCKET NUMBER
PROPOSED RULE PR-60
(46FR35280)

1516 San Pedro
Las Vegas, NV 89104
April 2, 1982

Nuclear Regulatory Commission
Washington, DC 20520

While politicians, environmental groups, scientists, and anyone else seeking publicity argue over where to dump high-level nuclear wastes, I'm inclined to believe that burial, which leads to the contamination of the Earth on which we all live and exist, is not the only answer to nuclear waste disposal. I am not an authority on radiation or nuclear waste, and I am not an environmentalist - I am a concerned and very worried citizen who believes in mankind and will do his best to make sure that we do not destroy ourselves and the generations to come.

I suggest that special containers for high-level nuclear waste, dangerous chemicals, and other harmful substances be designed that can replace the warheads of nuclear rockets or I.B.M.'s in missile sites around the country. These rockets can then be fired in a trajectory aimed at the sun, there to be destroyed forever. The knowledge, technical facilities, and financing are available to make this suggestion work. In addition, this procedure could create more jobs to boost the economy and would have an overwhelming effect on the well being of the people of the world.

Some people will consider me a crackpot and completely ignore this whole idea. However, to date there has been no satisfactory solution to nuclear waste disposal, and I believe my suggestion is entirely feasible.

Your serious consideration and study of this proposal would be appreciated because the human race has a right to live as long as God will let us and public servants have an obligation to the people to investigate every avenue possible to insure the well being of the human race.

I would appreciate hearing your comments, pro and con, concerning this proposal.

Sincerely,

Robert Montgomery

Robert Montgomery

Acknowledged by card....... J.S.T. 4/9/82

CORRECTION NOTIFICATION

To Recipients of PR-60 (46 FR 35280) - Disposal of High-Level Radioactive Wastes in Geologic Repositories

Comment No. 86 was miscoded. The number will not be used again.

Docketing and Service Branch
Office of the Secretary

6/14/82

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

August 16, 1982

'82 [illegible]

Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555

(89)
PR-60
(46 FR 35280)

Dear Dr. Palladino:

SUBJECT: PROPOSED REGULATION ON DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

During its 268th meeting on August 12-14, 1982, the ACRS discussed the status of the draft regulation, "Disposal of High Level Radioactive Wastes in Geologic Repositories," 10 CFR 60. This matter was also discussed with the NRC Staff at a meeting held by our Subcommittee on Waste Management on June 8, 1982.

As you know, we submitted a report to you on September 16, 1981 concerning an earlier version of these regulations that appeared in the Federal Register on July 8, 1981. Our latest meetings with the NRC Staff indicate that they have given detailed consideration to our comments. In particular, we endorse the change in approach in which the disposal of transuranic wastes in a repository will be considered by the Commission on a case-by-case basis.

A new concern, however, is the proposed change in the definition of the "accessible environment" as it relates to the potential impact of radioactive wastes placed in a repository. Although the Staff stated that this change was suggested to make the rule compatible with current concepts within the U.S. Environmental Protection Agency, it appears this goal was not achieved. We believe that the proposed NRC definition is vague and would make difficult the confirmation of acceptable performance by the operator of a disposal facility. We are particularly concerned how compliance with the required 1000-year groundwater travel time to the accessible environment can be verified under the proposed definition. We suggest reconsideration of the original definition. In a similar manner, we believe that the suggested redefinition of the "waste package" to exclude clay backfill may make it more difficult to determine compliance with the 1000-year containment requirement.

We trust these comments will be helpful. Please note that they are made on the basis of our understanding of the draft regulations as submitted by the Staff to the Commission on July 7, 1982 in SECY-82-288.

Sincerely,

P. Shewmon

P. Shewmon
Chairman

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352 6611 Telex [illegible]

'82 OCT 13 P3:07

October 5, 1982

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Mr. William J. Dircks
Executive Director
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

(90)
DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Dear Mr. Dircks:

Representatives of the American Nuclear Society met with you, Victor Stello, John Davis and other NRC staff members on September 10, 1982. The purpose of the meeting was to present ANS's initial reaction, from a technical perspective, to the July 29, 1982 version of 10CFR Part 60 (Technical Criteria for Geologic Repositories for High-Level Radioactive Waste), including NRC staff Recommendations and the technical Rationale Document. At the meeting, ANS reiterated its general position on proposed 10CFR Part 60 to NRC on October 14, 1981:

> "ANS strongly recommends that all numerical subsystem performance requirements be deleted in favor of more general statements permitting system trade-offs to achieve the desired overall system or repository performance". And,

> "It is our concerted view that overly restrictive and specific performance standards are not necessary, and that such standards in regulation form are likely to add to the overall cost of the waste disposal without achieving any degree of benefit to the public health and safety. Instead, using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. The application of such a single performance standard would not only coincide with the Environmental Protection Agency's recommended approach of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing site and geologic medium characteristics".

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Additionally, we expressed our concern about NRC staff's rejection of the overall system or repository standard approach (similar with EPA's) which was recommended by ANS and other technical specialists and organizations. There was a broad general technical consensus on this point which seems to have been inadequately considered by the NRC without substantive technical justification.

While ANS had a relatively brief period to review the July 30, 1982, technical Rationale Document prior to the September 10, 1982, meeting, knowledgeable ANS members on this subject are in general agreement that the numerical subsystem performance standards (now "objectives") cited in the proposed regulation have not been technically justified. Further, we believe it will be very difficult, if not impossible, for the NRC to technically justify any variation from these numerical subsystem performance objectives on a "case-by-case" basis with these unmeasurable and technically unjustified values cited in the regulation.

With the preceding in mind, ANS strongly recommends NRC take the following actions before approving 10CFR Part 60:

- o Based on a preponderance of technical community opinion, including ANS, supporting a single, overall repository performance standard, NRC should reconsider the proposed numerical subsystem performance objectives in favor of more generalized design objective statements in the regulation.

- o NRC should submit technical rationale documentation for 10CFR Part 60 to a peer review by the technical community for the adequacy of analytical methodology, parameters, assumptions and conclusions.

Relative to the preceding, ANS has taken the following steps:

- o A technical paper is being prepared to present ANS and technical community views on the approaches used and material presented in the Rationale Document. This paper is scheduled to be completed and available on November 22, 1982, and would provide the basis for a technical presentation to the NRC staff and Commissioners.

- o A special peer review session on 10CFR Part 60 is being organized to be held during the ANS Winter Meeting (Nov. 14-18, 1982) in Washington, D. C.

The American Nuclear Society would [illegible] to meet with the Commission and the staff to assist in the development of a technically sound regulation.

Very sincerely,

L. Manning Muntzing
President
American Nuclear Society

LMM:DB:evm

(90)

PR-60
(46 FR 35280)

'82 [illegible] 10 [illegible]:35

[illegible]

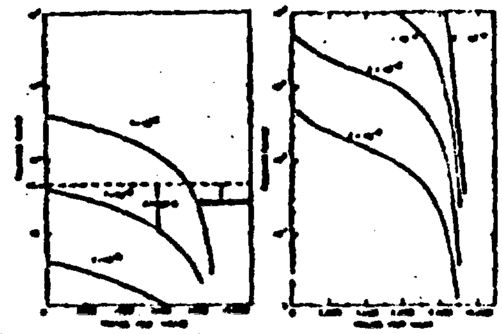
Table I. [illegible]

[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]

The effect of different canister lifetimes (t_c) ... on the release of nuclides in Group I is shown in Fig. 4. Note that if a constant release rate ... groundwater travel time greater than 100 years is assumed, ... the presence of canister has little effect on releases.

Temperature dependence of the release rate of radionuclides from waste form has been demonstrated in laboratory studies. This temperature dependence can be converted to a time dependence. In Fig. 5 the results of similar calculations on the effect of canister lifetimes are shown when a time-dependent release rate is used. For our calculations we arbitrarily assumed a release rate of [illegible] from 0 to 100 yr. after closure of the repository, [illegible] between 100 yr. and 500 yr., and [illegible] thereafter. When this release behavior is assumed, the significance of canister lifetime becomes apparent. Effort is underway to collect realistic data for time (temperature) dependent release rates.

Fig. 1 Fig. 2



Release Ratio Curves for Group I Radionuclides. r = Release Rate (yr^{-1}), Canister Lifetime = 1,000 Yr.

Release Ratio Curves for Group II Radionuclides. r = Release Rate (yr^{-1}), Canister Lifetime = 1,000 Yr.

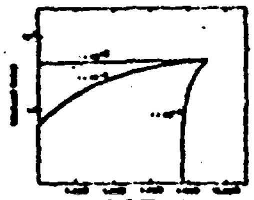


Fig. 3 "Hot Spot" Release Ratio Curves for Group II Radionuclides.

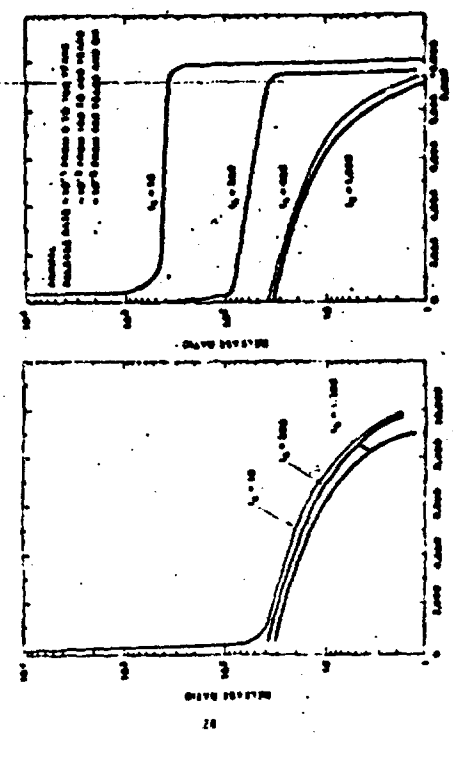


Fig. 4 Effect of Different Canister Lifetimes (t_c) for Release Rate = 10^{-5} yr^{-1}.

Fig. 5 Effect of Different Canister Lifetimes (t_c) for a Time-Dependent Release Rate.

Parametric Analysis Including Geochemical Retardation for Basalt

There are large uncertainties associated with many of the input parameters used in modeling the performance of a real waste isolation system. In our models, these uncertainties are treated by:

1) Assigning a probability distribution to the range of values for each parameter.
2) Dividing the input parameter ranges into finite intervals of equal probability.
3) Computing the consequence (using our model) for combinations of input values selected by the Latin-Hypercube Sampling technique (LHS)[?].

With this scheme, the uncertainties of input are reflected as a range of output values (consequences). The results are presented in a plot which shows the fraction of calculations with release ratio greater than some value.

In this analysis three sets of calculations were performed for an inventory of 1 000 MTHM of spent-fuel. Each set of calculation involves a parametric variation of one of the performance objectives of 10CFR60. Ranges of all other parameters were divided into 25 intervals and sampled by LHS. A computation was performed to calculate the release ratio for each combination of input variables. Ranges of retardation for each radionuclide in the inventory were chosen from the published data to represent the range of chemical retardation in a reducing basalt environment. The detailed geologic properties of a basalt site are not considered. Calculations were performed for several values of the groundwater travel time from the underground facility to the discharge location. The dispersivity was sampled over a range of 10-100 ft. The release rate was constant with respect to time for each calculation. The input data for each set of calculations are summarized in Table II.

TABLE II

SET	CANISTER LIFETIME (yr)	RELEASE RATE (yr^{-1})	GROUNDWATER TRAVEL TIME (yr)
1	100 300 500 1,000	[illegible]	(10^3 - 10^5)
2	300	[illegible]	300 500 1,000 5,000
3	300	[illegible]	(10^3 - 10^5)

Figures 6 through 8 present the results of these calculations. In these figures, the curves indicate the fraction of calculation results in release ratios greater than the value on the abscissa. In Fig. 6 it can be seen that the waste containment period has little effect on compliance. Longer groundwater travel times and slower release rates result in a reduction in release as demonstrated by the shifting of the curves to the left in Figs. 7 and 8.

Parametric analysis for a Hypothetical Basalt Site

These calculations were based on a hypothetical basalt site with the stratigraphy shown in Fig. 9. Ranges of hydraulic properties and retardation factors for radionuclides were assigned to each unit based on its postulated lithology and mineralogy respectively. Figures 10 and 11 show the two scenarios considered in this analysis. The first scenario is a base case (routine) release scenario; the second scenario involves fracturing the dense basalt unit that contains the underground facility. In these calculations 100 combinations of input values were sampled from the data ranges, producing 100 consequences for each scenario. Two canister lifetimes (100 and 1,000 yrs.) and two release rate

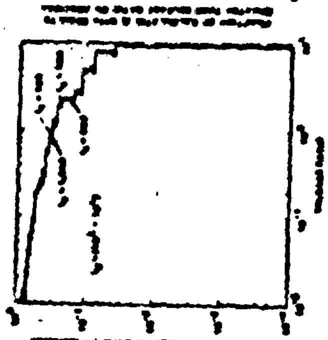


Fig. 6

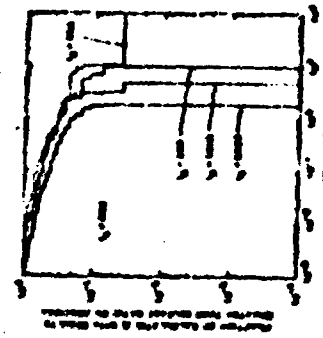


Fig. 7

Fraction versus Release Ratio Curves for a Generic Basalt Site. T_c = Canister Lifetime (yr), r = Release Rate, T_g = Groundwater Travel Time (yr).

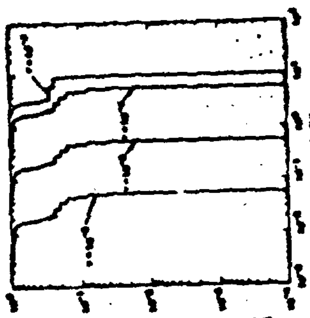


Fig. 8 Fraction versus Release Ratio Curves for a Generic Basalt Site. Canister = 300 Yr., r = Release Rate, T_g = Groundwater Travel Time.

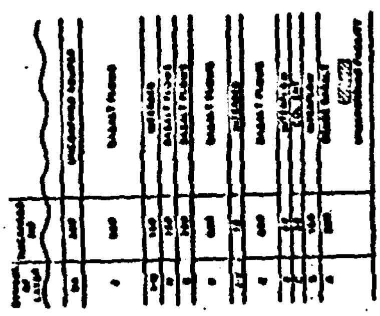


Fig. 9 Stratigraphic Cross-section of Hypothetical Repository in Basalt.

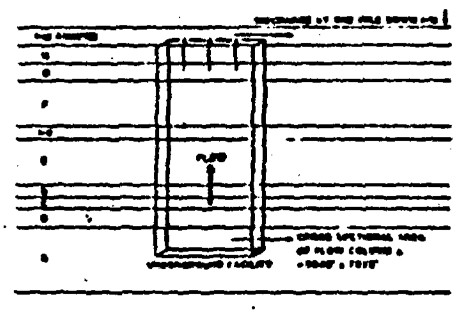


Fig. 10 Routine Release Scenario in a Hypothetical Basalt Site.

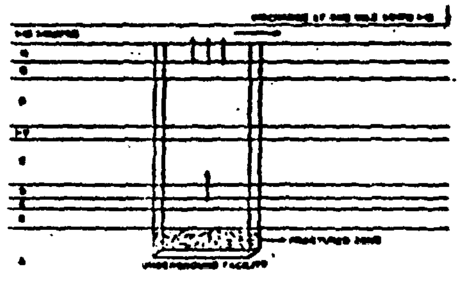


Fig. 11 Fractured Dense Basalt Scenario in a Hypothetical Basalt Site.

ranges [illegible] and [illegible] yr^{-1}) were considered. Figures 10 and 11 show the results of these calculations for Scenarios [illegible] and [illegible] respectively. These results are similar to those obtained from the generic parametric analyses. It can be seen that varying the lifetime of the canister has a minor effect on the shape or position of the fraction-release rate curves when a temperature independent release rate is assumed. Variations in the groundwater travel time caused by choice of scenario or variability in hydrologic or geochemical parameters significantly affect the curves. Variation in the range of sampled release rates also has a strong effect on these curves. The shifting of these curves to the left could be interpreted as an increase in the safety margin with respect to compliance.

<u>Summary and Comments</u>

In these preliminary analyses, the ability of the three numerical criteria in 10CFR60 to facilitate compliance with the EPA draft standard was examined. It was found that the waste containment period had minor importance in assisting compliance with the EPA draft standard, if the release rate of radionuclides is independent of time (temperature). However, the waste containment period will have a significant impact if the release rate changes significantly with time (temperature). In the latter case, the [illegible] of the waste containment period, or the time period at which radionuclide release could occur, may have a significant impact in meeting the EPA draft standard.

It was noticed that for relatively large release rates ([illegible] yr^{-1}) and if some radionuclides were unretarded by the geo-media (e.g., [illegible] and [illegible]), these radionuclides alone could violate the EPA standard unless compensated by a good site (e.g., long groundwater travel time). For relatively smaller release rates ([illegible] yr^{-1}) compliance with the EPA draft standard could be obtained if the site exhibited a minimum retardation factor for those radionuclides which could be released. In the present draft of 10CFR60, geochemical retardation of radionuclides is addressed only by non-quantitative (soft) requirements. In this study, minimum retardation factors were calculated for simple generic sites and for several combinations of groundwater travel time, release rate and canister lifetime.

The criterion on groundwater travel time showed a significant effect on compliance with the EPA draft standard. Sites with relatively long groundwater travel times will help in meeting the

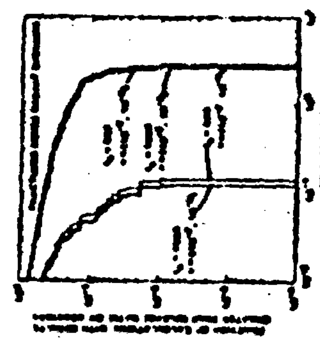


Fig. 10

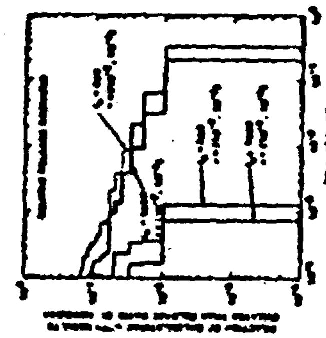


Fig. 11

EPA draft standard. It is interesting to note that for very short waste containment periods (Figs. 4 & 5), the release ratio versus groundwater travel time curves show a large change in slope near 1,000 year groundwater travel time. This implies that in the event of premature failure of canisters, a site would have to have about 1,000 years groundwater travel time to prevent massive releases of radionuclides.

The 10CFR60 rule defines discrete minimum values for the performance objectives (technical criteria) in regulating the risk involved in HLW isolation. However, the characteristics of natural systems and the performance of engineered systems cannot be described without a degree of uncertainty. The calculations described in this paper demonstrate a method to estimate the impact on compliance with the EPA draft standard from uncertainties in the input data. Similar analyses can be performed to estimate the impact on compliance with the EPA draft standard from other interpretations of the performance objectives. For example, the values of the technical criteria may be set equal to the lower limit or the mean of a probability distribution which describes the engineered system performance or the natural variability of the site.

It is important to note that 10CFR60 also contains "soft" (non-quantitative) requirements described as favorable conditions and potentially adverse conditions for the geologic setting. These requirements shall be considered together with the numerical criteria in assessing the impact of 10CFR60 in reducing the risk and/or uncertainty in meeting the EPA draft standard. The above conditions intend to guide the applicant in selecting a site that protects the health and safety of the public. For example, compliance with these requirements could help to reduce the probability of having scenarios (e.g., faults, volcanic activity) which could lead to radionuclide releases to the accessible environment. An assessment of the impact of these requirements on compliance with the EPA draft standard will be performed.

REFERENCES

1. "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," 40CFR191, Draft #19, March 1981.

2. "Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste," 10CFR60, July 1981.

3. Campbell, J.E., et al., 1980, "Risk Methodology for Geologic Disposal of Radioactive Waste: The Distributed Velocity Method of Solving the Convective-Dispersion Equation," SAND80-[illegible], NUREG/CR-1376, Sandia National Laboratories, Albuquerque, NM.

4. [illegible], J. and [illegible], 1980, <u>Scientific Basis for Nuclear Waste Management</u>, Vol. 3: [illegible].

5. Iman, R. L., et al., 1980, "Latin Hypercube Sampling (Program User's Guide)," SAND79-1473, Sandia National Laboratories, Albuquerque, NM.

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352-6611

November 1, 1982

DOCKET NUMBER PR-60
PROPOSED RULE (46 FR 35280)

The Hon. N. J. Palladino
The Hon. James K. Asselstine
The Hon. Thomas M. Roberts
The Hon. John F. Ahearne
The Hon. Victor Gilinsky

I understand that you will have Part 60 Regulations under consideration in the near future.

Therefore, enclosed is a recent letter that I sent to Mr. William J. Dircks.

Very sincerely,

L. Manning Muntzing

LMM:evm
Enclosure

AMERICA NUCLEAR SOCIET
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352-6611

October 5, 1982

Mr. William J. Dircks
Executive Director
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Dircks:

Representatives of the American Nuclear Society met with you, Victor Stello, John Davis and other NRC staff membe on September 10, 1982. The purpose of the meeting was to pre ANS's initial reaction, from a technical perspective, to the '29, 1982 version of 10CFR Part 60 (Technical Criteria for Geologic Repositories for High-Level Radioactive Waste), incl ing NRC staff Recommendations and the technical Rationale Doc ment. At the meeting, ANS reiterated its general position on proposed 10CFR Part 60 to NRC on October 14, 1981:

> "ANS strongly recommends that all numerical subsyst performance requirements be deleted in favor of mor general statements permitting system trade-offs to achieve the desired overall system or repository pe formance". And,

> "It is our concerted view that overly restrictive a specific performance standards are not necessary, a that such standards in regulation form are likely t add to the overall cost of the waste disposal witho achieving any degree of benefit to the public healt and safety. Instead, using current engineering pra tices, a carefully sited, engineered, and designed repository coupled with effective confirmation and sign validation can assure compliance with a single overall performance criterion for the repository as whole system. The application of such a single per formance standard would not only coincide with the Environmental Protection Agency's recommended appro of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing and geologic medium characteristics".

Additionally, we expressed our concern about NRC staff's rejection of the overall system or repository standard approach (similar with EPA's) which was recommended by ANS and other technical specialists and organizations. There was a br general technical consensus on this point which seems to have been inadequately considered by the NRC without substantive technical justification.

While ANS had a relatively brief period to review th July 29, 1982, technical Rationale Document prior to the Septe ber 10, 1982, meeting, knowledgeable ANS members on this subje are in general agreement that the numerical subsystem perform standards (now "objectives") cited in the proposed regulation have not been technically justified. Further, we believe it be very difficult, if not impossible, for the NRC to technica justify any variation from these numerical subsystem performa objectives on a "case-by-case" basis with these unmeasurable technically unjustified values cited in the regulation.

With the preceding in mind, ANS strongly recommends take the following actions before approving 10CFR Part 60:

- o Based on a preponderance of technical community opinion, including ANS, supporting a single, overal repository performance standard, NRC should reconsi the proposed numerical subsystem performance object in favor of more generalized design objective state ments in the regulation.

- o NRC should submit technical rationale documentat for 10CFR Part 60 to a peer review by the technical community for the adequacy of analytical methodolog parameters, assumptions and conclusions.

Relative to the preceding, ANS has taken the following steps:

- o A technical paper is being prepared to present ANS and technical community views on the approaches used and material presented in the Rationale Document. This pape is scheduled to be completed and available on November . 1982, and would provide the basis for a technical presen tation to the NRC staff and Commissioners.

- o A special peer review session on 10CFR Part 60 is being organized to be held during the ANS Winter Meeting (Nov. 14-18, 1982) in Washington, D. C.

The American Nuclear Society would be pleased to meet with the Commission and the staff to assist in the development of a technically sound regulation.

Very sincerely,

L. Manning Muntzing
President
American Nuclear Society

LMM:DB:evm

OCT 2 1 1982

PR-60

'82 NOV -7 P3:15

Mr. L. Manning Muntzing
President
American Nuclear Society
555 North Kensington Avenue
LaGrange, Illinois 60525

DOCKET NUMBER
PROPOSED RULE PR-60
(46 FR 35280)

Dear Mr. Muntzing:

Thank you for your letter of October 5, 1982 drawing to our attention the continued concerns the American Nuclear Society (ANS) has with the numerical criteria set forth in the proposed rule--10 CFR Part 60--"Disposal of High-Level Radioactive Wastes in Geologic Repositories: Technical Criteria," and with a subsequent draft version of the revised rule dated July 29, 1982.

The U.S. Nuclear Regulatory Commission (NRC) is aware of, and sensitive to, the issues relating to the adoption of the numerical criteria which were raised by public commenters on the proposed rule (46 FR 35280). I want to assure you that the concerns and recommendations of the ANS will be considered prior to the issuance of final technical criteria. To that end, I have arranged for your October 5, 1982 letter to be docketed with the comment letters received on the proposed rule.

NRC appreciates the interest the ANS has shown during the development of the technical criteria for 10 CFR Part 60.

Sincerely,

Signed William J. Dircks

William J. Dircks
Executive Director for Operations

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone 312/352-6611 Telex 254635

'82 NOV -7 P3:15

November 1, 1982

The Hon. N. J. Palladino
The Hon. James K. Asselstine
The Hon. Thomas M. Roberts
The Hon. John F. Ahearne
The Hon. Victor Gilinsky

I understand that you will have Part 60 Regulations under consideration in the near future.

Therefore, enclosed is a recent letter that I sent to Mr. William J. Dircks.

Very sincerely,

L. Manning Muntzing

L. Manning Muntzing

LMM:evm
Enclosure

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue LaGrange Park Illinois 60525 USA
Telephone 312 352 6611 Telex 254635

October 5, 1982

Mr. William J. Dircks
Executive Director
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Dircks:

Representatives of the American Nuclear Society met with you, Victor Stello, John Davis and other NRC staff members on September 10, 1982. The purpose of the meeting was to present ANS's initial reaction, from a technical perspective, to the July 29, 1982 version of 10CFR Part 60 (Technical Criteria for Geologic Repositories for High-Level Radioactive Waste), including NRC staff Recommendations and the technical Rationale Document. At the meeting, ANS reiterated its general position on proposed 10CFR Part 60 to NRC on October 14, 1981:

"ANS strongly recommends that all numerical subsystem performance requirements be deleted in favor of more general statements permitting system trade-offs to achieve the desired overall system or repository performance". And,

"It is our concerted view that overly restrictive and specific performance standards are not necessary, and that such standards in regulation form are likely to add to the overall cost of the waste disposal without achieving any degree of benefit to the public health and safety. Instead, using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. The application of such a single performance standard would not only coincide with the Environmental Protection Agency's recommended approach of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing site and geologic medium characteristics".

Additionally, we expressed our concern about NRC staff's rejection of the overall system or repository standard approach (similar with EPA's) which was recommended by ANS and other technical specialists and organizations. There was a broad general technical consensus on this point which seems to have been inadequately considered by the NRC without substantive technical justification.

While ANS had a relatively brief period to review the July 29, 1982, technical Rationale Document prior to the September 10, 1982, meeting, knowledgeable ANS members on this subject are in general agreement that the numerical subsystem performance standards (now "objectives") cited in the proposed regulation have not been technically justified. Further, we believe it will be very difficult, if not impossible, for the NRC to technically justify any variation from these numerical subsystem performance objectives on a "case-by-case" basis with these unmeasurable and technically unjustified values cited in the regulation.

With the preceding in mind, ANS strongly recommends NRC take the following actions before approving 10CFR Part 60:

- o Based on a preponderance of technical community opinion, including ANS, supporting a single, overall repository performance standard, NRC should reconsider the proposed numerical subsystem performance objectives in favor of more generalized design objective statements in the regulation.

- o NRC should submit technical rationale documentation for 10CFR Part 60 to a peer review by the technical community for the adequacy of analytical methodology, parameters, assumptions and conclusions.

Relative to the preceding, ANS has taken the following steps:

- o A technical paper is being prepared to present ANS and technical community views on the approaches used and material presented in the Rationale Document. This paper is scheduled to be completed and available on November 22, 1982, and would provide the basis for a technical presentation to the NRC staff and Commissioners.

o A special peer review session on 10CFR Part 60 is being organized to be held during the ANS Winter Meeting (Nov. 14-29, 1982) in Washington, D. C.

The American Nuclear Society would be pleased to meet with the Commission and the staff to assist in the development of a technically sound regulation.

Very sincerely,

L. Manning Muntzing

L. Manning Muntzing
President
American Nuclear Society

LMM:DD:evb

A-395

(91)

DOCKET NUMBER PR-60
PROPOSED RULE (46 FR 35280)

DOCKETED

'82 OCT 29 P4:13

Department of Energy
Washington, D.C. 20585

OCT 29 1982

MEMORANDUM FOR Honorable Nunzio J. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

On July 29, 1982, the Department of Energy met with the NRC staff in an open meeting to discuss the proposed final draft of 10 CFR Part 60. Others who had participated in the rulemaking proceeding were also invited to this meeting.

Draft copies of the final Rule and "Rationale for Performance Objectives in 10 CFR Part 60" were distributed. Based upon those documents and discussions at that meeting, it is clear that a number of basic Department concerns are not being adequately addressed by the NRC staff as it proceeds with the development of the Rule. Accordingly, I am writing to advise the Commission directly that the Department has serious difficulties with certain aspects of the Rule as now written, despite extensive discussions with NRC staff management and the apparent accommodations of our concerns.

The Department's major concern with the proposed Rule, which has been noted in our comments and in those of other reputable reviewers, is the inclusion of ad hoc numerical design requirements for subsystems (individual barriers). Because the degree to which a repository contains radionuclides over time is the ultimate test of its adequacy, we believe the Rule should be based on and derived from an overall system performance objective, as were the curie release limits which have been proposed by EPA in their draft Standard. Instead, the Rule centers on the imposition of performance requirements for individual components that are neither derived from nor related to an overall system performance objective.

Further, inclusion in the Rule of numerical performance requirements for individual barriers will, because of the difficulties in demonstrating compliance, significantly complicate the licensing process and add needless expense of the disposal of high-level waste. The NRC has issued drafts for public review and comment twice, first on May 13, 1980, and again on July 8, 1981. In response, the Department and other concerned parties have expressed reservations about the NRC's approach. These comments, however, have not been fully addressed by the NRC staff, perhaps partially because of a failure to appreciate the potential licensing pitfalls involved.

In its current form the Rule still contains rigid, numerical requirements for individual components that are not justified. For example, the Rule states in section 60.113(a)(1)(ii)(A):

> "Containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission."

The NRC staff position is that the phrase "or such other period as may be approved or specified by the Commission" sufficiently addresses the Department's concern that the 1,000-year period constitutes a firm requirement. We, however, cannot agree: As a practical matter, case-by-case approvals of deviations from specific numerical requirements are almost never granted, require extensive litigation, and, accordingly, are not a realistic alternative to compliance with specific numerical criteria.

We are seriously concerned over the numerical requirements prescribed in 60.113 for components in the Rule for three reasons. First, we believe that the need to demonstrate compliance will unnecessarily complicate and prolong the licensing process. Simply determining the requirements necessary for demonstrating a 1,000-year waste package, for example, is likely to consume considerable time. Secondly, the requirements in the Rule are not technically justifiable. For example, as discussed in our previous comments on the proposed Rule, a long lived (1,000-year) waste package makes no measurable contribution toward protecting the health and safety of the public. The third reason for concern is that of unnecessary cost. The cost of a very long-lived waste package--and exotic, very low release rate waste forms, which also appear to be required by the Rule--would needlessly add to the expense of the disposal of the Nation's waste.

In addition, we have found that the NRC staff's "Rationale" document, which accompanies the draft Rule and sets forth the staff's bases for the requirements it contains, does not, in fact, support the specific requirements in the Rule. During their presentation to the Commission on the proposed Rule, the NRC staff acknowledged that the imposition of the numerical values will not in and of themselves ensure that the proposed EPA Standards will be met. The geologic conditions in the repository must provide a measure of protection from premature radionuclide release. In assessing the effectiveness of the geology, however, minimal credit was allowed because of assumed conditions which were seriously flawed compared to geologic options the Department is investigating.

Enclosed are excerpts from the comments of others on the NRC Rule. You can see that the Department is not alone in taking a position against the specific design requirements included in the proposed Rule. Even one of the NRC staff's principal contractors, Sandia National Laboratories, has stated "If a constant release rate and a groundwater travel time greater than approximately 500 years is assumed, then the presence of [a] canister has little effect on releases."

We understand that on November 2, 1982, the NRC staff is scheduled to brief the Commission on alternative procedures to finalize the technical criteria portion of 10 CFR 60. Given our concerns with the requirements of the Rule as presently drafted, we urgently request an opportunity to present to the Commission our concerns and to suggest alternatives which we believe will significantly improve the Rule. Unfortunately, senior members of DOE management will be out of the country on November 2. Consequently, we request that the Commission reschedule the NRC's staff presentation to a mutually convenient time. Additionally, we request that the Commission defer any action on this matter until we have had an opportunity to present our concerns to the Commission.

Thank you for your consideration of our request. I am sure that we can work together to develop a useful, technically sound rule.

Sincerely,

Shelby T. Brewer

Shelby T. Brewer
Assistant Secretary
for Nuclear Energy

Enclosure

cc:
John F. Ahearne, Commissioner
James Asselstine, Commissioner
Victor Gilinsky, Commissioner
Thomas Morgan Roberts, Commissioner

Enclosure

SUMMARY OF OTHER PARTICIPANTS' COMMENTS

I. SYSTEMS APPROACH

Many commentors supported the systems approach to performance assessment and suggested elimination of subsystem performance requirements. A few of these comments are quoted below.

NRC Advisory Committee on Reactor Safeguards

". . . we believe that the licensee should be given a greater degree of flexibility for compliance with the overall safety goal. One approach would be to emphasize the fact that the NRC will be evaluating the anticipated performance of the total waste repository as a system, in contrast to the performance of its individual components. Since we foresee only one or two repositories being built within the next several decades, we believe that each should be evaluated in relation to overall performance on a case-by-case basis."

American Nuclear Society

"... . ANS strongly recommends that all subsystem numerical performance requirements be deleted in favor of more general statements permitting system trade-offs to achieve the desired overall system or repository performance. Specifically, the following values should be deleted:

1000-Year Waste Package Life (Section 60.111(b)(2))
10 Long-Term Release Rate (Section 60.111(b)(2)(ii)(A))
1000-Year Undistrubed Water Travel Time (Section 60.112(c))
50-Year Retrieval Time (Section 60.111(a)(2))"

"It is our concerted view that overly restrictive and specific performance standards are not necessary, and that such standards in regulation form are likely to add to the overall cost of waste disposal without achieving any degree of benefit to the public health and safety. Instead, using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. The application of such a single performance standard would not only coincide with the Environmental Protection Agency's recommended approach of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing site and geologic medium characteristics."

Utility Nuclear Waste Management Group

". . . the NRC barrier performance objectives approach, as embodied in the current proposed regulations, can only be viewed as the arbitrary imposition, on individual system components, of special-value standards that are without scientific or other technical support."

". . . we cannot agree that the inclusion of such component requirements will increase the ability to show compliance with an overall system performance requirement (e.g., EPA protection standards), since such a showing will necessarily involve the use of mathematical models independent of specific component performance requirements."

"UNWMG is firmly of the view that overall repository performance should be addressed directly by means of the systems approach. Utilization of an overall performance standard would correctly serve to focus attention on total repository performance. In addition, it would provide for appropriate design flexibility; something which is important in order to both be able to take advantage of new developments, as this new undertaking proceeds, and to accommodate and effectively utilize the specific characteristic of individual sites."

National Research Council/National Academy of Sciences

"The BRWM (Board on Radioactive Waste Management) questions the adequacy of the proposed numerical criteria to accomplish these (their) purposes." . . . "Specifically, our conclusions regarding the proposed numbers are as follows:

1. NRC has not presented adequate evidence that these numerical criteria can "support a finding of no unreasonable risk to the health and safety of the public" . . .
2. NRC has not shown that these numerical criteria are either necessary or sufficient to meet the "EPA Standard." . . .
3. It has not been shown that adoption of the numerical criteria will simplify the licensing process . . .
4. No attempt has been made to demonstrate the technical validity of the proposed criteria. . .
5. NRC has not shown how the proposed numerical criteria for the waste package can be verified . . ."

". . . we recommend that precise numerical criteria for major elements of the repository system be eliminated."

II. 1000-YEAR WASTE PACKAGE

The NRC received many technical comments questioning the validity of the 1000-year waste package containment requirement. A few of the comments are quoted below.

Lawrence Livermore Laboratory

"The zero-released containment limit as proposed by the Commission is not necessary because more reliance can and should be placed on the other barriers . . ." "In addition, it should be recognized that small releases are not intolerable, in view of the vast inventory of naturally-occuring radionuclides in the earth's crust . . ." "The containment time proposed by the Commission is not reasonable because the function of the waste package should be to provide containment primarily during handling and shipping, including possible retrieval, not long-term containment."

American Nuclear Society

"The requirement for a 1,000-year containment period by engineered barriers is grossly excessive and unsupported by scientific fact." "NRC claims that the basis for the choice of 1,000 years is mainly that the heat induced by the waste in the geologic medium will increase the waste package leachability and reduce the near-field transport time, with the net result that the radiological source term from the "distrubed zone" increases. NRC does not argue that the 1,000-year containment period is necessary to reduce the overall radiological release to man's environment to an acceptable level."

It is agreed that the postulated release from the underground facility would be accelerated due to resulting higher temperatures in the geologic medium but, generally, the calculational models used do not take credit for any holdup or delay of radionuclines in the region of relatively higher temperatures. Rather, the radiological source term for the far-field transport models are derived directly from the waste package release rate as if the heated geologic medium region or "distrubed zone" did not exist. Thus, any acceleration of release from the underground facility due to temperature effects has already been discounted and, therefore, should not be used to penalize the waste package design."

Dr. T. H. Pigford, University of California at Berkeley

Dr. Pigford has prepared a detailed analysis of the NRC's proposed 1,000-year waste package containment period. Seven areas were analyzed: (1) the NRC's purpose; (2) the importance of 1,000-year containment to overall performance; (3) temperatures assumed by the NRC; (4) temperature effects; (5) extrapolation from current knowledge; (6) compliance verification; and (7) cost estimate.

Dr. Pigford summarizes:

"The above analysis shows that NRC's proposed criterion that the radionuclides be confined within the waste package for 1,000 yr is without adequate on valid technical foundation, is based upon questionable assumptions, and may not be important to long term public health and safety. There is no showing by NRC that the proposed criterion is necessary or sufficient for NRC's stated purposes."

Environmental Protection Agency

"Although we strongly support the multiple barrier approach, we think that the 1000 year waste package requirement may be excessive. Studies published by the Electric Power Research Institute (EPRI) and confirmed by EPA indicate that in almost all situations improvements in canister life are less important for reducing long-term risks than improvements in waste form or careful selection of site characteristics. If the waste package lasted only a few hundred years, it would guard against uncertainties during the period of greatest heat generation, however, the 1000-year life requirement for the waste package could necessitate the use of very expensive or exotic materials (such as titanium) for waste canisters. The supporting documentation for the rule does not consider the potential cost of this requirement. In light of the relatively small benefits and possible high cost, we believe the Commission should reexamine this requirement."

Institute of Electrical and Electronics Engineers

"The 1000-year requirement for Waste Package integrity would probably be unduly restrictive in cases where engineered barriers are available and/or groundwater travel times are longer than 1000 years. In addition, it may be prohibitively difficult and expensive to fabricate waste packages that will remain intact for 1000 years, and impossible to provide assurance that the requirement will be met."

III. RELEASE RATE REQUIREMENT

The NRC proposed release limit of one part in 100,000 per year was also disputed by most of the technically qualified commentors.

Dr. T. H. Pigford, University of California at Berkeley

"The numerical specification of a fractional release rate of 10^{-5}/yr is of questionable importance to long-term safety and is proposed without a technically valid basis and with invalid assumptions of existing technology and cost if such a numerical criterion were adopted, compliance could probably not be verified. It would be more appropriate for NRC to state the considerations which may help guide DOE in its development and proof of the waste package as one of the possible barriers that may aid in meeting whatever safety standards that emerge."

Dr. H. P. Ross, Geophysical Consultant

"The one part in 100,000 release requirement for the engineered system again will be impossible to verify and ignores the positive features of a good geologic site to contain or delay transport of radionuclides. The requirement as stated requires engineering overkill for a single component of the system which will be unnecessarily costly and still impossible to verify. Sorption, long travel paths, and dilution all tend to offset the effects of release from the engineered system."

IV. 1,000-Year Groundwater Travel Time

Several commentors disagreed with the 1,000-year groundwater travel time requirement.

Dr. T. H. Pigford, University of California at Berkeley

"NRC has not shown need or adequate technical basis for its proposed numerical criterion for water travel time. It would be more appropriate for NRC to state its considerations of water travel time as a contributor to overall safety performance. It would be appropriate for DOE to have the flexibility to select sites with water travel times sufficient so that, in combination with the other properties of the site and of the engineering design, there will be reasonable assurance that a regulatory specified overall performance standard will be achieved."

Institute of Electrical and Electronics Engineers

"Placing the requirement on water travel time, rather than on radionuclide travel time, may, in effect, result in focusing on an implicit assumption that no retardation occurs. This is another compounding conservatism."

V. INTERNATIONAL COMMENTS

Agencies from two countries, the Netherlands and the United Kingdom, were concerned about the performance criteria proposed by the NRC.

Netherland Energy Research Foundation

" . . . there should be only one approach for setting performance criteria for a high-level waste repository. That approach should be the prescription of a single performance standard for the overall disposal system." . . . "It is only by means of an iterative process of safety assessment and regulatory system improvement that the relative importance of the different components to the overall system can be evaluated."

"At least for a carefully designed HLW-repository in salt the waste package is therefore not a key component of the overall engineered system . . ."

"The restrictive containment or confinement of the radioactive waste to the waste package is an irrational requirement. The boundary of confinement can easily be shifted more outward without any consequences from the point of view of radiological hazard to man and his environment."

Department of the Environment, United Kingdom

"Document 10 CFR 61 illustrates the setting of overall performance objectives whilst allowing some flexibility in designing and operating each individual repository, whereas document 10 CFR 60 appears to set acceptance criteria not always justified by technical evidence."

"The rule has been developed in the absence of radiological protection criteria (environmental standards), for disposal of high-level wastes; the proposed technical criteria are, therefore, arbitrary. This approach to setting technical criteria is incorrect in principle. It leads to criteria which are inflexible because, since they have no clear basis, there can be no basis for changing them. In addition the approach is very likely to lead to criteria which are too restrictive, thus causing more expenditure on high-level waste disposal than is warranted by radiological protection consideration."

"The rule does not define in any detail the means by which compliance with performance objectives is to be demonstrated. As a consequence the proposed performance objectives have little meaning and it is very difficult to decide whether they are appropriate or achievable."

". . . the proposed rule is unsatisfactory and should not be adopted in its present form. It would be preferable to leave the rule in "proposed" form until the EPA standards have been published and until there is sufficient information available to derive technical criteria from these standards. The rule should then be revised."

"We feel that too many firm numbers are being laid down without sufficient experimental and theoretical justification. Particularly if disposal will not take place for many years it is better to set overall dose limits to define the required performance of the multiple barrier. It is then up to designers to optimize the individual elements in the system as models and experimental data are improved over the years. The proposed rule would freeze options too soon."

STATE OF WISCONSIN

RADIOACTIVE WASTE REVIEW BOARD

82 DEC 22 AIO :26

December 7, 1982

(92)

PR-60 (46 FR 35280)

U.S. Nuclear Regulatory Commission
Washington, DC 20555

Re: NRC Rulemaking--10CFR60, Technical Criteria for Geological Repositories

Gentlemen:

The State of Wisconsin Radioactive Waste Review Board strongly objects to the attempt made by the United States Department of Energy to eliminate the 1000 year containment criterion for high level waste packaging. This action comes well after the comment period has ceased. Should the Nuclear Regulatory Commission consider revising its rule in accordance with the Department of Energy request, the State Radioactive Waste Review Board demands that the Commission reopen its rulemaking to allow further comment from interested parties regarding the Department of Energy proposal. The department's attempt to unilaterally influence the current rulemaking after-the-fact is legally indefensible and may require legal action should such a procedure be adopted by the Commission.

Sincerely,

Patrick Walsh

Patrick Walsh
Executive Director
Wisconsin Radioactive Waste Review Board

PW:tab/821112/4

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA

#93

PR-60 (46 FR 35280)

January 24, 1983

Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Chairman Palladino:

The American Nuclear Society has reviewed the proposed technical rule of 10CFR Part 60 and its Rationale Document (July 30, 1982) as prepared by the Commission staff. The attached paper reports the review and the Society's Statement of Position.

After review of the proposed technical rule, 10CFR Part 60, and its Rationale Document (July 30, 1982), the American Nuclear Society concludes that the numerical standards on the performance of a nuclear waste repository proposed by the Nuclear Regulatory Commission (NRC) in sections 113 (a)(1)(ii)(A), 113 (a)(1)(ii)(B) and 113 (a)(2) of 10CFR Part 60 are technically indefensible, are premature in advance of the Environmental Protection Agency's (EPA's) generally applicable standards for releases of radioactivity from a repository, are inappropriate in their generic application to any and all prospective geologic media and sites, and are structured in such a way as to add to the overall cost of waste disposal without achieving any degree of relative benefit to public health and safety.

[illegible]
[illegible]
[illegible]

It is the position of the Society that nuclear wastes must be managed and disposed of in a manner that preserves the public well being, including public health and safety as well as financial burden. Further, the Society is of the concerted view that all regulatory and developmental activities pursuant to a nuclear waste repository must be technically, legally and procedurally comprehensive and defensible, in order to assure protection of the public well being and to secure the confidence of the public that their well being is indeed protected.

The Society would be pleased to pursue our findings and their rationale with the Commission and staff.

Very sincerely,

L. Manning Muntzing, President

LMM:evm
Enclosures

cc: Commissioner John F. Ahearne
Commissioner James K. Asselstine
Commissioner Victor Gilinsky
Commissioner Thomas M. Roberts
Mr. William J. Dircks

REVIEW

AND

STATEMENT OF POSITION

OF THE

AMERICAN NUCLEAR SOCIETY

ON THE

PROPOSED TECHNICAL RULE

10CFR PART 60

AND

RATIONALE DOCUMENT

(JULY 30, 1982)

OF THE

NUCLEAR REGULATORY COMMISSION

January 1983

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REVIEW AND STATEMENT OF POSITION OF THE AMERICAN NUCLEAR SOCIETY ON THE PROPOSED TECHNICAL RULE 10CFR PART 60 AND RATIONALE DOCUMENT (July 30, 1982) OF THE NUCLEAR REGULATORY COMMISSION

The American Nuclear Society has reviewed the proposed technical rule of 10CFR Part 60 and its rationale Document (July 30, 1982) as prepared by the Commission staff. This document reports the review and the Society's Statement of Position.

I. SUMMARY

After review of the proposed technical rule, 10CFR Part 60, and its Rationale Document (July 30, 1982), the American Nuclear Society concludes that the numerical standards on the performance of a nuclear waste repository proposed by the Nuclear Regulatory Commission (NRC) in sections 113 (a)(1)(ii)(A), 113 (a)(1)(ii)(B) and 113 (a)(2) of 10CFR Part 60 are technically indefensible, are premature in advance of the Environmental Protection Agency's (EPA's) generally applicable standards for releases of radioactivity from a repository, are inappropriate in their application to any and all geologic media and sites, and are structured in such a way as to add to the overall cost of waste disposal without achieving any degree of benefit to public health and safety. It is the position of the Society that nuclear wastes must be managed and disposed of in a manner that preserves the public well being, including public health and safety as well as financial burden. Further, the Society is of the concerted view that all regulatory and developmental activities pursuant to a nuclear waste repository must be technically, legally and procedurally comprehensive and defensible, in order to assure protection of the public well being and to secure the confidence of the public that their well being is indeed protected.

II. INTRODUCTION

The American Nuclear Society has undertaken a review of the NRC proposed technical rules and Rationale Document for the technical criteria of a geologic, high-level radioactive waste repository, and has formed a statement of position. This review was undertaken to determine the technical propriety and defensibility of the proposed rules.

The review of the numerical requirements of the proposed rule examines the rationale of the NRC staff in proposing each numerical value, the defensibility of the staff's conclusions, and the implications of the proposed rule. The review is based upon the July 2, 1982 draft of the rule, and the June 30, 1982 rationale document authored by the staff, which were made public by NRC on July 29, 1982 at an NRC public briefing held in Germantown, MD. The review focuses upon three numerical requirements contained in Section 113 of 10CFR Part 60. The evaluations in this review were based on three criteria:

(1) The adequacy with which the public's health and safety were protected by the proposed technical rule numerical requirements.

(2) The reasonableness of the cost/benefit to meet these requirements.

(3) The quality of the technical basis of the requirements.

The chronology of key events leading to the completion of this review is listed below.

- December 6, 1979 - NRC publishes draft procedural rules of 10CFR Part 60 for public comment.
- February 25, 1981 - NRC publishes final procedural rules of 10CFR Part 60.
- July 8, 1981 - NRC published draft technical rules of 10CFR Part 60.
- October 14, 1981 - ANS transmits written comments to NRC on draft technical rules (see Appendix A).
- July 29 1982 - NRC staff makes public its proposed final technical rule with technical Rationale Document.
- September 10, 1982 - Representatives of ANS meet with NRC staff to express ANS initial technical assessment of proposed final technical rule and its technical Rationale Document.
- October 5, 1982 - ANS transmits to NRC letter comments on proposed technical rule and Rationale Document (see Appendix B).
- January, 1983 - ANS completes its technical review and statement of position on the proposed final technical rule.

III. REVIEW CONCLUSIONS AND RATIONALE

It is the conclusion of the ANS review of the proposed final technical rule of 10CFR Part 60 that the three numerical standards specified in Sections 113 (a)(1)(ii)(A), 113 (a)(1)(ii)(B) and 113 (a)(2) are: (1) technically indefensible, (2) premature in advance of EPA's generally applicable standards for releases of radioactivity from a repository, (3) inappropriate in their application to any and all geologic media and sites, (4) structured in such a way as to potentially constrain the ability to design and fabricate or construct waste packages and repositories that have a realistic

cost/benefit to public health and safety. The three above-referenced sections of 10CFR Part 60 specifies (1) the minimum waste package life, (2) the acceptable rate of release of radionuclides from the engineered system, and (3) the minimum groundwater travel time at the repository site. Specific review comments on these three sections in the proposed technical rule are presented in the discussion that follows.

The American Nuclear Society concludes that the numerical subsystem performance objectives are technically indefensible. The Society believes that all regulatory and developmental activities associated with nuclear power and nuclear waste repositories must be founded on a basis that will withstand the strictest technical review. In the case of the three numerical subsystem performance objectives, the Society believes that technically defensible objectives for overall repository performance must be established and then numerical design criteria calculated from these objectives. The NRC acknowledges that its responsibility is to implement the generally applicable environmental standards established by EPA. This acknowledgement is made by the NRC in the Federal Register on February 25, 1981, and reiterated in the NRC staff's 10CFR Part 60 Rationale Document of June 30, 1982. Indeed, in the staff discussion accompanying the Rationale Document (Enclosure A, Page 5), recognition is given to the "extensive" criticism to the approach of establishing numerical subsystem performance objectives in the NRC's proposed technical rule:

> While the usefulness of multiple barriers was recognized, the establishment of fixed numerical values for performance was extensively criticized. The criticism took two forms. First, numerous commenters argued that until such time as an EPA standard is established, no logical connection can be demonstrated between the performance of the particular standard. The second criticism was that the performance appropriate to a particular barrier is greatly dependent upon design features and site characteristics and that values such as those proposed by the Commission could unduly restrict the applicant's flexibility - possibly imposing great additional expense without compensating protection of public health and safety.

However, review of the NRC's rationale for the three numerical standards reveals that the NRC standards are neither derived from nor assure compliance with the draft EPA standards. The NRC staff position implicitly acknowledges this finding when it states (Rationale Document, page 48),

> ...we [the NRC staff] consider numerical requirements for containment, controlled release, and groundwater flow time which, if met, will contribute to meeting it" [the EPA standard, draft 19 of proposed 40CFR Part 191]. (emphasis added)

The Society's review has also found that the NRC staff has not based its numerical subsystem performance objective on any overall performance requirement for a repository. Further, the rationale for all three standards are subjectively based upon reasoning that could lead to many alternate conclusions, other than those arrived at by the NRC staff. For example, based on the reasoning used by the Commission staff, a waste package lifetime range of 100 to 10,000 years might be specified with equal defensibility as the 1000-year requirement.

The second conclusion of the review is that the NRC's proposed numerical requirements are premature in advance of the EPA standards. As presented above, the NRC acknowledges its responsibility to implement the standards established by EPA. That responsibility was established through the President's Reorganization Plan No. 3 of 1970, and is reaffirmed in the Nuclear Waste Policy Act of 1982. The NRC staff acknowledges some consideration of EPA draft 19 of 40CFR Part 191 in developing its numerical requirements. However, at the time the NRC staff made public its rationale report, the EPA had issued two additional drafts (at least for internal review) which were different from draft 19, which NRC considered. Further, the EPA on December 29, 1982, published for comment its draft 40CFR Part 191 which has standards that are yet different from any considered by NRC. It should be noted that draft 19 of 40CFR Part 191 differs significantly from the December 29, 1982 version, and raises the question of technical compatability between NRC staff rationale for 10CFR Part 60 with the latest version of 40CFR Part 191. Also, Congress has directed the NRC to assure that its regulations are consistent with and implement EPA's standards. Such consistency cannot be attained by NRC if it develops its regulations while the EPA standard is open for public comment. Thus, it is clearly premature for NRC to promulgate the three numerical requirements at this time.

The third review conclusion of the Society is that it is inappropriate to develop and apply regulations on repository subsystem performance that do not reflect inherent differences in geologic media and sites under consideration. The three leading prospects for the first repository are the basalt site at Hanford, the tuff site at the Nevada Test Site, and a site in salt in either Utah, Texas, Louisiana or Mississippi. Each site will be selected so as to protect man's environment by preventing any significantly radionuclide contaminated groundwater contacting humans in concentrations which are hazardous to their health. However, each site is hydrologically very unique in comparison to others. The basalt site is fractured and saturated. Within a very few years after closure, waste packages may be immersed in water as the repository resaturates. Radiologic protection will be provided by low radionuclide solubility in groundwaters large mass transfer resistances outside the waste form, long travel times to man's environment, and sorption provided by the natural geochemistry of the site. In selected salt formations, water is virtually precluded from flowing through the repository because after closure large masses of salt would have to be dissolved before external water could come into contact with the waste. The waste form characteristics and the sorption provided in the natural surroundings provides isolation from man's environment. The tuff repository site will likely be in the unsaturated zone of Yucca Mountain. In order for a release to man's environment to occur, rain water would be required to flow downward to the waste form, flow further downward to the water table, and be transported to man's environment. Again, the same type of retarding mechanisms discussed above will add protection to this system. In another medium, granite, it is possible that in some fractures, very small quantities of water could move quickly over long distances. However, the quantities of flow can be exceedingly small. Any releases would be inhibited by mechanisms such as sorption, corrosion resistance and solubility. Thus, while the principal of isolation is constant, and while each medium and site can be required to achieve a common, acceptable level of performance in terms of human radiation dose, the strengths of certain designs, site specifications and rock types are lost if general numerical subsystem requirements are applied to the subsystems or all rock types and sites in a generic manner.

In spite of the fact that U.S. high-level waste management and geologic disposal program is examining a number of geologic media, the Nation is only likely to have two or three repositories for the foreseeable future. Therefore, the selected sites will have specific individual charateristics and repository design problems will have a variety of engineering methods that can be applied which should be stressed for cost/benefit in protecting public health and safety, rather than some preselected generic numerical value, as in the proposed rule.

The final conclusion of the Society's review is that the three numerical requirements are structured in such a way as to potentially limit the ability to engineer a repository that protects the public health and safety at a rational and acceptable cost for the realized benefits. The review has found that implementation of the regulations may require large expenditures because of the generic application of groundwater travel time, as well as because of imprecisions in the language applying that numerical subsystem performance requirement. Further, the review has found that large expenditures in engineering and construction may be required because of performance requirements on the engineered system.[1] Indeed, overall cost optimization would be essentially impossible with generic numerical requirements specified for the component performances. The Society is not convinced, nor does the NRC staff provide support that the requirements which may be exceedingly costly to implement are necessary to preserve the public health and safety, nor that the requirements necessarily even substantially contribute to improved public health and safety.

With regard to the different hydrologic nature of the candidate repository geologies and site, the intent of the proposed NRC rule concerning minimum acceptable pre-emplacement water travel time may be difficult to meet. Moreover, the requirement is stated in a very imprecise manner in which the bounds of the travel time determination are set from the extent of the

[1] For example, it is clear that a waste package with a design lifetime of 1000 years will be substantially more costly than a package with a 100 year design lifetime.

"disturbed zone" to the "accessible environment". The "disturbed zone" is defined such that it could be in the very near proximity to the repository excavation, or it could intersect the "accessible environment". This requirement and its imprecision, if interpreted in the strictest sense, could force an intensive and perhaps futile siting effort. Yet the NRC staff does not demonstrate that this requirement is, by itself, a prerequisite to some level of public health and safety.

The requirements on the engineered system are that packages must survive with no leakage for at least 1000 years, and that following this period, one part in one hundred thousand of the radionuclide inventory may be released each year to the geologic setting. The NRC staff defends the 1000-year package life not because of public health and safety but because of the difficulties they assume in predicting performance when the waste is hottest.

The NRC selects 1000 years as the thermal period of concern with a "logic" that could equally well lead to a selection of a large range of values. Likewise, the 10^{-5} per year release limit is selected as an apparently reasonable number. However, the NRC staff analysis shows that it is not well founded, nor does it necessarily achieve the desired effect. Further, its selection and application to all radionuclides ignores the scientific knowledge base for radiation dosimetry, which is acknowledged by NRC in 10CFR Part 20, by treating all nuclides the same irrespective of their potential, individual impacts to the overall repository system performance. The consequence of these two requirements is that repositories may be designed at a large and excessive cost to meet standards which have no demonstrated foundation in protecting the public health and safety.

With regard to the preceding point, a significant change has occurred in the assumed thermal loading requirement for EPA's proposed 40CFR Part 191. Whereas EPA specified the disposal of "five-year old" high-level radioactive waste in earlier drafts of 40CFR Part 191, the December 29, 1982 version no longer specifies this requirement. Consequently, the waste form can be allowed to cool even further before geologic disposal. This practical mechanism, in addition to the option of further dilution of radionuclide concentrations in the fabrication of the waste form, brings into question the validity of the NRC staff's thermal assumptions in the analysis for the proposed 10CFR Part 60.

NRC has noted, and Congress has affirmed, that no environmental impact statement will be prepared for issuance of 10CFR Part 60. This decision will allow promulgation of this standard without public scrutiny of the real costs and benefits associated with it. The Society concludes that NRC still has a responsibility to enact responsible regulations which protect the public health and safety at a rationale and acceptable cost, and to make the accounting for that judgment available for technical and public review.

IV. CRITIQUE OF CONTAINMENT REQUIREMENT

Section 113(a)(1)(ii)(A) of 10CFR Part 60 establishes the following waste package containment requirement:

> [In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that] containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

The NRC does not base this requirement on meeting EPA standards but rather upon the belief that leach rates and transport mechanisms will be difficult to predict when temperatures in the repository are highest. The specification of 1000 years is based upon the following statement, excerpted from page 73 of the 10CFR Part 60 Rationale Document.

> <u>At about 1000 years</u>, the fission product contribution (to inventory and heat generation) either becomes extremely small or, having decreased dramatically up to that time, becomes relatively constant. Thus, on the basis of the fission product contributions to either radionuclide inventory in curies, to heat generation rate, or to hazard, <u>containment for about 1000 years appears to be appropriate</u>. Therefore, from the perspective of impact on repository performance, <u>a containment time of 1000 years</u>, with provision for flexibility, <u>is most appropriate</u> for dealing with uncertainties involved in assessing routine releases (emphasis added).

The Society believes that neither the rationale for imposing a containment period nor the logic for selecting one are technically sound. If the NRC is to justify a specific, numerical waste package containment requirement, it should show that anything less in time results in unacceptable performance from an overall isolation system perspective. In its Rationale Document, the NRC staff argues that leach rates probably cannot be predicted in "high" temperatures while canister lifetimes, under the same thermal, geochemical, the mechanical forces, "may be extrapolated with confidence". In contrast, studies, such as ONWI-286 and -352, show that delaying release initiation from the waste form has no impact on the potential, maximum doses to the public within the range of waste package lifetimes or containment periods being considered by the NRC. Therefore, the Society concludes that this numerical subsystem performance requirement should not be promulgated.

V. CRITIQUE OF RELEASE RATE REQUIREMENT

Section 113(a)(1)(ii)(B) of 10CFR60 imposes the following release rate requirement:

> [In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that]

the release rate of any radionuclide following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total annual release at 1000 years following permanent closure.

The NRC staff does not derive this limit in a technically rigorous manner, but rather determines that the value is able to contribute substantially to overall repository performance. In making this argument, the staff does not demonstrate that the value leads to compliance with an EPA standard. The staff likewise does not consider the impact of varying toxicities of individual radionuclides in a waste repository.

"The NRC staff does put forward an "uncertainty analysis" of repository performance to defend its selection of the 10^{-5} per year release limit. Table 4 of the 10CFR Part 60 Rationale Document presents the data ranges used in the uncertainty analysis. The ranges of input data used by the NRC are so large as to be without credibility. For example, the NRC staff asserts that the solubility limit for Neptunium ranges over eighteen orders-of-magnitude. The NRC staff provides no reference for this input data. Further, the NRC staff presents data distributions for its input parameters. However, neither does the staff present a defense for these input distributions, nor does it provide a reference for them. Further, DOE has not to date, to the knowledge of the Society put forward any such distributions. Thus without reference of defense, these values and distributions are viewed without validity. A final criticism of this input data is that it is doubtful that the NRC would issue a license for a site that had such a wide variation in predicted properties, nor such an indefensible analysis of site performance. Thus, it is not acceptable nor rational to establish regulations on the basis of an unacceptable level of input data and indefensible analysis."

"In interpreting its uncertainty analysis, the NRC staff implicitly asserts that a confidence level of 90% is satisfactory to determine acceptable repository performance. The Society applauds this step, provided the NRC will codify in the standard or in regulatory guidance, such a value (that is defensible) as an acceptable level of performance uncertainty in repository performance."

The Society believes that any proposed NRC regulation for releases of radionuclides from the engineered system must be firmly based upon the generally applicable environmental release standards of the EPA. The Society believes that the engineering and construction costs associated with meeting this proposed NRC regulation value are unnecessary because little to no credit is allowed to be taken for the radionuclide decay that will occur during sorptive holdup even if the radionuclides are released to the geologic setting. Thus, the Society concludes that this proposed numerical subsystem performance requirement should not be issued.

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VI. CRITIQUE OF PRE-EMPLACEMENT HYDROLOGY REQUIREMENT

In Section 113(a)(2) of 10CFR60, the following requirement is placed upon the candidate repository site.

> The geologic repository shall be located so that pre-waste emplacement groundwater travel time along the fastest of likely radionuclide travel from the distributed zone to the accessible environment shall be at least 1000 years, or such other travel time as may be approved or specified by the Commission.

The requirement for a minimum pre-emplacement groundwater travel time of 1000 years is the most ill-defined of the three values discussed in this review. The first difficulty is that the language of the requirement potentially has the impact of excluding any repository site in which heat-generating wastes are to be placed. This is because the requirement specifics that the 1000-year travel time be measured from the extent of the "disturbed zone" to the "accessible environment". The "disturbed zone" has a subjective definition that allows a large range of interpretations. Contractor studies for both NRC and DOE have shown that heat generated by wastes will result in uplift of the controlled zone at the surface in nearly all sites and geologies.[2] Further, NRC and DOE studies have shown that the thermal driving force from decaying wastes can alter the flow regime over a repository, and to the "accessible environment". Thus, narrowly interpreted, it could be argued that for a high-level waste repository, the "disturbed zone" and the "accessible environment" intersect. If this interpretation is made, then the travel time from the "disturbed zone" to the "accessible environment" is zero. While this interpretation was not the apparent intent of the NRC staff, once promulgated, only the words are codified, not their intent.

A more fundamental error with this proposed performance objective is that pre-emplacement groundwater travel time is, at best, a weak substitute for terms that are actually relevant to isolation of radioactive wastes and the protection of public health and safety. Release of radionuclides to man's environment is, mathematically, a function of (1) the release rate of nuclides from the engineered system to the geologic setting, (2) the volume flow rate of groundwater, (3) the hydraulic conductivity, (4) the effective porosity, the (5) the retardation factors for each radionuclide, which reflect sorption, reconcentration, and filtering. The speed of groundwater flow is not a direct factor in this equation, though obviously is a function of volume flow rate, hydraulic conductivity and porosity. The impact of applying this substitute measure as a regulatory requirement may be to exclude fractured rock from

[2] For example, see Appendix K of U.S. Department of Energy, "Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste", DOE/EIS-0046F, October 1980.

consideration. In some fractured rock, the actual amount of water present is very small, and the flow area of factures is also quite small. This may lead to very rapid flow speeds, accompanied by very small flow rates. While this numerical subsystem performance requirement leaves the Commission a means for accepting shorter pre-emplacement travel time, past practices of the Commission support the premise that adopting . . alternative position is unlikely.

The final problem with this numerical performance requirement standard is that it cannot be shown to have been derived from any version of 40CFR191. Nor can this value be defended as being necessary to meet any overall repository performance requirements. In the Society's view all numerical requirements related to overall repository performance must be defensible and shown to be necessary to meet performance requirements for the repository as a total system. The Society further concludes that if the NRC staff wishes to establish into regulation a minimum groundwater travel time, that the NRC must do so not only with the objective of meeting an overall repository system performance requirement, but with the cognizance that such a property will vary widely over otherwise acceptable sites. Clearly, this property is a site-specific characteristic.

VII. CONCLUSIONS AND RECOMMENDATIONS

The American Nuclear Society concludes that the three numerical subsystem performance objectives contained in Section 113 of the proposed final technical rules of 10CFR Part 60 are technically indefensible. The American Nuclear Society is concerned that the final issuance of these three numerical subsystem requirements by the NRC would be an error that would greatly handicap sound engineering and scientific practice in isolating nuclear wastes. Clearly, these performance objectives greatly limit the alternatives engineers have to optimize waste disposal systems in terms of public health and safety, environmental impact, cost and schedule. Therefore, the Society strongly urges the following:

(1) The NRC should not promulgate the above referenced sections of 10CFR60.113.

(2) The NRC should promulgate the balance of 10CFR Part 60, within the framework of our previous comments.

(3) The NRC should actively support the efforts of the EPA in finalizing 40CFR Part 191.

(4) The NRC should reexamine the need for geologic media-specific and subsystem performance objectives. If such subsystem performance objectives are needed and justified, they could be issued in regulatory guide form, rather than as numerical performance objectives in regulation form.

APPENDIX A

AMERICAN NUCLEAR SOCIETY
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October 14, 1981

Secretary of The Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Docketing and Service Branch
Room 1121
1717 H Street, N.W.

Gentlemen:

On behalf of the American Nuclear Society, I respectfully submit the Society's comments and position on the proposed rule, 10 CFR Part 60 (Technical Criteria for Disposal of High-Level Radioactive Waste in Geological Repositories). ANS has actively followed the progress of the rule-making with a technical support committee of interested and technically qualified members of the Fuel Cycle and Waste Management Technical Division. These official ANS comments and position were prepared and reviewed by members of the aforementioned Technical Division, a special committee of senior ANS members, and the Society's Executive Committee.

The American Nuclear Society respectfully submits that the proposed regulation should be withdrawn or, at a minimum, extensively revised. If it is withdrawn, we would hope that a substitute proposed rule would be developed expeditiously. Further, ANS strongly recommends that all subsystem numerical performance requirements be deleted in favor of more general statements permitting system trade-offs to achieve the desired overall system or repository performance. Specifically, the following values should be deleted:

- 1000-Year Waste Package Life [Section 60.111(b)(2)]
- 10^{-5} Long-Term Release Rate [Section 60.111(b)(2)(ii)(
- 1000-Year Undisturbed Water Travel Time [Section 60.11
- 50-Year Retrieval Time [Section 60.111(a)(2)]

Secretary of The Nuclear Regulatory Commission
October 14, 1981
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It is our concerted view that overly restrictive and specific performance standards are not necessary, and that such standards in regulation form are likely to add to the overall cost of waste disposal without achieving any degree of benefit to the public health and safety. Instead, using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. The application of such a single performance standard would not only coincide with the Environmental Protection Agency's recommended approach of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing site and geologic medium characteristics.

We would be pleased to discuss these comments further with the Commission and assist you in the development of appropriate, alternative criteria.

Sincerely,

Corwin L. Rickard

Corwin L. Rickard
President

cc: N. J. Palladino, Chairman
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PACIFIC LEGA
FOUNDATION

COMMENTS OF THE AMERICAN
NUCLEAR SOCIETY ON PROPOSED RULE
FOR
TECHNICAL CRITERIA: DISPOSAL OF HIGH-LEVEL
RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

46 Fed. Reg. 35280 (July 8, 1981)
(to be codified at 10 C.F.R. Part 60)

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The enclosed official comments were prepared and reviewed by American Nuclear Society members of the Fuel Cycle and Waste Management Division and the Ad Hoc Overview Committee on 10 C.F.R. Part 60 and the Society's Executive Committee.

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I

SUMMARY

The American Nuclear Society (ANS) respectfully submits that the proposed regulation should be withdrawn or, at a minimum, extensively revised.

ANS is of the concerted view that the draft regulation should apply the systems concept, instead of the present stress on subsystems, and as recommended by the Environmental Protection Agency (EPA) in the March 19, 1981, Working Draft of 40 C.F.R. Part 191.[1] Further, the present draft regulation contains significant sections, with related arguments, that are technically unjustifiable and that overly constrain the design of specific components and subsystems.

The concept of the repository as a system requires consideration of both natural and engineered barriers in arriving at a regulatory decision. Each repository site will differ in the reliance that can be placed on natural barriers and, therefore, varying degrees of compensating design margins through engineered systems should be permitted. The designer should not be constrained from optimizing these relationships by the imposition of "design specifications" or subsystem numerical performance requirements such as those stated by the Nuclear Regulatory Commission (NRC) in the proposed rule.

[1] Environmental Protection Agency, 40 C.F.R. Part 191 (1981), Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Fuel, HLW and TRU Wastes, Working Draft 19 (March 19, 1981).

ANS strongly recommends that all subsystem numerical performance requirements be deleted in favor of more general performance objectives which would permit subsystem trade-offs to achieve the desired overall repository system performance. Specifically the following values should be deleted:

1. 1,000-Year Waste Package Life (Section 60.111(b)(2));
2. 10^{-5} Long Term Release Rate (Section 60.111(b)(2)(ii)(A));
3. 1,000-Year Undisturbed Water Travel Time (Section 60.112(c)); and
4. 50-Year Retrieval Time (Section 60.111(a)(2)).

II

INTRODUCTION

A. The American Nuclear Society

ANS, an international organization of engineers and scientists, now in its 27th year, is a nonprofit scientific, technical, and educational organization. ANS currently has an individual membership of over 13,000 and is governed by its officers and a Board of Directors elected by the individual membership.

To carry out its purposes, ANS has 16 separate technical divisions. The objective of each division is to provide means for furthering the science, engineering, and art of that branch of scientific discipline. The disciplines range from those related to nuclear power--such as nuclear fuel cycles, waste management, radiation protection and shielding, reactor safety, and reactor operations--to other disciplines, such as controlled nuclear fusion, isotopes and radiation, environmental sciences, and alternative energy technologies and systems.

B. Scope of American Nuclear Society Review

These comments are in response to NRC's proposed rule on "Disposal of High-Level Radioactive Wastes in Geologic Repositories," 46 Fed. Reg. 35280 (July 8, 1981) (to be codified at 10 C.F.R. Part 60, Subpart E--Technical Criteria, Nuclear Regulatory Commission). ANS has actively followed the progress of this proposed rule with a technical support committee of interested and technically qualified members of the Fuel Cycle and Waste Management Technical Division. Based on a technical presentation of these division members and the overview of a special committee of senior ANS members, ANS has developed and formulated the enclosed formal, official position on the proposed rule.

III

REGULATORY APPROACH

A. The Proposed Performance Standards for the Repository Are Overly Restrictive and Unnecessary

NRC lists three alternatives to regulate geologic disposal of high-level waste. They are:

1. Alternative No. 1: Prescribe a single overall performance standard for the repository that must be met. The standard in this case would be the EPA standard.

2. Alternative No. 2: Prescribe minimum performance standards for each of the major elements or subsystems, in addition to requiring the overall system to meet EPA standards.

3. Alternative No. 3: Prescribe detailed numerical criteria on critical engineering attributes of the repository system.

NRC concludes that Alternative No. 2 appears to be the most practical compromise between Alternative Nos. 1 and 3. However, a compromise alternative is not necessarily the best alternative. Alternative No. 1 is more acceptable because it permits the use of a systems concept to incorporate the contributions from natural and engineered barriers. Overly restrictive and specific component and subsystem performance standards are not necessary and are likely to add to the overall cost of waste disposal, without achieving any significant degree of benefit to the public health and safety.

Using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. In satisfying a system or repository performance standard, the use of natural and engineered barriers will assure acceptable containment of the waste for the appropriate period of time and provide the required protection of the public health and safety and man's environment.

During operation of the first repository, appropriate modifications can be made in design features and repository layout if results of operation necessitate such changes. Therefore the overly restrictive standards now proposed for components and subsystems are not warranted.

B. The Proposed Multiple Barrier Approach Should Allow Appropriate Credit for Natural Barriers

In evaluating multiple barriers, NRC has considered three alternatives. These are:

1. rely entirely on the natural barriers of the site to meet the system performance standard;

2. rely entirely on engineered barriers to meet the system performance standard; and

3. rely on a combination of engineered and natural barriers to meet the system performance standards. 46 Fed. Reg. 35281 (July 8, 1981).

Alternative Nos. 1 and 2 were abandoned by NRC because of (1) uncertainties in the natural barrier performance under the stress of waste-induced changes, and (2) avoiding "unduly constraining system design."

In adopting Alternative No. 3, NRC states (see, Enclosure 3 at 26)[2] that the "staff decided to set a long-term release rate for the underground facility and waste packages working together," without mention of the natural barriers as a part of the system. This is not Alternative No. 3; but rather a more tightly constrained Alternative No. 2.

The concept of the repository as a radioactive waste isolation system requires consideration of the contribution of all barriers in arriving at a regulatory decision. Each repository site will be able to place differing reliance on the natural barriers and, therefore, the site-independent numerical subsystem performance specifications stated in Sections 60.111 and 60.112 should be withdrawn.

2 Enclosure 3, Commission Paper SECY-81-257, Rationale for Performance Objectives and Required Characteristics of the Geologic Setting (April 27, 1981).

EPA in its working draft of 40 C.F.R. Part 191 (1981) has commented on the system concept in several places. Specifically, EPA's draft notes: "We believe that making the overall disposal system meet numerical performance requirements by taking advantage of substantial protection from each of its components will provide adequate protection most economically" (40 C.F.R. Part 191 at 13). This concept more nearly complies with Alternative No. 3 than specific numerical design specifications for each subsystem or component.

C. The Proposed Rule Should Recognize that Performance Uncertainties Can Be Minimized by Bounding Analysis and Design

NRC has placed undue emphasis on the nature of the uncertainties associated with the transport of the waste through the geosphere to the exclusion of other important considerations. For example, uncertainties can be ascertained and made inconsequential by bounding analysis and design. Potential performance uncertainties are better addressed and minimized in the design of a repository and other features through the establishment and incorporation of acceptable nonregulatory design limits for the uncertainties which may reside in a particular set of circumstances, rather than the establishment of overly conservative technical criteria in the form of a rule to cover all supposed repository arrangements and contingencies. Further, a careful site selection process, using currently available investigatory techniques and engineering practices and based on the proven historical stability of the geologic setting, can minimize tectonic and hydrogeologic uncertainties and provide adequate protection of the public health and safety and man's environment.

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IV

PERFORMANCE OBJECTIVES

A. The Requirement for a 1,000-Year Containment Period by Engineered Barriers is Grossly Excessive and Unsupported by Scientific Fact

Section 60.111(b)(2)(i) requires that the waste packages contain all* radionuclides for the first 1,000 years after permanent closure.

NRC claims that the basis for the choice of 1,000 years is mainly that the heat induced by the waste in the geologic medium will increase the waste package leachability and reduce the near-field transport time, with the net result that the radiological source term from the "disturbed zone" increases. NRC does not argue that the 1,000-year containment period is necessary to reduce the overall radiological release to man's environment to an acceptable level.

It is agreed that the postulated release from the underground facility would be accelerated due to resulting higher temperatures in the geologic medium but, generally, the calculational models used do not take credit for any holdup or delay of radionuclides in the region of relatively higher temperatures. Rather, the radiological source term for the far-field transport models are derived directly from the waste package release rate as if the heated geologic medium region or "disturbed zone" did not exist. Thus, any acceleration of release from the underground facility due to temperature effects has already been discounted and, therefore, should not be used to penalize the waste package design.

Furthermore, heat or high temperature does not make waste-package containment more necessary, only more difficult to achieve. The waste-package containment requirement during any period should be based on the acceptable release quantity during that period, not on changes in nearby or adjacent conditions. A relatively higher temperature environment and the presence of water in a repository will make the waste package more difficult to design, but these factors should not influence the required waste-package performance, particularly when no credit is taken for near-field or "disturbed zone" retardation.

In addition, analyses have shown that NRC's stipulated 1,000-year containment period for waste packages or an engineered barrier would not have the suggested effect of supposedly reducing the release of radionuclides via hydrogeologic transport to man's environment. For example, Cloniger, et al.,[3] have shown that a waste-package containment period between 0 and 100,000 years does not contribute to reducing radiological consequences

* The use of "all" could be interpreted that no waste package failure could be allowed in 1,000 years. Using probabilistic design analyses, it must always be concluded that some chance of failure exists. Consequently, percent of failure allowed must be defined if any fixed life is to be required for the waste package. Therefore, the proposed wording is unrealistic.

3. M. O. Cloniger, et al., An Analysis on the Use of Engineered Barriers for Geologic Isolation of Spent Fuel in a Reference Salt Site Repository, PNL-3356 (December 1980).

to man's environment; instead, this reduction is satisfied through the regional geology or natural barriers. Thus, the 1,000-year containment period results in relatively no benefit for reduction in radionuclide releases, as compared to that for the natural barriers. It should also be noted that NRC's implied "zero leakage" criterion in the proposed 1,000-year containment period is impossible to prove.

Using somewhat different models, an almost identical conclusion is reached by Pigford, _et al_.[4] Their results indicate that in varying waste package containment times from 1 to 10,000 years makes no difference to release rates for a spectrum of important long-lived isotopes.

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For the above reasons, the 1,000-year containment period by engineered barriers provides no added safety and is unsupported by scientific evidence.

B. <u>The Long-Term Release Rate Is Unsupported by Analyses and Studies</u>

Section 60.111(b)(2)(ii) requires that the engineered system design shall provide the annual release of any radionuclides not exceeding one part in 10^5 of the waste inventory after 1,000 years. Three alternatives for the criterion for the release rate from the engineered system after the containment period were proposed (_see_ Footnote No. 2, Enclosure 3).

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[4] T. H. Pigford, _et al._; _Migration of Radionuclides Through Sorbing Media, Analytical Solution, - II_, LBL-11616, UC-70, Vol. 1 (October, 1980).

"(i) a range of 10^{-3} to 10^{-4}/year, which is typical of leach rates of many borosilicate glasses at low temperature;

(ii) a release rate of 10^{-5}/year;

(iii) a release rate of 10^{-7} year."

Alternative No. (i) states that the borosilicate glass "is expected ... to crack into fragments 10 cm on a side." The section goes on to state that the 10^{-5} to 10^{-6} g/cm^2/day leach rates of the glass in conjunction with the expected cracking results "in a range of annual release rates of 10^{-3} to 10^{-4} of the waste inventory." The basis for this conclusion is not clear since the dissolution rate of the waste inventory will depend on waste matrix parameters, groundwater flow rates and properties, local geochemistry characteristics, and local temperature, as well as fragment size and leach rate. Thus, the annual release rate is expected to be a strong function of the repository system design, the selected geologic medium, and local hydrogeologic characteristics.

EPA rationale expressed for leach rates appears to be more appropriate. The leach rates of various waste forms must be cast in the role of contributing to confinement in conjunction with the repository. Borosilicate glass has excellent low leach rates over the long term. NRC-quoted high rates of 10^{-5} gm/cm^2/day are usually for shorter term tests for 90 Sr and 137 Cs leaching, which are likely to be chemically retained in quantity in the near-field or "disturbed zone"; longer term tests with actinides fall in a much lower range of values. The setting of annual release rates would be better handled through the establishment of an overall repository release limit by incorporating this limit in an overall system performance standard.

NRC has chosen the annual release rate of waste of 10^{-5}/year as the long-term performance objectives for the engineered system or barriers. In arriving at this number, NRC argues that a larger number, such as 10^{-3}/year, would require relying almost entirely on the geology and the far-field geochemistry while the selected number of 10^{-5}/year would contribute to reducing doses and substantially reduce reliance on geochemical retardation. This argument is provided without reference to supporting analyses or studies.

As an example, the preceding argument by NRC is contrary to an analysis by Cloniger, et al. (see Footnote No. 3) who concludes:

> "While the need for and the effectiveness of a release rate limiting barrier function is somewhat dependent on the sorption properties of the geologic media, generally a release rate of less than $10^{-3}yr^{-1}$ (fractional) is necessary to reduce the potential dose from 14C, 99Tc, and 129I to a baseline level below that of the actinides. Beyond that, a release rate of less than $10^{-5}yr^{-1}$ is required before the potential dose from the actinide chains can be further lowered by this mechanism. This is because the distribution of actinide chain members in time and space, due to their different sorption properties and the characteristics of the groundwater flow field, has the same effect as a release rate reduction of between 10^{-3} to 10^{-4} yr^{-1}. Only in extreme cases of the intrusion water well scenario is there a direct relationship between release rate from the repository and release to the biosphere."

C. The Water Travel Time to the Accessible Environment Is Invalid Without a Clear Definition of "Accessible Environment" and Analysis of Differing Site Specific Characteristics

Section 60.112(e) states a requirement that prewaste emplacement groundwater travel times through the far-field to the accessible environment are at least 1,000 years.

While the "water travel time" concept may have validity in assessing multiple barriers, the ambiguity of what constitutes the "accessible environment" can lead to a number of interpretative results for this factor, as applied to differing site specific characteristics. It would be better to more clearly define the "accessible environment" as a surface or near surface water body or body of significant quantities of water that could conceivably realize extensive use. In the absence of analyses justifying 1,000 years for differing site specific characteristics and a clear definition of "accessible environment," ANS recommends deleting this numerical value.

D. The Retrievability Criteria Is Unnecessary

Section 60.111(a)(2) states a requirement for a waste retrievability period for up to 50 years after waste emplacement operations are completed. NRC's concept of retrievability and the states' arguments concerning related time periods are inappropriate.

NRC decision to require a final licensing step prior to decommissioning or permanent closure provides the opportunity for examination of the repository performance up to that time. Since the repository is planned to be operational for more than 30 years, the first waste emplaced will have been in monitored storage for this time period when the last waste is emplaced. If the applicant can demonstrate safety based on these data, no further period of retrievability should be necessary.

We understand that the 50-year retrievability period is designated to assure the retrieval option remains open during repository operation and is not precluded by repository design. This objective can be achieved without defining an artificial time frame if the rule is so worded to set forth this objective. The retrieval option can be easily exercised, for one of the distinguishing features of deep geologic disposal is that the waste inventory and location is well documented. Technologically there should be no problem, for what can be emplaced can also be removed. The design and engineering of such retrieval are well within current state of the art. This concept is reflected in the current National Waste Terminal Storage (NWTS) position[5] which we believe presents a logical approach for satisfying the retrievability objective.

CONCLUSIONS AND RECOMMENDATIONS

AWS is of the concerted view that the present draft regulation should apply the systems concept instead of the present stress on subsystems, and contains significant sections, with related arguments, that are technically unjustifiable and overly constrain the design of specific components and subsystems. Therefore, the proposed regulation should be withdrawn or, at a minimum, extensively revised. The following general conclusions are made:

- With regard to the regulatory approach and the technical criteria alternatives, Alternative No. 1 or a single overall repository performance standard is more acceptable. Overly restrictive component and subsystem performance standards are not necessary and are likely to add to the overall cost of waste disposal, without achieving any significant degree of benefit to the public health and safety.

- The concept of the repository as a radioactive waste isolation system requires consideration of the contribution of all barriers in arriving at a regulatory decision. Each repository site will be able to place differing reliance on the natural barriers and, therefore, design margins through engineered systems should be provided on a site-specific basis.

- NRC has placed undue emphasis on the nature of the uncertainties associated with the transport of the waste through the geosphere to the exclusion of other important considerations. Such uncertainties can be ascertained and made inconsequential by bounding analysis and design.

- Analyses have shown that NRC's stipulated 1,000-year waste-package containment period results in relatively no benefit for reduction in radionuclide releases as compared to that for the natural barriers.

- The setting of annual release rates for radionuclides would be better handled through the establishment of an overall repository release limit by incorporating this limit in an overall system performance standard.

- In the absence of analyses justifying 1,000-year water travel time for

[5] W. A. Carbiener, Retrievability: The NWTS Position, Proceedings of the Symposium on Waste Management in Tucson, Arizona (February 23-26, 1981).

differing site-specific characteristics and a clear definition of "accessible environment," the validity of this numerical value is questionable.

The retrievability concept reflected in the current NWTS position presents a logical approach for satisfying the retrievability objective and is more appropriate than the proposed 50-year period.

ANS strongly recommends all subsystem numerical performance requirements be deleted in favor of more general performance objectives which would permit subsystem trade-offs to achieve the desired overall repository system performance. Specifically the following values should be deleted:

1. 1,000-Year Waste Package Life;
2. 10^{-5} Long-term Release Rate;
3. 1000-Year Undisturbed Water Travel Time;
4. 50-Year Retrieval Time;

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DATED: October 19, 1981.

Respectfully submitted,

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APPENDIX D

AMERICAN NUCLEAR SOCIETY

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Telephone (312) 352-0611 Telex 254635

October 5, 1982

Mr. William J. Dircks
Executive Director
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Dircks:

Representatives of the American Nuclear Society met with you, Victor Stello, John Davis and other NRC staff members on September 10, 1982. The purpose of the meeting was to present ANS's initial reaction, from a technical perspective, to the July 29, 1982 version of 10CFR Part 60 (Technical Criteria for Geologic Repositories for High-Level Radioactive Waste), including NRC staff Recommendations and the technical Rationale Document. At the meeting, ANS reiterated its general position on proposed 10CFR Part 60 to NRC on October 14, 1981:

> "ANS strongly recommends that all numerical subsystem performance requirements be deleted in favor of more general statements permitting system trade-offs to achieve the desired overall system or repository performance". And,
>
> "It is our concerted view that overly restrictive and specific performance standards are not necessary, and that such standards in regulation form are likely to add to the overall cost of the waste disposal without achieving any degree of benefit to the public health and safety. Instead, using current engineering practices, a carefully sited, engineered, and designed repository coupled with effective confirmation and design validation can assure compliance with a single, overall performance criterion for the repository as a whole system. The application of such a single performance standard would not only coincide with the Environmental Protection Agency's recommended approach of the systems concept, but would permit repository designers to optimize the repository as a system of both natural and engineered barriers for differing site and geologic medium characteristics".

Additionally, we expressed our concern about NRC staff's rejection of the overall system or repository standard approach (similar with EPA's) which was recommended by ANS and other technical specialists and organizations. There was a broad general technical consensus on this point which seems to have been inadequately considered by the NRC without substantive technical justification.

While ANS had a relatively brief period to review the July 29, 1982, technical Rationale Document prior to the September 10, 1982, meeting, knowledgeable ANS members on this subject are in general agreement that the numerical subsystem performance standards (now "objectives") cited in the proposed regulation have not been technically justified. Further, we believe it will be very difficult, if not impossible, for the NRC to technically justify any variation from these numerical subsystem performance objectives on a "case-by-case" basis with these unmeasurable and technically unjustified values cited in the regulation.

With the preceding in mind, ANS strongly recommends NRC take the following actions before approving 10CFR Part 60:

- o Based on a preponderance of technical community opinion, including ANS, supporting a single, overall repository performance standard, NRC should reconsider the proposed numerical subsystem performance objectives in favor of more generalized design objective statements in the regulation.
- o NRC should submit technical rationale documentation for 10CFR Part 60 to a peer review by the technical community for the adequacy of analytical methodology, parameters, assumptions and conclusions.

Relative to the preceding, ANS has taken the following steps:

- o A technical paper is being prepared to present ANS and technical community views on the approaches used and material presented in the Rationale Document. This paper is scheduled to be completed and available on November 22, 1982, and would provide the basis for a technical presentation to the NRC staff and Commissioners.

- A special peer review session on 10CFR Part 60 is being organized to be held during the ANS Winter Meeting (Nov. 14-18, 1982) in Washington, D. C.

The American Nuclear Society would be pleased to meet with the Commission and the staff to assist in the development of a technically sound regulation.

Very sincerely,

L. Manning Muntzing
President
American Nuclear Society

LMM:DB:ewm

APPENDIX B

Operations, or designee, the letter must contain the following statement:

"If you wish to have the above decision further reviewed, you may appeal in writing to [*review officer/address*] within 30 calendar days of the date of this letter explaining why you believe the decision is incorrect. Your request for review should be submitted through this office. Since this review will be based on the record, including papers filed, FmHA files, notes, or transcripts of the appeal meeting, my decision, applicable statutes and regulations, and any *additional written* information you wish to submit, you should include any additional information you think is important, including any changes you believe should be made on the attached hearing notes."

* * * * *

2. Exhibit D is revised to read as follows:

EXHIBIT D.—HEARING/REVIEW OFFICERS DESIGNATIONS

Decision maker or decision	Hearing officer	Review officer
County Supervisor	District Director or person designated by State Director	State Director or designee (who has not been significantly involved with the case).
County Committee	State Director or designee	Deputy Administrator, Program Operations or designee.
District Director	State Director or designee	Deputy Administrator, Program Operations or designee.
State Director	Deputy Administrator, Program Operations or designee	(No review.)
Division Director or Assistant Administrator	Deputy Administrator, Program Operations or designee	Do.
Deputy or Associate Administrator	Administrator or designee	Do.
Decision to foreclose chattels	District Director	State Director or designee.
Decision to foreclose real estate:		
For accounts serviced in the county office	District Director from another district or other person not involved in the initial decision designated by State Director.	Deputy Administrator, Program Operations or designee.
For accounts serviced in the district office	Deputy Administrator, Program Operations or designee	(No review.)

Notes.—

1. District Director also means Assistant District Director.
2. County Supervisor also means Assistant County Supervisor with loan approval authority.

3. Designee is the person designated by the Hearing/Review Officer to conduct a hearing or review. The designee signs the decision letter to the appellant without the concurrence of the original Hearing/Review Officer except:

a. For hearings on County Committee decisions. For these hearings the State Director or Acting State Director may designate other persons to act on his or her behalf in conducting the hearing; however, the State Director or Acting State Director must sign the hearing decision letter.

b. When the Hearing/Review Officer, designated by the Deputy Administrator, Program Operations, is not a member of the National Office staff, the complete case file, hearing notes, tapes recordings, and a recommended decision will be sent to the Deputy Administrator, for review and a final decision.

c. When the Hearing/Review Officer is a member of the National Office staff, after the decision is written, but prior to notification of the applicant, in all cases requiring corrective actions or training (e.g., reversals or other problems which may become evident) the Hearing/Review Officer will brief the Deputy Administrator, Program Operations, concerning the decision and will notify the State Director involved that the decision will be reversed or modified, and will advise the State Director of what corrective action will have to be taken.

4. For decision not directly covered above, the Hearing/Review Officer is the person in the next higher level of FmHA authority.

(7 U.S.C. 1989; 42 U.S.C. 1480; delegation of authority by the Secretary of Agriculture, 7 CFR 2.23; delegation of authority by the Under Secretary for Small Community and Rural Development, 7 CFR 2.70)

Dated: June 1, 1983.

Neal Sox Johnson,

Acting Administrator, Farmers Home Administration.

[FR Doc. 83-16467 Filed 6-20-83; 8:45 am]

BILLING CODE 3410-07-M

NUCLEAR REGULATORY COMMISSION

10 CFR Part 60

Disposal of High-Level Radioactive Wastes in Geologic Repositories Technical Criteria

AGENCY: Nuclear Regulatory Commission.

ACTION: Final rule.

SUMMARY: The Nuclear Regulatory Commission (NRC) is publishing technical criteria for disposal of high-level radioactive wastes (HLW) in geologic repositories, as required by the Nuclear Waste Policy Act of 1982. The criteria address siting, design, and performance of a geologic repository, and the design and performance of the package which contains the waste within the geologic repository. Also included are criteria for monitoring and testing programs, performance confirmation, quality assurance, and personnel training and certification.

EFFECTIVE DATE: July 21, 1983.

FOR FURTHER INFORMATION CONTACT: Patricia A. Comella, Deputy Director of the Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone (301) 427-4616.

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Background

On February 25, 1981, the Nuclear Regulatory Commission published rules which established procedures for the licensing of geologic disposal, by the U.S. Department of Energy (DOE), of high-level radioactive wastes (HLW). 46 FR 13971. On July 8, 1981, NRC proposed technical criteria which would be used in the evaluation of license applications under those procedural rules (46 FR 35280). NRC received 93 comment letters on these proposed technical criteria, 89 of which were received in time for the Commission to consider in preparing the final technical criteria that are published here. No significant new issues were raised in the four letters received too late for consideration. The principal comments, and the Commission's responses, are reviewed in the discussion below. A more detailed analysis of the comments is contained in a NRC staff report (NUREG–0804) which is being distributed to all commenters on the proposed rule and which may be purchased by other interested parties from the NRC's GPO Sales Program, Washington, D.C. 20555. Upon publication, a copy will be placed in the Public Document Room (PDR), 1717 H Street NW., Washington, D.C. 20555. This staff report includes a technical rationale for the performance objectives in 10 CFR Part 60 as well as the comment analysis. The final rules contain a number of changes, explained in this statement, that reflect concerns addressed in the public comments.

The licensing procedures referenced above provide for DOE to submit site characterization reports to NRC prior to characterizing sites that may be suitable for disposal of HLW. NRC would analyze these reports, taking into account public comments, and would make appropriate comments to DOE.

The licensing process will begin with the submission of a license application with respect to a site that has been characterized. Following a hearing, DOE may be issued a construction authorization. Prior to emplacement of HLW, DOE would be required to obtain a license from NRC; an opportunity for hearing is provided prior to issuance of such a license. Permanent closure of the geologic repository and termination of the license would also require licensing action for which there would be opportunity for hearing.

The purpose of the technical criteria is to define more clearly the bases upon which licensing determinations will be made and to provide guidance to DOE and information for the public with respect to the Commission's policies in this regard. The criteria also indicate the approach the Commission is taking with respect to implementation of an Environmental Protection Agency (EPA) standard, particularly with respect to the classification of processes and events as "anticipated" or "unanticipated" and the definition of the "accessible environment" from which radionuclides must be isolated.[1]

The Commission anticipates that licensing decisions will be complicated by the uncertainties that are associated with predicting the behavior of a geologic repository over the thousands of years during which HLW may present hazards to public health and safety. It has chosen to address this difficulty by requiring that a DOE proposal be based upon a multiple barrier approach. An engineered barrier system is required to compensate for uncertainties in predicting the performance of the geologic setting, especially during the period of high radioactivity. Similarly, because the performance of the engineered barrier system is also subject to considerable uncertainty, the geologic setting must be able to contribute significantly to isolation.

The multibarrier approach is implemented in these rules by a number of performance objectives and by more detailed siting and design criteria.[2] In addition to the objective of assuring that licensed facilities will adequately isolate HLW over the long term, these provisions also address considerations related to health and safety during the operational period to permanent closure of the geologic repository.

In this statement of considerations the Commission will first discuss six issues on which it had specifically requested public comment. It will then review other principal changes to the rule which have been adopted in the light of comments received. The discussion will then take up suggestions of a policy nature which the Commission has declined to adopt. Finally, a section-by-section analysis reviews all changes made other than those of a strictly editorial nature. As appropriate, reference is made to relevant provisions of the Nuclear Waste Policy Act of 1982, Pub. L. 97–425, approved January 7, 1983 and to the Environmental Protection Agency's proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes, 47 FR 58196, December 29, 1982. The Commission regards the publication of these rules as constituting full compliance with Section 121(b)(1)(A) of the Nuclear Waste Policy Act, which requires promulgation of the Commission's technical criteria for geologic repositories not later than January 1, 1984.[3] The Commission will review these criteria after EPA's environmental standards are published in final form and will initiate subsequent rulemaking actions, as necessary, to take any such standards into account. The Commission further intends additional rulemaking to deal with any changes in licensing procedures that may be necessary in light of the Nuclear Waste Policy Act.

Issues Raised by the Commission

As noted above, the Commission specifically requested public comment on six issues, each of which will be reviewed here before turning to other considerations. These issues dealt with: (1) A single overall performance standard vs. minimum performance

[1] Reorganization Plan No. 3 of 1970 (35 FR 15623, October 6, 1970) authorizes EPA to establish generally applicable environmental standards for radioactivity. EPA's recently proposed standard would allow higher levels of radioactivity for "unanticipated processes and events" than would be permitted if "anticipated processes and events" were to occur. The proposed standard also relates these levels to places within the "accessible environment." The Commission has assumed that these concepts will be reflected in final standards that may be established by EPA.

[2] Under the Nuclear Waste Policy Act of 1982, the Commission's technical criteria "shall provide for the use of a system of multiple barriers in the design of the repository . . . as the Commission deems appropriate." Section 121(b)(1)(B). The criteria set forth in this rule represent the criteria which, for purposes of this provision, the Commission deems appropriate.

[3] The technical criteria are explicitly stated to be applicable to construction authorization, § 60.101(b), and to the issuance of licenses to receive and possess high-level radioactive waste at geologic repositories, § 60.101(a). An application to authorize permanent closure requires a license amendment, § 60.51(a); the relevant technical requirements and criteria are set out in the rules here being adopted. Inasmuch as the Commission is to be "guided by the considerations that govern the issuance of the initial license to the extent applicable," § 60.46(b), The Commission interprets the statutory provisions pertaining to applications for "decommissioning" to refer to the procedure described in § 60.52 pertaining to termination of a license; such an application would also require a license amendment, and the Commission here, too, would be guided by the present rules to the extent applicable together with the additional criteria already set out at § 60.52(c). Thus at every stage of the licensing process the central inquiry will be the adequacy of DOE's plans and activities as they relate to the isolation of wastes (as well as to safety during operations), and for each decision point we have provided, as is appropriate, for an evaluation that takes into account both the performance objectives and the more detailed criteria that the Commission here adopts. (If Section 121(b)(1)(A) applies to the decommissioning of surface facilities, the required criteria have been included in § 60.132(e). That paragraph provides that surface facilities must be designed to facilitate decontamination or dismantling to the same extent as would be required under other NRC regulations for equivalent activities. This topic may be treated again, in greater detail, in connection with the development of rules that would be generally applicable to decontamination and decommissioning of facilities at which activities subject to Commission regulatory authority are carried out.)

standards for each of the major elements of the geologic repository; (2) the need for, and appropriate duration of, a waste retrievability period; (3) the level of detail to be used in the criteria, particularly with respect to design and construction requirements; (4) the desirability of population-related siting criteria; (5) the application of an ALARA (as low as reasonably achievable) principle to the performance requirements dealing with containment and control of releases; and (6) alternative approaches on dealing with possibilities of human intrusion into the geologic repository.

Single vs. Multiple Performance Standards

The Commission identified two potentially viable approaches to assuring achievement of the desired isolation goal of controlling releases so as to assure that radioactivity in the general environment is kept to sufficiently low levels. The Commission suggested that a course that would be "reasonable and practical" would be to adopt a "defense-in-depth" approach that would prescribe minimum performance standards for each of the major elements of the geologic repository, in addition to prescribing the EPA standard as a single overall performance standard. However, as an alternative, the Commission invited comment on an approach that would specify the EPA standard as the sole measure of isolation performance.

There was general acceptance of the Commission's multiple barrier approach, with its identification of two major engineered barriers (waste packages and underground facility), in addition to the natural barrier provided by the geologic setting.

While the usefulness of multiple barriers was recognized, the establishment of fixed numerical values for performance was extensively criticized. The criticism took two forms. First, numerous commenters argued that until such times as an EPA standard is established, no logical connection can be demonstrated between the performance of the particular barriers and the overall system performance objective. The values specified by NRC, it was argued, had not been shown to be either necessary or sufficient to meet any particular standard. The second criticism was that the performance appropriate to a particular barrier is greatly dependent upon design features and site characteristics and that values such as those proposed by the Commission could unduly restrict the applicant's flexibility—possibly imposing great additional expense without compensating protection of public health and safety.

The Commission recognizes the force of both these arguments. Nevertheless, if the Commission were simply to adopt the EPA standard as the sole measure of performance, it would have failed to convey in any meaningful way the degree of confidence which it expects must be achieved in order for it to be able to make the required licensing decisions. More should be done. To that end, the Commission considers it appropriate to include reasonable generic requirements that, if satisfied will ordinarily contribute to meeting the standards even though modifications may need to be made for some designs and locations.

The Commission's response, therefore, has been to apply, for illustrative purposes, an assumed EPA standard and to examine the values for particular barriers that would assist in arriving at the conclusion that the EPA standard has been satisfied. For this purpose, a draft EPA standard which was referred to in some of the comments has been used. A copy of this draft standard has been placed in the PDR and will be contained in NUREG-0804. Following publication of EPA's proposed standard in the Federal Register, on December 29, 1982, a supplemental evaluation was made to take into account certain departures from EPA's earlier draft. In this way, the Commission has been able to demonstrate the logical connection which it makes between the overall system performance objective for anticipated processes and events, as set out in EPA's proposed standard, and the performance of specific barriers. One of the considerations that affects its judgment in this regard is the need to take proper account of uncertainties in the performance of any of the barriers. As one commenter noted, "To provide a safety factor to compensate for this uncertainty, a multi-barrier system has many advantages. Since the Commission cannot answer the global problem and predict every possible combination of circumstances that might cause releases of waste, multiple, independent mechanisms of slowing or limiting the discharge of radioactive materials to the environment are desirable." There is nothing inconsistent between the multiple barrier, defense-in-depth approach and a unitary EPA standard, on the contrary, in view of the many possible circumstances that must be taken into account, the Commission firmly believes that the performance of the engineered and natural barriers must each make a definite contribution in order for the Commission to be able to conclude that the EPA standard will be met. The Commission's task is not only a mathematical one of modeling a system and fitting values for particular barriers into the model in order to arrive at a "bottom line" of overall system performance. The Commission is also concerned that its final judgments be made with a high degree of confidence. Where it is practical to do so, the Commission can and will expect barrier performance to be enhanced so as to provide greater confidence in its licensing judgments. Accordingly, a variance between actual and assumed EPA standards will not necessarily require a change of corresponding magnitude in the individual barrier performance requirements.

While use of an assumed EPA standard provides a basis for specifying anticipated performance requirements for individual barriers, it does not deal with the concern about undue restriction upon the applicant's flexibility. The Commission's response to this has not been to abandon the values altogether, but rather to allow them to be modified as the particular case warrants. Thus, to take one example, the Commission continues to be concerned that thermal disturbances of the area near the emplaced waste add significantly to the uncertainties in the calculation of the transport of radionuclides through the geologic environment. The proposed rule addressed this problem by providing that all radionuclides should be contained within the waste packages for a period of 1,000 years. The Commission continues to consider it important to limit the source term by specifying a containment period (as well as a release rate). But the uncertainties associated with the thermal pulse will be affected by a number of factors, such as the age and nature of the waste and the design of the underground facility. For some repositories, a period substantially shorter than 1,000 years may be sufficient to allow for some of the principal sources of uncertainty to be eliminated from the evaluation of repository performance. For cases analyzed by the Commission on the basis of specified assumptions, a range of 300 years to 1,000 years would be appropriate. (These values appear in § 60.113(a)(ii)(A)). Yet even a shorter designed containment period might be specified, pursuant to § 60.113(b), in the light of conditions that are materially different from those that had been assumed. For example, if the wastes had been processed to remove the principal heat-generating radionuclides (cesium-137 and strontium-90), the 300-years provisions would not be controlling

Similarly, the Commission may approve or specify a radionuclide release rate or a pre-waste-emplacement groundwater travel time that differs from the normal values, provided that the EPA standard, as it relates to anticipated processes and events, is satisfied. Appropriate values will be determined in the course of the licensing process, in a manner sensitive to the particular case, using the principals set out in the performance objectives, without having to have recourse to the exemption provisions of the regulations.

The numerical criteria for the individual barriers included in the rule are appropriate, insofar as anticipated processes and events are concerned, in assisting the Commission to determine with reasonable assurance that the proposed EPA standard has been satisfied. It should be noted, however, that in order to meet the EPA standard as it applies to unanticipated processes and events, higher levels of individual barrier performance may be required. DOE would need to provide in its design for such performance as may be necessary to meet the EPA standard with respect to such unanticipated processes and events even though in all other respects the values specified by § 60.113(a) and § 60.113(b) would be sufficient.

Retrievability

The purpose of this requirement was to implement in a practical manner the licensing procedures which provided for temporal separation of the emplacement decision from the permanent closure decision. Since the period of emplacement would be lengthy and since the knowledge of expected repository performance could be substantially increased through a carefully planned program of testing, the Commission wished to base its decision to permanently close on such information. The only way it could envision this was to insist that ability to retrieve—retrievability—be incorporated into the design of the geologic repository.

The proposed rule would have required in effect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years (30 years for emplacement, 50 years to confirm performance, 30 years to retrieve). The Commission solicited comment, noting that it would not want to approve construction of a design that would unnecessarily foreclose options for future decisionmakers, but that it was concerned that retrievability requirements not unnecessarily complicate or dominate repository design.

While the benefits of retaining the option of retrieval were recognized, the length of the proposed requirement, in the opinion of several commenters, was excessive. In their view, the Commission had given inadequate consideration to the additional costs of design, construction, and operations implied in the original proposal; however, no new cost or design information was presented by the commenters.

The Commission adheres to its original position that retrievability is an important design consideration. However, in response to the concerns expressed, the Commission has decided to rephase the requirement in functional terms. The final rule thus specifies that the design shall keep open the option of waste retrieval throughout the period during which the wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. By that time, significant uncertainties will have been resolved, thereby providing greater assurance that the performance objective will be met. In particular, the performance confirmation program can provide indications whether engineered barriers are performing as predicted and whether the geologic and hydrologic response to excavation and waste emplacement is consistent with the models and tests used in the Commission's earlier evaluations. While the commission has provisionally specified that the design should allow retrieval to be undertaken at any time within 50 years after commencement of emplacement operations, this feature is explicitly subject to modification in the light of the planned emplacement schedule and confirmation program for the particular geologic repository.

Some commenters suggested that the technical criteria specify the conditions that would require retrieval operations to be initiated. Such provisions would not belong in Subpart E, which is concerned with siting and design. Nor are they needed elsewhere. In the Commission's view, it is clear that retrieval could be required at any time after emplacement and prior to permanent closure if the Commission no longer had reasonable assurance that the overall system performance objective would be met. This situation could exist for a variety of reasons and the Commission believes that it should retain the flexibility to take into account all relevant factors and that it would be imprudent to limit the Commission's discretion by specifying in advance the particular circumstances that would make it necessary to retrieve wastes. It should be noted that DOE may elect to maintain a retrievability capability for longer period that the Commission has specified, so as to facilitate recovery of the economically valuable contents of the emplaced materials (especially spent fuel). So long as the other provisions of the rule are satisfied this would not be prohibited. This consideration, however, plays no role in the Commission's requirement pertaining to retrievability. The Commission's purpose is to protect public health and safety in the event the site or design proves unsuitable. The provision is not intended to facilitate recovery for resource value.[6]

The Commission has also included a specific provision clarifying its prior intention that the retrievability design features do not preclude decisions allowing earlier backfilling or permanent closure. A related clarifying change has been the incorporation of a definition of "retrieval." This definition indicates that the requirement of retrievability does not imply ready or easy access to emplaced wastes at all times prior to permanent closure. Rather, the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation. The idea is that it should not be made impossible or impractical to retrieve the wastes if such retrieval turns out to be necessary to protect the public health and safety. DOE may elect to backfill parts of the repository with the intent that the wastes emplaced there will never again be disturbed, this is acceptable so long as the waste retrieval option is preserved.

The Commission has thus retained the essential elements of the retrievability design feature, but has provided greater flexibility in its application. The

[6]Under the Nuclear Waste Policy Act of 1982, the Commission's technical criteria "shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel in the repository as the Commission deems appropriate." Section 121(b)(1)(B). The criteria set forth in this rule represent the criteria which, for purposes of this provision, the Commission deems appropriate.

Section 122 of the Nuclear Waste Policy Act provides that, at the same time a repository is designed, DOE shall specify an appropriate period during which spent fuel could be retrieved for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting recovery of the economically valuable components of such spent fuel. The period of retrievability is subject to approval or disapproval by the Commission as part of the construction authorization process. Insofar as health and safety considerations are concerned, the Commission intends to grant such approval so long as the technical criteria are satisfied, and the Commission further intends to modify the licensing procedures to so specify.

Commission recognizes that retrievability implies additional costs—more, perhaps, for some media and designs than for others—yet it believes this is an acceptable and necessary price to pay if it enables the Commission to determine with reasonable assurance, prior to an irrevocable act of closure, that the EPA standard will be satisfied.

Level of Detail

The proposed rule contained general and detailed prescriptive requirements, derived from Commission experience and practice in licensing other facilities, with respect to the design and construction of a geologic repository. The Commission noted, however, that it was continuing to examine other possibilities for promulgating the more detailed of these requirements and it invited comments on the topic.

The public response included arguments addressed both to the level of detail generally and to specific criteria which were deemed to be unduly restrictive.

The Commission has concluded that there is merit in describing, in functional terms, the principal features which should be incorporated into geologic repository design—such as protection against dynamic effects of equipment failure, protection against fire and explosions, emergency capability, etc. Certain of these proposed criteria, however, such as those dealing with subsurface ventilation and shaft and borehole seals, were excessively detailed and, in some cases, inappropriate. At this stage of development, the Commission believes it should place emphasis upon the objectives that must be met and not become unduly concerned about the particular techniques that may be used in doing so. The changes that have been made are addressed in some detail in the section-by-section analysis of the rule.

Population-Related Siting Criteria

The proposed rule did not include any siting requirements which dealt directly with population density or proximity of population centers to a geologic repository operations area. The Commission indicated its belief that a more realistic approach, given the long period of time involved, would be to address the issue indirectly through consideration of resources in the geologic setting.

The numerous comments submitted in response to the Commission's specific question on this issue fell generally into two categories—those that endorsed the proposed approach and those that argued that population factors were important. The latter group addressed not only the geologic repository's long-term isolation capability, but also the relevance of population considerations in connection with the period when wastes are being received and emplaced.

The Commission is persuaded that population factors may need to be considered in connection with the period when wastes are being received and emplaced through evaluation of the adequacy of DOE's emergency plans. That section of the safety analysis report dealing with emergency planning (see § 60.21(c)(9)) will be reviewed on a case-by-case basis in the licensing process according to criteria that will be set forth in the future in Subpart I. (It should also be noted that under Section 112(a) of the Nuclear Waste Policy Act of 1982, DOE is required to develop guidelines that, among other things, will specify population factors that will disqualify a site from development as a repository. Issuance of those guidelines is subject to the concurrence of the Commission. The Commission has made no determination whether such guidelines, when issued, should in some manner be reflected in either the technical criteria or licensing procedures portions of 10 CFR Part 60.)

Population distribution over the long term is immaterial if the geologic repository operates as anticipated. Demographic factors could nevertheless be of concern to the extent that they could increase the probability or the consequences of releases associated with unanticipated processes or events. As to probability, it is difficult to relate the likelihood of releases to population factors; it is the view of the Commission that it is more realistic, as originally stated, to reduce the probability by avoiding sites with significant resource potential and by using records and monuments to caution future generations. Consequences of unanticipated releases would be greater if they occur in densely populated areas. Nevertheless, it is the view of the Commission that it make little sense to attempt to limit such consequences by means of a population-related siting criterion, since long-range demographic forecasts are so inherently speculative and unreliable; instead, the Commission is taking the approach that releases that result from the occurrence of unanticipated processes and events must be evaluated and must satisfy the EPA standard.

While the Commission considers, based on the above, that the rule should not now contain explicit requirements, particularly numerical limits, on population density or distance from population centers, it notes that considerations related to future human activities, particularly uses of groundwater, are an important source of uncertainty in assessing future performance of a geologic repository. The Commission would consider it a favorable condition if these sources of uncertainty, which would be affected by a large nearby population, were not present at a particular site. Therefore, the Commission has included in the final rule, as a favorable condition, a low population density within the geologic setting and a controlled area that is remote from population centers.

The Commission anticipates that the selection of a densely populated area would be unlikely even in the absence of express constraints in NRC regulations. For one thing, such a site would be disqualified under the guidelines to be developed under the Nuclear Waste Policy Act. Additionally, DOE will need to acquire interests in land within the controlled area and may have to have additional powers beyond the boundaries of the controlled area. These requirements may be difficult to satisfy unless a remote location is selected for the geologic repository.

ALARA

The notice of proposed rulemaking requested comment on "whether an ALARA (as low as reasonably achievable) principle should be applied to the preformance requirements dealing with containment and control of releases." Some commenters believed that ALARA should be applied to all licensed activities, and that no exception should be made for geologic repositories. Other commenters argued against incorporating ALARA, since the allowable releases under the EPA standard would already be so low as to eliminate any significant risk to public health and safety.

Based in part upon the standard recently proposed by EPA, the Commission considers it reasonable to anticipate that the permissible amounts of radioactivity in the general environment will be established at a very low level. In fact, the statement of considerations accompanying EPA's proposed rule explains that EPA has chosen to propose disposal standards that limit the risks to future generations to a level no greater than the risks which those generations would be exposed to from equivalent amounts of unmined uranium ore and thus, any risks to future generations from disposal of high-level wastes would be no greater than, and probably much less than, risks which those generations would face if the wastes had not been created in the first place. Efforts to reduce releases further would have little, if any, demonstrable value commensurate with their costs.

The EPA limits require the performance of geologic repositories to be effective over a long period of time. There will always be substantial uncertainties in predicting the long-term performance of geologic repositories. The Commission will insist upon the adoption of a variety of design features, tests, or other measures in order to be able to conclude with confidence that the EPA standard is met. The result may be the same as if the Commission were to impose similar requirements in the name of keeping releases as low as reasonably achievable. Given the substantial uncertainties involved with predicting long-term performance, the already low EPA limits and the already stringent geologic performance requirements, it is doubtful that the ALARA concept could be applied in a meaningful way.

When the Commission finds that certain measures are needed to improve confidence in dealing with uncertainties, it is making a substantial safety judgment. The same kinds of balancing that are undertaken in ALARA determinations may be appropriate. That is, if confidence in the performance of the geologic repository is sensitive to a particular source of uncertainty, it will be in order for the Commission to take into account both the significance of the factor involved and the costs of reducing or eliminating it.

In short, the Commission has concluded that the long-term performance requirements should not explicitly be tied to an ALARA principle, and the rule remains as it was when proposed. The Commission believes the concerns of the commenters in support of the ALARA approach will be largely accommodated in connection with its treatment of uncertainties in the course of the licensing process.

EPA's proposed rule (Part 191) indicates that appropriate measures must be taken, in light of the uncertainties involved in predicting repository performance, to assure that the "containment requirements" will be met. One of the measures identified by EPA would be the selection and design of disposal systems to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations. The Commission is recommending to EPA that the assurance requirements, including the ALARA provision, be omitted from the final rule. The Commission emphasizes that its rules accommodate the underlying concerns of EPA, as articulated in its statement of considerations, that measures must be taken to assure confidence that the numerical release limits will be met.

Human Intrusion

The Commission observed, in the preamble of the proposed rule, that everything that is reasonable should be done to discourage people from intruding into the geologic repository. Those measures which its believed to be reasonable included directing site selection toward sites having little resource value and marking and documentation of the site. Beyond that the Commission felt there would be no value in speculating on the "virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard." The Commission explained that inadvertent intrusion was highly improbable, at least for the first several hundred years during which time the wastes are most hazardous; and even if it should occur, it is logical to assume that the intruding society would have capability to assess the situation and mitigate consequences. The Commission recognized that deliberate intrusion to recover the resource potential of the wastes could result in elevated releases of radioactivity, but concluded that the acceptability of such releases was properly left to those making the decision to undertake resource recovery operations. It noted that comment on its proposal and alternative approaches would be welcome.

Commenters generally accepted the approach outlined. A number of commenters did emphasize the importance of intrusion scenarios as having the potential to lead to releases of radionuclides to the environment, but they suggested no alternative means for dealing with the prospect. One commenter correctly calls attention to the possibility of a third category of intrusion—that which is "intentional yet indifferent"—which was not covered in the earlier discussion of "inadvertent" or "deliberate" intrusion. This behavior presupposes knowlege (albeit imperfect) of the existence and nature of the geologic repository and a level of technology that could be applied to remedial action as well as to the intrusion itself, yet makes no judgment as to whether a societal decision has been made concerning the intrusion. The Commission has addressed this and other concerns in the revised language that is being adopted, as explained below.

Although the discussion accompanying the proposed rule indicated that intrusion scenarios need not be considered, the rule itself was not explicit on this point. The Commission considers it necessary to clarify its position and, in doing so, allows for examination of intrusion under appropriate bounding conditions. After careful consideration of the public comments received on questions relating to human intrusion, the Commission is of the view that while the passive control measures it is requiring will reduce significantly the likelihood of inadvertent intrusion into a geologic repository, occasional penetration of the geologic repository over the period of isolation cannot be ruled out, and some provision should be made in the final rule for consideration of intrusion should these measures fail. Its objective is to provide a means for evaluating events that are reasonably of concern, while at the same time excluding speculative scenarios that are inherently implausible. The Commission will not require this generati[illegible] to design for fanciful events whi[illegible] Commission has an abiding conv[illegible] will never occur; on the contrary, it will grant a license if it is satisfied that the risk to the health and safety of future generations is not unreasonable.

The rule now incorporates a definition of "unanticipated processes and events" which are reviewable in a licensing proceeding; such processes and events expressly include intrusion scenarios that have a sufficiently high likelihood and potentially adverse consequence to exceed the threshold for review. The scenarios must be "sufficiently credible to warrant consideration." The Commission is requiring that certain assumptions be made in assessing this likelihood. First, the monuments required by the rule are assumed to be sufficiently permanent to serve their intended purpose. The Commission takes this position because of its confidence that monuments can be built to survive. While it assumes that the monuments will last, it does not automatically assume that their significance will continue to be understood. Second, the Commission requires an assumption that the value to future generations of potential resources can be assessed adequately at this time. Consistent with its previously stated views, it thinks that the selection of a site with no foreseeably valuable resources could so reduce the likelihood of intrusion as to reduce, or eliminate, any further need for it to be considered. Third, the Commission requires the assumption that some functioning institutions—though not necessarily those undertaking the intrusion—

understand the nature of radioactivity and appreciate its hazards. The extent of intergenerational transfer of knowledge is, of course, debatable; it is conservative, in the light of human history to date, to predict this minimal level of information and to take it into account in assessing the likelihood that intrusion will occur. Fourth, the Commission provides that relevant records are preserved, and remain accessible, for several hundred years after permanent closure. While perhaps this period could not be justified on the basis of historic precedents alone, the Commission considers the required deposit in land records and archives, together with current data handling technology, to provide a sufficient basis for assuming that information about the geologic repository will continue to be available for several hundred years.

The definition of "unanticipated processes and events" also implicitly bounds the consequences of intrusion scenarios. This is accomplished not only by the assumption of continued understanding of radioactivity and survival of records, but also by the further assumptions that if there are institutions that can cause intrusion at depth in the first place, there will also be institutions able to assess the risk and take remedial action. It need not be assumed that today's technology would be used—merely that a level of social organization and technological competence equivalent to that applied in initiating the processes or events concerned would be available to deal with the situation.

It was suggested that another way to reduce the likelihood of human intrusion would be to adopt additional design criteria for the waste form or waste package. These would prohibit, or at least discourage, the emplacement of materials which themselves might attract recovery operations—for example, operations to recover the residual energy resource value in spent fuel or scarce and expensive materials in the waste package. But, under the definition of "unanticipated processes and events" in the final rule, intrusion for such proposes would have to be reviewed in the licensing process if the particular circumstances are sufficiently credible to warrant consideration. This imposes a reasonable constraint. The Commission believes that any further limitation would unduly interfere with the flexibility of DOE as a designer and could, in the case of spent fuel disposal, conflict with other national objectives.

In summary, the Commission has retained the principle that highly speculative intrusion scenarios should not be allowed to become the driving force in license reviews, but has introduced some flexibility to permit consideration of intrusion on a case-by-case basis where circumstances warrant.

Other Principal Changes in the Final Rule Anticipated/Unanticipated Processes and Events

The proposed rule defined anticipated processes and events as "those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived" At the same time, the Commission was requiring that the facility be designed so as to assure that long-term releases conform to standards established by EPA. The statement of considerations pointed out that if the process or event is unlikely, the overall system must still limit the release consistent with the EPA standard as applied to such events. This created a contradition because on the one hand it was stated that the design bases should be derived from anticipated processes and events while, on the other hand, the design was to meet an EPA standard as applied to what was unanticipated.

The Commission has resolved this conflict by eliminating the reference to design bases from the definition of "anticipated processes and events." It has also included a definition of "unanticipated processes and events." In the final rule, numerical performance objectives are established for particular barriers, assuming "anticipated processes and events." Such numerical criteria are not established for "unanticipated processes and events." Rather, additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

It should be noted that the distinction between anticipated and unanticipated processes and events relates solely to natural processes and events affecting the geologic setting. The Commission intends that a judgment whether a natural process or event is anticipated or unanticipated be based upon a careful review of the geologic record. Such processes or events would not be anticipated unless they were reasonably likely, assuming that processes operating in the geologic setting during the Quaternary Period were to continue to operate but with the perturbations caused by the presence of emplaced waste superimposed thereon. Unanticipated processes and events would include those that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which nevertheless are sufficiently credible to warrant consideration. These include processes and events which are not evidenced during the Quaternary period or which, though evidenced during the Quaternary, are not likely to occur during the relevant time frame. Identification of anticipated and unanticipated processes and events for a particular site will require considerable judgment and will not be amenable to accurate quantification, by statistical analysis, of their probability of occurrence.[6]

Because the design basis for the engineered barrier system will be derived from the identification of anticipated and unanticipated processes and events, such identification will have a pervasive effect on the basic structure of the licensing proceedings. The Commission therefore contemplates directing that rulings made in the course of construction authorization hearings on the scope of anticipated and unanticipated processes and events be separately identified by the presiding officers and certified to the Commission for interlocutory review, pursuant to 10 CFR 2.718(i).

The license review will thus need to include a determination whether the proposed activities will meet the EPA standard as applied to anticipated processes and events and as applied to such unanticipated processes and events, if any, as have been found to warrant consideration. Each determination will be made in the light of assessments which will involve interpretation of the geologic record and consideration of credible humaninduced events as bounded by the assumptions set forth above. Worst-case scenarios would be analyzed to the extent they may be encompassed by the definition of unanticipated processes and events. Complex quantitative models will need to be employed, and a wide range of factors considered in arriving at a determination of whether there is reasonable assurance, making allowance for the time period and

[6] The Commission views the proposed EPA standard as being directed to the evaluation of releases arising out of the categories that we have defined as "anticipated processes and events" and "unanticipated processes and events." As EPA itself recognizes, there can only be estimates rather than rigorous demonstrations of probabilities of occurrence. The Commission's translation of the EPA language into qualitative terms provides a clearer basis for judging, under the Atomic Energy Act, whether there is unreasonable risk to the health and safety of the public.

hazards involved, that the EPA standard will be met. There are two principal elements that will go into the Commission's application of this "reasonable assurance" concept. First, the performance assessment which has been performed must indicate that the likelihood of exceeding the EPA standard is low. Second, the Commission must be satisfied that the performance assessment is sufficiently conservative, and its limitations are sufficiently well understood, that the actual performance of the geologic repository will be within predicted limits.

Transuranic Waste (TRU)

The proposed rule included a definition of transuranic waste and performance objectives that would apply to the disposal of TRU in a licensed geologic repository. This was widely misconstrued as a requirement that radioactive material conforming to the definition must be disposed of in this manner. This was not the intention, nor in fact did the rule so specify. Rather, the Commission was merely indicating what performance objectives would apply *if* TRU were disposed of in a licensed geologic repository. Some commenters also took exception to the definition of TRU in the rule.

Whether or not a geologic repository is subject to licensing depends upon the applicability of Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974. (See definition of "HLW facility.") If a facility is licensed, then the Commission must consider the radiological hazards associated with whatever wastes may be emplaced. The Commission attempted, in the proposed rule, to address the requirements for one such kind of waste—TRU. But the Commission was too restrictive, in that its definition of TRU was too limited for present purposes and in that wastes other than HLW and TRU were not covered at all. For the time being, the Commission has concluded that the matter is best handled by eliminating all references to TRU. The remaining performance objectives provide adequate guidance to deal with TRU-related issues that may arise.

The Commission has also reviewed the waste package requirements, which as originally written would have applied to all emplaced radioactive waste. It is appropriate to include such requirements for HLW, which must necessarily be disposed of in a licensed facility. Since the Commission does not know what other radioactive wastes, if any, will also be emplaced, and what their chemical, radiological, thermal, and other characteristics may be, it has decided to leave pertinent waste package requirements to be determined on a case-by-case basis as the need arises.

Siting Criteria

Although provisions relating to site characteristics have been revised, the Commission has retained the same two basic concepts. First, a site should exhibit an appropriate combination of favorable conditions, so as to encourage the selection of a site that is among the best that reasonably can be found. By referring to a "combination" of conditions, it implies that the analysis must reflect the interactive nature of geologic systems. Second, any potentially adverse conditions should be assessed in order to assure that they will not compromise the ability of the geologic repository to meet the performance objectives. It is important to recognize that a site is not disqualified as a result of the absence of a favorable condition or the presence of a potentially adverse condition. The Commission emphasizes this point here because several commenters who characterized the siting criteria as unduly restrictive failed to appreciate that the presence of potentially adverse conditions would not exclude a site from further consideration while others mistakenly assumed that favorable conditions were requirements.

The changes do not reflect any departure from the Commission's original philosophy, but they are designed to express its purpose more clearly. Thus, its interest in specifying that the geologic setting shall have exhibited "stability" since the start of the Quarternary Period was to assure only that the processes be such as to enable the recent history to be interpreted and to permit near-term geologic changes to be projected over the relevant time period with relatively high confidence. This concept is best applied by identifying, as potentially adverse conditions, those factors which stand in the way of such interpretation and projection; this is the approach the Commission has chosen to follow.

One revision is the elimination of the classification of potentially adverse conditions into one set pertaining to the "geologic setting" (corresponding to "site" in the final rule) and one set pertaining to the "disturbed zone." The Commission has determined that by defining these conditions as potentially adverse only when they occur in the site or disturbed zone, respectively, some significant factors bearing upon waste isolation may not be assessed. The Commission has changed the siting criteria, therefore, so that the presence of any of the enumerated conditions is to be regarded as potentially adverse if it applies to the controlled area and, in addition, such a condition outside the controlled area is to be regarded as potentially adverse if it may affect isolation within the controlled area.

Another change, discussed under *Single vs. Multiple Performance Standards*, may have the effect of increasing the importance of the geological conditions. Under the final rule, the performance objectives for the engineered barrier system (§ 60.113(a)(1)) may be adjusted, on a case-by-case basis, if the overall system performance objective, as it relates to anticipated processes and events, is satisfied. This feature of the final rule may provide the designer additional incentive to select the site so as to maximize its isolation capabilities.

The Commission's review of the siting criteria, as modified, has led it to conclude that the isolation capabilities of the geologic repository will be given the emphasis that they merit. This review has included a consideration of suggestions that the rule require that the state of sites be among the best that can be found on the basis of geological factors alone and that the geologic characteristics of the site provide the highest reasonably available degree of the site's isolation capabilities. These topics are discussed below, under the heading *Geologic Conditions*.

A detailed review of the siting criteria is contained in the Section-by-Section Analysis.[6]

Containment

Several commenters took exception to the performance objective calling for a design of the waste packages to "contain all radionuclides" for a specified period after permanent closure. The objections were, first, that 100% performance cannot be expected in view of the very large number of containers that may be emplaced; second, that 100% performance cannot be justified as being needed in order to meet any likely EPA standard, and, third, that the adequacy of design to contain "all" radionuclides for long

[6] Under Section 112(a) of the Nuclear Waste Policy Act of 1982, DOE is required to develop guidelines for the recommendation of sites for repositories. Among other things, such guidelines are to "specify detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media." Issuance of these guidelines is subject to the concurrence of the Commission. The Commission has made no determination whether such guidelines, when issued, should in some manner be reflected in either the technical criteria or licensing procedures portions of 10 CFR Part 60.

periods of time is not demonstrable. The commenters failed, in part, to recognize that under the specified standard of proof (see *Reasonable Assurance*, below), the applicant would not be forced to carry an impossible burden. Nevertheless, since the Commission does not expect proof that literally all radionuclides will be contained, the performance objective now requires design so that containment of HLW within the high-level waste packages will be "substantially complete" for the specified period.

Terminology

Several commenters criticized, as vague or confusing, the terms used by the Commission to describe the various geographical locations that are addressed by the rule. There are many such locations—and there must be—because the Commission must deal with different concerns during site characterization, during operations, and after permanent closure. The Commission has nevertheless attempted to clarify the terms. In addition to the significant changes reviewed here, see also the discussion in the Section-by-Section Analysis.

Accessible Environment/Controlled Area. The isolation capability of a geologic repository is evaluated at a boundary which the Commission has referred to as the "accessible environment." Under the proposed rule, this was defined as "portions of the environment directly in contact with or readily available for use by human beings." Several commenters criticized his definition as being excessively vague. further, the definition failed to ssure that the isolation capability of he rock surrounding the underground acility would be given appropriate eight in licensing reviews.

The Commission agrees with the iticism and has revised the definition several respects—most importantly , excluding from the accessible ivironment that portion of the hosphere that is inside what the ommission is calling in the final rule, a ontrolled area." This is an area arked with monuments designed to ution future generations against bsurface penetrations. The size and ape of the controlled area will depend on the characteristics of the particular ologic repository, but it must be small ough to justify confidence that the numents will effectively discourage surface disturbances. The mmission has therefore limited the of the controlled area so that it ends no more than 10 kilometers n the emplaced waste. The term cessible environment" also appears in the proposed EPA standard. The Commission has used the EPA language as a starting point—for example, in specifying the surface locations that are part of the accessible environment. But there is an important difference between the two definitions, in that EPA includes in the accessible environment only those parts of the lithosphere that are more than 10 kilometers from the emplaced waste, whereas NRC may include parts of the lithosphere that are less than 10 kilometers from the emplaced waste, depending on the extent of the "controlled area" for a geologic repository. In other words, the accessible environment may be larger under 10 CFR Part 60 than might be the case under the proposed EPA Standard. The two definitions are nevertheless consistent in the sense that if the isolation requirements are satisfied at the boundary of the accessible environment specified by 10 CFR Part 60, they will necessarily be satisfied at the boundary defined by EPA as well.

Both technical and legal considerations have influenced the Commission's decision not to adopt an unqualified 10-kilometer standard. The technical consideration is that uncertainties about activities that may be undertaken in the area outside the controlled area are so great that the Commission would not be warranted in giving credit to the isolation capability of the undisturbed lithosphere there. The legal consideration is that the standards established by EPA are to apply outside the boundaries of locations controlled by NRC licensees, and in the context of 10 CFR Part 60 this refers most appropriately to the "controlled area" as defined by the regulation. The Commission believes that the final rule is fully responsive to the concerns of the commenters while conforming as well to the policies underlying EPA's proposed standard.

Geologic Setting. The proposed rule limited this term to systems that provide isolation of the waste. This is too restrictive a definition to cover the wider region of interest which the Commission seeks to encompass by "geologic setting." The definition has accordingly been extended to include the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

Site. "Site" had been defined in the proposed rule as being equivalent to "geologic setting." This was appropriate where geologic setting referred to an area having isolation capability. In the final rule, isolation is to be provided within a controlled area rather than within the geologic setting and accordingly "site" now refers to the location of this controlled area.

Decommissioning. As used in the proposed technical criteria, the term "decommissioning" was intended to apply to that stage at which the underground facility was closed and shafts and boreholes were sealed. It was these activities that were addressed in § 60.51, "License amendment to decommission." This intention is better expressed by employing the term "permanent closure." Several commenters on the proposed rule expressed the opinion that including the requirement for dismantlement of all surface facilities in the definition of the term "decommissioning" may be unnecessary and overly restrictive. Upon consideration of these comments the Commission believes that where there is a need to refer to decontamination or dismantlement of surface facilities, this can readily be done without referring to "decommissioning."

Accordingly, references to "decommissioning" with one exception (see § 60.132(e)), have been deleted from the rule, and the language now refers to "permanent closure" or to "decontamination or dismantlement of surface facilities," as appropriate.

Important to Safety. In response to public comments on Part 60, the NRC has adopted a numerical criterion for determining which structures, systems and components are important to safety. Structures, systems, and components are important to safety if, in the event they fail to perform their intended function, an accident could result which causes a dose commitment greater than 0.5 rem to the whole body or any organ of an individual in an unrestricted area.[4] The value of 0.5 rem is equal to the annual dose to the whole body of an individual in an unrestricted area that would be permitted under 10 CFR Part 20 for normal operations, the same as permitted for normal operations of certain other activities licensed by NCR. Such systems, structures, and components would be subject to additional design requirements and to a quality assurance program to ensure that they performed their intended functions. The choice of 0.5 rem in this instance should not be construed as implying that it would be appropriate if applied to any other types of activities subject to regulation by the Commission.

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[4] 10 CFR Part 50 Appendix A uses the term "important to safety" in a different context for nuclear power plants. The 10 CFR Part 60 definition does not supersede the 10 CFR Part 50 definition in nuclear power applications.

(The permissible annual dose in unrestricted areas—now 0.5 rem—is currently under review. The Commission contemplates that if this dose limit were to be revised, a corresponding change would be considered here.)

In the final rule, the term "important to safety" applies solely to the functioning of structures, systems, and components during the period of operations prior to repository closure. The proposed rule had also applied this term to structures, systems, and components which must function in a particular way in order to meet the long-term isolation objective after repository closure. In the final rule, this latter group, which is intended to meet the design criteria that address long-term performance, is characterized as "important to waste isolation." Quality assurance requirements apply to structures, systems, and components equally whether they be "important to safety" or "important to waste isolation."

Discussion of Other Comments

These issues raised by commenters merit discussion here even though they have resulted in no change to the rule.

Comparative Safety Analyses

Several commenters took exception to the proposed requirement that the safety analysis report include a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, (now termed "important to waste isolation"), on the ground that a safety analysis should be directed at the specific design being proposed. As a general principle, the commenters are correct. In the context of licensing activities at a geologic repository operations area, however, the Commission thinks it is well within its discretion to seek the requested information. If the Commission finds, on the basis of its review, that the adoption of some alternative design feature would significantly increase its confidence that the performance objectives would be satisfied, and that the costs of such an approach are commensurate with the benefits, it should not hesitate to insist that the alternative be so adopted. This is consistent with the views expressed above in the discussion of the ALARA principle and, also, with the provisions of the revised performance objectives which contemplate that the performance objectives for particular barriers are subject to modification, on a case-by-case basis, as needed to satisfy applicable EPA standards.

Unsaturated Zone

The Commission had explained that the proposed criteria were developed for disposal in saturated media, and that additional or alternative criteria might need to be developed for regulating disposal in the unsaturated zone. Accordingly, the performance objective for the engineered barrier system (proposed § 60.111(b)(2)(i)) was written so as to require the assumption of full or partial saturation of the underground facility and the favorable and potentially adverse conditions concerned only siting in the saturated zone.

This approach was criticized on the basis that disposal in the unsaturated zone was a viable alternative, and that since the criteria were generally applicable without regard to the possibility of saturations, their scope and applicability should not be unduly restricted. The Commission has reviewed the criteria in the light of the comments and finds this criticism to be well-founded. Although the criteria as written are generally appropriate to disposal in both the saturated zone and the unsaturated zone, some distinctions do need to be made. Rather than promulgating the criteria which will apply to the unsaturated zone at this time, the Commission will shortly issue such criteria in proposed form so as to afford a further opportunity for public comment. However, those criteria that are uniquely applicable to the saturated zone are so indicated.

Geologic Conditions

One commenter recommended that the rule should require that the slate of sites characterized by DOE be among the best that can reasonably be found on the basis of geological factors alone. The Commission did indicate, when it adopted licensing procedures, that the site characterization requirements will assure that DOE's preferred site will be chosen from a slate of sites that are among the best that reasonably could be found. The standard proposed by the commenter is quite different. The Commission intended that DOE should be able to take into account a variety of non-geological considerations in its screening process. It could properly exclude such locations as (1) Areas, such as national parks and wilderness, devoted to other paramount uses, (2) locations which would be subject to unusually severe environmental and socioeconomic impacts, and (3) locations where necessary surface, mineral, and water rights may be obtainable only at great expense and with severe dislocating effects on residents. The Commission considers the rule, as written, properly conveys its meaning on this score.

The same commenter ur[illegible] it to require a demonstratic[illegible]ve geologic characteristic[illegible]hosen site proved the h[illegible] achievable deg[illegible] of the waste isolatio[illegible] of the geologic repositor[illegible]. Again, th[illegible] Commission declines to a[illegible]cept the suggestion. In the first place, it anticipates that DOE would on its own initiative strive to maximize isolation capabilities in order to demonstrate more conclusively the facility's compliance with the performance objectives and other technical criteria. Beyond this, however, the Commission believes the proposal could have undesirable and unintended consequences. Maximizing isolation capabilities could dictate development at one particular location instead of at another a few miles away; this could result in the same kind of adverse environmental or other effects as were described above. Furthermore, adherence to the proposed standard could unduly interfere with, or increase the cost of, achievement of other goals, such as maintenance of retrievability, providing for worker safety, etc.

There were other related comments which argue that the Commission's approach places too great an emphasis on engineered barriers and provides insufficient incentive to select a site with optimal geologic and hydrologic characteristics. The Commission considers both engineered and natural barriers to be important, and it has structured the technical criteria in a manner that demands not only the use of advanced engineering methods, but also selection of a site with a excellent isolation capabilities. As explained in the discussion of *Reasonable Assurance*, below, uncertainties in the models used in the analysis of repository performance must be considered in the Commission's deliberations on the issuance of a construction authorization or license. Selection of a site with favorable geologic conditions will greatly enhance the Commission's ability to make the prescribed findings. Moreover, since the final rule provides flexibility for the Commission to approve or specify performance objectives for the engineered barriers on a case-by-case basis, the applicant is afforded still a further incentive to pick a site in which the host rock has favorable geochemical characteristics or in which other particular sources of uncertainty about hydrogeologic conditions are substantially reduced. But in any event, the Commission anticipates that a high standard of engineering will be necessary—not only to compensate for geologic uncertainties at even the best reasonably available sites, but perhaps also to mitigate the consequences of unanticipated processes and events (including potential intrusion) during the years when fission product inventories remain high.

Although the Commission agrees with the underlying appraisal of the commenters that the isolation capabilities of the site play a key role in assuring that the performance objectives will be met, it finds no reason to change the rule's approach.

Reasonable Assurance

The proposed rule stated that with respect to the long-term objectives and criteria under consideration, "what is required is reasonable assurance, making allowance for the time period and hazards involved, that the outcome will be in conformance with those objectives and criteria." A number of commenters took exception to this formulation on the ground that it provides inadequate guidance as to the required level of proof. Others were concerned that "reasonable assurance" was too weak a test and that the Commission should not license DOE activities without a "high degree of confidence" that releases would be very small. Some commenters suggested that a statistical definition of acceptability should be employed. For the reasons set forth below, the Commission has not modified the language.

In the Commission's view, the "reasonable assurance" standard neither implies a lack of conservatism nor creates a standard which is impossible to meet. On the contrary, it parallels language which the Commission has applied in other contexts, such as the licensing of nuclear reactors, for many years. See 10 CFR 50.35(a) and 50.40(a). The reasonable assurance standard is derived from the finding the Commission is required to make under the Atomic Energy Act that the licensed activity provide "adequate protection" to the health and safety of the public; the standard has been approved by the Supreme Court. *Power Reactor Development Co. v. Electrical Union*, 367 U.S. 396, 407 (1961). This standard, in addition to being commonly used and accepted in the Commission's licensing activities, allows the flexibility necessary for the Commission to make judgmental distinctions with respect to quantitative data which may have large uncertainties (in the mathematical sense) associated with it.

The Commission has not modified the language, but has explained elsewhere (see *Anticipated/Unanticipated Processes and Events*, above) how the concept will be applied. The Commission expects that the information considered in a licensing proceeding will include probability distribution function for the consequences from anticipated and unanticipated processes and events. Even if the calculated probability of meeting the Commission's standards is very high that would not be sufficient for the Commission to have "reasonable assurance"; the Commission would still have to assess uncertainties associated with the models and data that had been considered. This involves qualitative as well as quantitative assessments. The Commission would not issue a license unless it were to conclude, after such assessments, that there is reasonable assurance that the outcome will in fact conform to the relevant standards and criteria.

It is important to keep in mind this distinction between, first, a standard of performance and, second, the quality of the evidence that is available to support a finding that the standard of performance has been met. In principle, there is no reason why the first of these—the performance standard—cannot be expressed in quantitative terms. The rule does this in several places—notably, in including as performance objectives a designed containment period, a radionuclide release rate, and a pre-waste-emplacement groundwater travel time. Similarly, EPA's standard will establish limits on concentrations or quantities of radioactive material in the general environment.

Expressing a requisite level of confidence in quantitative terms is far more problematical. To be sure, measurement uncertainties are amenable to statistical analyses. Even though there may be practical limitations on the accuracy and precision of measurements of relevant properties, it is possible to make some quantitative statement as to how well these values are known. The licensing decisions which the Commission will be called upon to make involve additional uncertainties—those pertaining to the correctness of the models being used to describe the physical systems—which are not quantifiable by statistical methods. Conclusions as to the performance of the geologic repository and particular barriers over long periods of time must largely be based upon inference; there will be no opportunity to carry out test programs that simulate the full range of relevant conditions over the periods for which waste isolation must be maintained.

The validity of the necessary inferences cannot be reduced, by statistical methods, to quantitative expressions of the level of confidence in predictions of long-term repository performance. Similarly, the Commission will not be able to rigorously determine the probability of occurrence of an outcome that fails to satisfy the performance standards. It must use some other language, such as "reasonable assurance," to characterize the required confidence that the performance objectives will be met. In practice, this means that modeling uncertainties will be reduced by projecting behavior from well understood but simpler systems which conservatively approximate the systems in question. Available data must be evaluated in the light of accepted physical principles; but, having done so, the Commission must make a judgment whether it has reasonable assurance that the actual performance will conform to the standards the Commission has specified in this rule.

It should also be borne in mind that the fact-finding process is an administrative task for which the terminology of law, not science, is appropriate. The degree of certainty implied by statistical definition has never characterized the administrative process. It is particularly inappropriate where evidence is "difficult to come by, uncertain or conflicting because it is on the frontiers of scientific knowledge." *Ethyl Corp. v. EPA*, 541 F.2d 1, 28 (D.C. Cir. 1976).

Population vs. Individual Dose

Some commenters noted that the performance objectives are derived from an assumed EPA standard that is based upon consideration of doses to populations as a whole rather than to the maximally exposed individual. Several other analyses of repository design have examined prospective requirements in terms of keeping individual doses below specified values, and as a consequence have led to different conclusions. The differences represent a source of potential uncertainty regarding the overall goal for safety performance. However, the resolution of this question is a matter within the province of EPA. The Commission has assumed that the EPA approach will be based upon population dose, since that is the direction reflected in its working documents and its recently proposed standard. The Commission's rule, especially as modified to allow performance objectives for particular barriers to be adapted in the light of the EPA standard, can be applied whether the overall safety goal is expressed in terms of total releases to the environment or in terms of maximum dose to an individual or maximum concentration at any place or time.

If EPA were to establish a standard based upon individual doses, the Commission would review the provisions dealing with the content of the license application (§ 60.21) so as to develop requirements for any additional analyses that might be needed to evaluate site-specific pathways for released radionuclides to reach humans.

Long-Term Post-Closure Monitoring

Several of the commenters suggested that the performance confirmation program be required to be continued for as long as one thousand years after permanent closure of the underground facility. The Commission considers such measures unnecessary and unlikely to provide useful information on the performance of a geologic repository. The multiple barrier approach the Commission has adopted will result in containment of substantially all of the radioactive materials within the waste packages for centuries after permanent closure, the feasibility of obtaining reliable data on subsurface conditions over a period of centuries is questionable, and the practicality of taking remedial action after sealing of the shafts is doubtful. Moreover, the emplacement of remote subsurface monitoring instruments and the provision of data transmission capabilities, could provide additional pathways for release that would make it more difficult to achieve isolation. Rather, the Commission has adopted an approach where the retrievability option is maintained until a performance confirmation program can be completed that will allow the Commission to decide, with reasonable assurance, that permanent closure of the facility, with no further active human intervention with the emplaced wastes, will not cause an unreasonable risk to public health and safety. See also, *Retrievability*, above.

Section-by-Section Analysis

The final rule included numerous changes that reflect the considerations discussed above. Other changes, not involving significant policy issues, have also been incorporated in the final rule. The following section-by-section analysis identifies the changes from the proposed rule and includes an appropriate explanation for the revisions not previously discussed. Principal references are to the text of the final rule. Where the counterpart provision of the proposed (or procedural) rule appeared in a different place, that citation is given in brackets.

Section 60.2 Definitions.

"Accessible environment." See *Accessible Environment/Controlled Area*, above.

"Anticipated processes and events." See *Anticipated/Unanticipated Processes and Events*, above.

"Candidate area." This term is unchanged, but will be considered again in connection with the Commission's review of the licensing procedures in the light of the Nuclear Waste Policy Act.

"Controlled area." New. See *Accessible Environment/Controlled Area*, above.

"Decommissioning." Deleted. See *Decommissioning*, above.

"Disposal." The undefined term "biosphere" has been changed to "accessible environment." As used in these rules, "isolation" refers specifically to radioactive materials entering the accessible environment. The definition here is related to the concept of isolation rather than to the concept of emplacement, as in Section 2(9) of the Nuclear Waste Policy Act; the Commission believes that in each instance the term is defined in a manner appropriate to its context, and that the differences in the definitions will not result in confusion or conflict.

"Disturbed zone." The term "disturbed zone" has been modified to relate changes in the physical or chemical properties of the controlled area to the performance of the geologic repository.

"Engineered barrier system." This term refers to the system for which containment and release rate requirements are specified. It does not include the shafts and boreholes, and their seals. The proposed rule referred instead to "engineered systems," a term that was misleading because it could be understood to include shaft and borehole seals. However, the Commission recognizes that as used in the Nuclear Waste Policy Act of 1982, the related term "engineered barriers" might be construed to include shaft and borehole seals. The NRC will review whether the definition requires change in light of the Nuclear Waste Policy Act. Preliminary review does not indicate a need for change in this definition.

"Far field." The term "far field" has been deleted from the rule. Therefore, the definition is no longer necessary.

"Floodplain." Deleted. This definition was taken from Executive Order 11988, which relates to environmental consequences of occupancy and modification of floodplains. Those effects need to be considered as part of the Commission's environmental review, but they do not implicate the radiological concerns that are addressed in Part 60. The term "floodplain" still appears in § 60.122(c)(1). However, rather than establishing any particular frequency as the means for defining its extent, the Commission will allow the factors specified in § 60.122(a)(3) to be used in assessing the significance of flooding, whenever it may occur.

"Geologic repository." Clarifying change, to bring the terminology into line with common usage. The new definition includes only that portion of the geologic setting that provides isolation—not the entire geologic setting. The term, as defined, is considered to be synonymous with "repository" as defined at Section 2(18) of the Nuclear Waste Policy Act. (The added clause "or may be used for" conforms to the statutory definition as well as the definition in existing Part 60).

"Geologic setting." See *Terminology*, above. The phrase "spatially distributed" was superfluous and has been deleted.

"High-level radioactive waste." The Nuclear Waste Policy Act distinguishes between "high-level radioactive waste" and "spent nuclear fuel." These technical criteria are applicable equally to both categories. Accordingly, no change in the definition of high-level radioactive waste is required at this time.

"Important to safety." See *"Important to Safety,"* above.

"Medium" or "geologic medium." Deleted. For the sake of clarity, the term "medium" is now replaced by "geologic medium" throughout the rule. Since the term "geologic medium" should be sufficiently clear to the professional community, it no longer appears necessary to define it.

"Overpack." This term has been deleted. Because the overpack could be a component of the waste package, it was included in the definition of the term "waste package." However, this term is not used in the final rule.

"Performance confirmation." The final rule's performance objective with respect to retrievability of the waste refers to the completion of a performance confirmation program and Commission review of the information obtained from such a program. The addition of this definition is intended to clarify the intended purpose of the performance confirmation program.

"Permanent closure." New. See *Decommissioning*, above.

"Restricted Area." New. See *Important to Safety*, above.

"Retrieval." New. See *Retrievability*, above.

"Saturated zone." New. Since the performance objectives in the final rule specifically refer to disposal in the saturated zone, a definition derived from Water Supply Paper 1988 (U.S.G.S., 1972) has been included.

"Site." See *Terminology*, above.

"Stability." Deleted. See *Siting Criteria*, above. Also, *Section by Section Analysis*, § 60.113, below.

"Subsurface facility." Deleted. Both "subsurface facility" and "underground facility" were defined in the proposed rule. The use of the two closely similar terms resulted in some confusion. "Subsurface facility" has been deleted and replaced (see definition of "Permanent closure") by explicit reference to shafts and boreholes, as well as the underground facility, where appropriate.

"Transuranic wastes." Deleted. See *Transuranic Waste*, above.

"Unanticipated processes and events." New. See *Human Intrusion*, above.

"Waste form." Clarifying change to bring terminology into line with comon usage.

"Waste package." Revised. Commenters questioned the clarity of this proposed definition and one commenter suggested an alternative definition. One commenter misinterpreted the proposed definition to require that the outermost component of the waste package be an airtight, watertight sealed container. The revised definition no longer uses the terms "discrete backfill" or "overpack," which were ambiguous. To the extent that absorbent materials or packing are placed around a container to protect it from corrosion by groundwater, or to retard the transport of radioactive material to the host rock, these materials would be considered part of the waste package. However, while the final rule no longer imposes a requirement for an airtight, watertight, sealed container as part of the waste package, the Commission believes it likely that DOE will incorporate such a component into the design of the waste package in order to meet the performance objectives for the engineered barrier system for the period following permanent closure. The related terms "disposal package" and "package," as defined at Section 2(10) of the Nuclear Waste Policy Act, include unspecified overpacks; for purposes of the Commission's rules, and specifically in connection with the performance objective set out at § 60.113(a)(1)(ii)(A), a more precise definition is needed. The differences in the definitions will not, in the judgment of the Commission, result in confusion or conflict.

"Water table." New. Required because the term appears in the definition of "saturated zone." The definition is derived from Water Supply Paper 1988 (U.S.G.S., 1972).

Section 60.10 Site characterization.

One amendment clarifies the point that investigations shall be conducted in such a manner as to limit adverse effects: the original language could have been construed to mean that the purpose of the investigations was to limit such effects. The provision calling, as a minimum, for the selection of borehole locations to limit subsurface penetrations was said to be confusing; the revision, which expresses the Commission's intention more clearly, includes a phrase that emphasizes that the number of penetrations must be adequate to obtain needed site characterization data. References to the "repository" have been replaced by terms that are more appropriate in their context.

Section 60.11 Site characterization report.

The ambiguous term "repository" has been replaced by defined terms ("geologic repository operations area" and "geologic repository") as appropriate in the context (in § 60.11(a)(6)(ii)).

Section 60.21 Content of application.

Section 60.21(c)(1)

Proposed § 60.21(c)(1) called for information regarding subsurface conditions "in the vicinity of the proposed underground facility." This has been clarified to refer to the controlled area and to other areas to the extent that subsurface conditions there may affect isolation within the controlled area.

Section 60.21(c)(1)(i)

The requirement for analysis of potential pathways has been extended to include "potentially permeable features" whether or not they are, as stated in the proposed rule, "permeable anomalies." Whether the feature is actually permeable or anomalous is not the point, what matters is the potential permeability.

The adjective "bulk," as applied to geomechanical, hydrogeologic, and geochemical properties, has been deleted as ambiguous and confusing.

Section 60.21(c)(1)(ii)(A)

Clarifying change to include analysis of climatology as well as meteorology.

Section 60.21(c)(1)(ii)(B) [§ 60.123(b)]

This paragraph concerns analyses of the favorable and potentially adverse conditions listed in § 60.122. The addition of language pertaining to the depth and breadth of investigations assures that the information needed to analyze these conditions will be available for NRC review. This is a modification of proposed § 60.123(b) for conduct of such investigations. The modification ties the extent of investigations to effects of potentially adverse conditions on waste isolation within the controlled area, rather than to specified distances, as originally proposed.

Section 60.21(c)(1)(ii)(C)

References to "expected" performance and releases have been deleted from § 60.21(c)(1)(ii)(C) because, as revised, the evaluation must also take into account the assumed occurrence of unanticipated processes and events. Since the performance objectives provide for consideration of unanticipated processes and events, relevant information must be included in the safety analysis report. The evaluation is limited to periods after permanent closure, as the option to retrieve the wastes is available earlier.

Section 60.21(c)(1)(ii)(D) [§ 60.21(c)(3)(iii)]

This paragraph reflects text that formerly was in § 60.21(c)(3). The latter paragraph relates to structures, systems, and components "important to safety." The term "important to safety," as used in the final rule, pertains to the period of operations. Because the requirement for evaluating the effectiveness of the barriers was directed to questions regarding containment and isolation, it was relocated so as to place it in the proper context.

Section 60.21(c)(1)(ii)(E) [§ 60.21(c)(1)(ii)(D)]

This paragraph, as proposed, was duplicative insofar as it related to performance of the geologic repository after permanent closure. It has therefore been revised so as to pertain solely to identification of structures, systems, and components important to safety. (As in § 60.21(c)(1)(ii)(C) reference to "expected" has been deleted as confusing.)

Section 60.21(c)(1)(ii)(F) [§ 60.21(c)(1)(ii)(E)]

This paragraph has been revised to require that analyses and models used to predict future conditions and changes in the geologic setting be "supported by" rather than "confirmed by" an appropriate combination of methods such as enumerated in the rule. Such support concerns not only the reliability of the codes themselves, but also the representativeness of the models with respect to the physical conditions of the site. The Commission recognizes that confirmation, in the strict sense, is not achievable. The term "field verified laboratory tests" has been clarified to read "laboratory tests which are representative of field conditions."

Section 60.21(c)(4)

Section 60.21(c)(4) has been amended to reflect the limitation on the scope of "important to safety." The footnote reference to 10 CFR Part 50 has been deleted because of the cross-reference contained in Subpart G.

Section 60.21(c)(8)

Section 60.21(c)(8) required a description of controls to restrict access. After permanent closure, monuments will be an important control. The paragraph has been amended to require that a conceptual design of such monuments be provided.

Section 60.21(c)(9) and § 60.21(c)(11)

Conforming changes required by elimination of the term "decommissioning."

Section 60.21(c)(13)

The changes in this paragraph reflect the revised definitions of "geologic setting," "site," "geologic repository," and "disturbed zone." No substantive change is intended.

Section 60.21(c)(14)

Conforming change reflecting limitation of "important to safety" to concerns related to the period of operations.

Section 60.21(c)(15)(i)

Editorial change limiting information on DOE organizational structure to that which pertains to construction and operation of the geologic repository operations area.

Section 60.21(c)(15)(ii)

Removed. This provision was redundant with § 60.21(c)(4) (Subsequent paragraphs have been renumbered.)

Section 60.21(c)(15)(vi)

Conforming change required by elimination of the term "decommissioning."

Section 60.21(c)(15)(vii) [§ 60.21(c)(15)(viii)].

Conforming change reflecting limitation of "important to safety" to concerns related to the period of operations.

Section 60.22 Filing and distribution of application.

Section 60.22(a) has been revised to conform to § 60.3(a). In both places, the rule now refers to receipt and possession of source, special nuclear, and byproduct material "at a geologic repository operations area."

The reference in § 60.22(d) to "geologic repository" has also been changed to "geologic repository operations area", as the latter term is a more precise designation of the HLW facility that is the subject of the proposed licensing action.

Section 60.31 Construction authorization.

The overall safety finding is related to the "geologic repository operations area" because that term refers to the HLW facility subject to NRC licensing authority. [This is also the reason for the change in § 60.31(a)(1)(ii).] In order to assure that the relevant features of the controlled area are considered in arriving at this finding, § 60.31(a)(2) now specifically refers to consideration of the "geologic repository." Because siting and design criteria are supplemental to performance objectives in Subpart E, § 60.31(a)(2) has been amended to provide for evaluation of the geologic repository's compliance with the performance objectives as well. The reference to Subpart F has been deleted: that subpart, which pertains to DOE's performance confirmation program, is now referenced in § 60.74

Section 60.32 Conditions of construction authorization.

The change of "site data" to "data about the site," in § 60.32(b), is a clarifying editorial amendment.

In § 60.32(c), "repository" has been replaced by the defined term "geologic repository." The restrictions that may be imposed under this paragraph can include measures to prevent adverse effects on the geologic setting as well as measures related to the design and construction of the geologic repository operation area.

Section 60.43 License specifications

Section 60.43(b)(3) has been clarified by substituting "host rock" for the ambiguous and undefined term "storage medium" that previously appeared.

Section 60.43(b)(5) has been amended to require that license conditions include items in the category of controls related to the controlled area rather than the geologic repository operations area. This is a conforming change, which is made possible by the new definition of "controlled area" as an area which may extend beyond the boundaries of the geologic repository operation area. However, since additional controls may be needed outside of the controlled area (see § 60.121), the provision is not limited to the controlled area alone. Under 10 CFR Part 20 and this part, the licensee will have to establish restricted areas for purposes of assuring radiological protection during the period of operations, but this will not necessarily require the incorporation of specific conditions in the license. (See 10 CFR 50.36, a corresponding provision in the Commission's facility licensing regulations.)

Section 60.46 Particular activities requiring license amendment.

Section 60.46(a)(3) has been amended for the reasons stated in the discussion of § 60.43(b)(5), to refer to the controlled area. This requirement would continue to be applicable even after permanent closure unless and until the license is terminated pursuant to § 60.52.

Section 60.46(a)(6). See Decommissioning, above.

A conforming change has been made to § 60.46(a), "Particular activities requiring license amendment," which adds a new paragraph (a)(7) to make clear that any activity involving an unreviewed safety question requires a license amendment. In its proposed form § 60.46(a) could have been read to require a license amendment only for the six specific activities listed. While the enumerated activities are quite broad and may well include any change involving an unreviewed safety question, the conforming language is intended to make this point explicit. It is of course clear that an amendment would also be necessary to accomplish a change in the license conditions incorporated in the license. (The revision in no way affects the authority of DOE, under § 60.44(a)(1), without prior Commission approval, to make changes, tests, or experiments that involve neither a change in the license conditions incorporated in the license nor an unreviewed safety question.)

Section 60.51 License amendment for permanent closure.

Conforming changes have been made to refer to "permanent closure" instead of "decommissioning." See *Decommissioning*, above.

The area required to be identified is now stated to be the "controlled area" because that encompasses the region in which waste isolation is required.

The significance of preserving information is discussed in the section on *Human Intrusion*, above. To assure complete recording of the location of the geologic repository, the Commission has now provided for information to be placed in land record systems as well as archives; this better reflects its original intention. It also includes a reference to State government agencies in order to further assure comprehensiveness. It is not the Commission's intention to require that any new systems or archives be created, but only that those that are available and appropriate should be employed. A further modification expresses the intention that information concerning the detailed location of the underground facility and boreholes and shafts, as well as the boundaries of the controlled area, must be recorded.

In § 60.51(a)(4), the undefined phrase "emplacement media" has been changed to "host rock."

Section 60.52 Termination of license.

Conforming changes. See *Decommissioning* above.

Subpart D—Records, Tests, and Inspections.

There are two substantive changes in Subpart D. First, the specification of required construction records has been determined to be more appropriately included here rather than in the design criteria in Subpart E. Editorial changes, including renumbering of sections, have been made to accomplish this. Second, the final rule now requires not only that the geologic repository operations area be designed so as to permit implementation of a performance confirmation program but, as the Commission had originally intended, that such a performance confirmation program should actually be required to be carried out.

Section 60.71 General recordkeeping and reporting requirement.

Paragraphs (a) and (b) have been retained. Paragraph (c) is moved to § 60.73. The caption has been changed because records and reports are now treated in §§ 60.71–60.73, rather than § 60.71 alone.

Section 60.72 Construction records [§ 60.134(c)].

Transferred from Subpart E. Survey records are to cover "underground facility excavations, shafts, and boreholes" rather than "underground excavations and shafts." This makes the inclusion of borehole records explicit. A clarifying amendment was made to indicate that the records must include a description of materials encountered rather than the materials themselves.

Section 60.73 Reports of deficiencies [§ 60.71(c)].

Renumbered. The change of "site characteristics" to "characteristics of the site" is editorial.

Section 60.74 Tests. [§ 60.72].

A new paragraph (§ 60.74(b)) of a clarifying nature has been added which requires tests carried out under this section to include a performance confirmation program carried out in accordance with Subpart F of this part. The proposed rule inadvertently did not require such a program, merely a description of one.

Section 60.75 Inspections. [§ 60.73]

References to "site" have been changed to "geologic repository operations area" or "location" where appropriate. See *Terminology*.

Subpart E—Technical Criteria

Section 60.101 Purpose and nature of findings.

A change has been made to § 60.101(a)(2) with respect to evaluations of performance of the engineered barrier systems and geologic media. The point that is being made is that the further into the future one must project, the greater the uncertainties will be. The Commission did not mean to suggest that the specific period of a thousand years is especially significant; the more general "many hundreds of years" specified in the final rule better expresses the Commission's intent.

A sentence has been added to § 60.101(a)(2) that emphasizes that demonstration of compliance with long-term performance objectives and criteria will involve the use of data from accelerated tests and suitably supported predictive models.

A reference to "repository" in § 60.101(b) has been changed to "geologic repository operations area" to conform with a parallel change in § 60.21.

Section 60.102 Concepts.

An introductory paragraph has been added to explain the purpose of this section and to indicate that it is subordinate to the definitions contained in § 60.2.

See *Transuranic Waste (TRU)*, above, with respect to the deletion of the reference to TRU.

The section on *Terminology*, above, explains changes affecting the terms "accessible environment," "controlled area," "geologic setting," and "site." These changes are reflected in amended § 60.102(c). The reference to the host rock was deleted so as to avoid any implication that other characteristics of the geologic setting might not, where appropriate, also receive "particular attention."

See *Decommissioning*, above, for an explanation of the change in the discussion of "permanent closure." Because activities unrelated to waste isolation may continue at the geologic repository operations area after permanent closure, the last sentence of § 60.102(d) has been deleted.

The treatment of containment and isolation has been consolidated in light of changes made in the performance objectives. The reference to assessment of uncertainties instead of prediction of consequences takes into account the need to compensate for a broader range of factors, such as identification of the events which are to be considered in the license review. See *Reasonable Assurance* and *Anticipated/Unanticipated Processes and Events*, above. A second reason for the change stems from a commenter's criticism of the statement that consequences of events are "especially difficult to predict rigorously" early during the life of a repository; on the contrary, he suggested, consequences would be more difficult to predict over longer periods of time. The matter need not be resolved in those terms. The point the Commission was trying to make is that containment measures are appropriate to compensate for the uncertainties involved in assessing radionuclide transport in the presence of high radiation and thermal levels.

The respective contributions of the engineered barrier system and the geologic setting to the achievement of isolation are highlighted in a new sentence. Other changes are made to conform with revised definitions. See analysis of § 60.2.

Performance Objectives

Section 60.111 Performance of the geologic repository operations area through permanent closure. [§ 60.111(a)]

The provisions of § 60.111(a) dealing with radiation protection and releases of radioctive material for the period through permanent closure of the underground facility are unchanged in substance from the proposed rule. The paragraph has been renumbered and some editorial changes have been made.

The provisions of § 60.111(b) dealing with retrievability of waste have been modified to link the period of retrievability more closely to the performance confirmation program and to allow the Commission to modify the retrievability period on a case-by-case basis based on the waste emplacement schedule and the planned performance confirmation program. The final rule also specifies that the period of retrievability begin at the initiation of waste emplacement rather than after waste emplacement is complete. Finally, the final rule explicitly states that backfilling of portions of the underground facility is not precluded, provided the retrievability option is maintained, and that the Commission may decide to allow permanent closure of the underground facility prior to the end of the designed retrievability period. While these provisions were discussed in the supporting information, they were not explicitly stated in the proposed rule. Also see *Retrievability*, above.

Section 60.112 Overall system performance objective for the geologic repository after permanent closure. [§ 60.111(b)(1)].

The term "subsurface facility" has been deleted, as explained in the analysis of § 60.2, and conforming changes have been made.

There is no conceptual difference between the proposed rule's reference to releases *from the geologic repository* and the final rule's reference to releases *to the accessible environment*. The Commission prefers the latter formulation because it more closely conforms to the standard-setting authority of EPA. The proposed rule's definition of "accessible environment" was too general to allow such an approach. Under the final rule, however, the subsurface portions of the accessible environment and the geologic repository are contiguous. See *Terminology*, above.

See also the discussion, above, relating to *Anticipated/Unanticipated Processes and Events*.

Several commenters recommended that it would be preferable to leave the rule in proposed form until the EPA standard had been published, at which time NRC could adapt its regulations to the standards that EPA actually promulgates. The Commission would, of course, prefer to have final EPA rules available; and, if they were, it could build EPA's provisions, where appropriate, into Part 60. In the absence of the final EPA standard, however, the Commission deems it important to provide not only to DOE but also to other interested persons, including governmental institutions, firm guidance with respect to the Commission's regulatory approach. As discussed under *Single vs. Multiple Performance Standards*, above, the technical criteria provide some flexibility to take into account a range of standards that might be adopted by EPA. Should such standards, when adopted, depart from those that the Commission has assumed for purposes of analysis, the Commission would consider whether further rulemaking on its part would be desirable. The procedure that is being followed conforms to that prescribed by Section 121(b) of the Nuclear Waste Policy Act. See also the discussion regarding *Population vs. Individual Dose*.

Section 60.113 Performance of particular barriers after permanent closure. [§ 60.111(b)(2)-(3); § 60.112].

The performance objectives for particular barriers have been modified for reasons discussed at length above.

The analysis of *Single vs. Multiple Performance Standards* explains the basis for retaining numerical values, while allowing them to be modified as the particular case warrants. The factors alluded to there as among those that might be taken into account are set out in § 60.113(b). § 60.113(c) reflects the observation there that considerations related to unanticipated processes and events could form the basis for additional performance requirements for individual barriers.

For the reasons presented under the heading *ALARA*, above, the Commission has elected not to apply an ALARA principle to the performance requirements in this section.

The reasons for elimination of requirements referring specifically to TRU are described in the section on *Transuranic Waste*, above. It should be noted, however, that the release requirements in § 60.113 apply to all radionuclides, including those that may be contained in any TRU that may be disposed of at a geologic repository operations area.

The proposed rule required an assumption that groundwater saturate the facility and that the performance of the waste packages be evaluated on this basis. This approach was proposed because mechanisms exist for groundwater transport to the underground facility, in salt formations as well as hard rock. It may not always be necessary or technically reasonable to assume the specified saturation conditions, provided that appropriate evaluations are made in the context of a particular application; the final rule therefore calls for the partial and complete filling with groundwater of available void spaces in the underground facility to be considered and analysed among the anticipated processes and events in designing the engineered barrier system. This provision would not appear to be needed for disposal in the unsaturated zone, even though there may be water transport from the underground facility, primarily because the design can, in principle, provide for adequate drainage. (Criteria applicable to disposal in the unsaturated zone will be the subject of additional rulemaking.) Other changes in the provision are of a clarifying or editorial nature.

Editorial changes have been made to avoid repetitious language in the performance objectives relating to the engineered barrier system's containment and controlled-release capabilities.

The proposed requirement with respect to containment would have specified that the HLW waste packages contain all radionuclides for at least the first 1,000 years after permanent closure. In response to comments relating to the demonstrability of a design to contain "all" radionuclides for an extended period, the Commission has modified the requirement so that the design must provide "substantially complete" containment. The reason for relying on containment as one means for assuring achievement of the overall system performance objective is that many sources of uncertainty are particularly significant during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay. This period will depend, to some extent, on the characteristics of the particular facility. The Commission has therefore allowed the containment period to be fixed, where appropriate, at a shorter period. See, also, the discussion of *Single vs. Multiple Performance Standards*.

The incorporation of a general standard for release of radionuclides from the engineered barrier system ("a gradual process which results in small fractional releases to the geologic setting over long times") places the specific criteria into context, thereby emphasizing the policy objective underlying these criteria. Moreover, it indicates the close relationship between the provisions dealing with containment and limited release. These are coupled parameters that should not be varied independently, but rather should be viewed as a system to control the release to the geologic setting. Again, see *Single vs Multiple Performance Standards.*

The fractional release rate has been modified slightly to eliminate an ambiguity identified by one commenter. The new language makes it clear that "one part in 100,000 per year" refers to the activity at 1,000 years following permanent closure. This is a substitute for 1 part in 100,000 of the maximum inventory of the particular radionuclide at any time after 1,000 years after permanent closure. The underlying concern in the proposed rule was that the amounts of certain radionuclides, such as Ra-226 and other actinide daughters, increased with time, and that it was necessary to consider the maximum inventory of these nuclides in assessing repository performance. The analyses performed in the rationale document indicate that these nuclides are not important with respect to meeting the EPA standard as presently formulated. Accordingly, the Commission has chosen the less complicated formulation that appears in the final rule. It should be noted that the release rate refers to activity at 1,000 years after closure, even though a different containment period may be approved or specified by the Commission; the rate may also be modified, however, under the provisions of the final rule. DOE, in its comments on the proposed rule, suggested that the fractional release rate requirement should not apply to nuclides that constituted less then 0.1% of the inventory remaining at 1,000 years. This recommendation has not been adopted since it could lead to excessive releases. Table 6 of the rationale document to NUREG-0804 shows that the inventory of radioactive material in a repository containing 100,000 metric tons of spent fuel is 1.7×10^{8} curies after 1,000 years. The DOE suggestion would eliminate nuclides whose inventories were less than 170,000 curies from consideration of their release rate from the engineered barrier system, whereas the NRC provisions of § 60.113(a)(1)(ii)(B) would eliminate nuclides whose release rates were less than 1.7 curies/yr from further consideration. While the Commission has not adopted the recommended change it notes that, under the provisions of the final rule, DOE could recommend an alternative release rate for nuclides in the light of the standard adopted by EPA or the geochemical characteristics of the host rock, surrounding strata, and groundwater. In particular, the characteristics of the host rock immediately adjacent to the underground facility may be well understood because of the excavation activities and, where appropriate, such characteristics could be taken into account in specifying the nuclide release rate.

The previously proposed performance objective for the geologic setting [§ 60.111(b)(3)] has been deleted. The new definition of "anticipated processes and events" includes the assumption that processes operating in the Quaternary Period continue to operate but with perturbations caused by the presence of emplaced radioactive waste superimposed thereon. The remainder of the proposed paragraph merely restates part of the overall system performance objective with respect to performance of the geologic setting and would be redundant.

The references to "stability" in the geologic setting since the start of the Quaternary Period have been deleted. What the Commission had intended was that the structural, tectonic, hydrogeologic, geochemical, and geomorphic processes be such as to enable the recent history to be interpreted and to permit near-term geologic changes to be projected with relatively high confidence. The selection of the term "stability" to convey this meaning was unfortunate. Commenters correctly pointed out that a geologic setting can only be said to exhibit stability in a relative sense. As they noted, the proposed rule gave no guidance as to the degree of required stability and, accordingly, the provision would introduce ambiguity with respect to one of the major elements of the geologic repository. The factors the Commission had identified are all important, but the appropriate way to consider them is to assess them in the context of favorable and unfavorable conditions and to evaluate the extent to which the geologic repository's achievement of the overall system performance objective might be affected. If the relevant processes are not well understood, one or more of the potentially adverse conditions will be exhibited and such an evaluation will be required.

The pre-waste-emplacement groundwater travel time provision is subject to adjustment on a case-by-case basis. See *Single vs. Multiple Performance Standards.* A clarifying amendment relates the travel time provision, as previously only implied, to the "fastest path of likely radionuclide travel from the disturbed zone to the accessible environment." Relating this provision to the "disturbed zone" instead of the "far field" involves no substantive change. As stated in the analysis of § 60.2, the term "far field" has been deleted from the rule.

Some commenters suggested that the groundwater travel time be expressed in terms of post-emplacement as well as pre-emplacement conditions. This assumes that post-emplacement changes would be significant. By definition, however, the portion of the geologic setting significantly affected by waste emplacement constitutes the "disturbed zone." The groundwater travel time provision applies to transport from the disturbed zone to the accessible environment. This parameter is not dependent upon the effects of waste emplacement.

One commenter characterized the travel time performance objective as "invalid" without a clear definition of "accessible environment." The Commission agrees that the proposed rule was subject to a number of interpretations. However, the modified definition provides a means for delineating the limits of the accessible environment so as to take proper account of site-specific conditions. Under this revised definition, a subsurface area extending no more than 10 kilometers from the underground facility may be used to isolate the waste from the accessible environment. This, in effect, places an upper limit on the rate of groundwater travel to the accessible environment. Refer to the discussion of "accessible environment" and "controlled area" under *Terminology,* above.

Land Ownership and Control

Section 60.121 Requirements for ownership and control of interests in land.

The proposed rule set out ownership and control requirements for the "geologic repository operations area." The text, however, related these requirements to the achievement of isolation. To express this concept properly, the Commission has made the requirements in § 60.121(a) applicable not only to the geologic repository operations area, but to the controlled area as well. Section 60.121(b), which deals with isolation and not with the period of operations, is amended so as to refer to the controlled area. (The reference here to the "geologic repository" instead of "site or engineered system" is not substantive; it reflects the revised definitions identified in the analysis of § 60.2.) A conforming change has also been made to the caption of the section.

In response to a commenter's suggestion, the acquisition of appropriate water rights is now explicitly required. This will not necessitate any separate action on the part of DOE if it appears that such needed water rights have been obtained, by implication, as a result of reservation or acquisition of lands. See *U.S. v. New Mexico*, 438 U.S. 696 (1978), *Cappaert v. U.S.*, 426 U.S. 128 (1976). The "purpose of the geologic repository operations area" is intended to be construed broadly to include the isolation of radioactive wastes after permanent closure as well as any water rights needed during the period of operations.

The Commission declines an invitation to define a specific area that must be acquired to assure public health and safety prior to permanent closure. The size of this area will depend upon the particular activities to be carried out by DOE. There must be an "unrestricted area" to which releases of radioactive materials will be maintained within the limits specified in 10 CFR Part 20. § 60.111(a). The establishment of this unrestricted area must also take accidents into consideration, since structures, systems, and components "important to safety," as defined in § 60.2, must be designed so as to limit radiation doses under accident conditions to 0.5 rem at the boundary of the unrestricted area.

Siting Criteria

Section 60.122 Siting criteria. [§ 60.123–60.124].

The following detailed comments supplement the discussion under the caption "*Siting Criteria*" in the main text, above.

Section 60.122(a) consolidates the introductory paragraphs of proposed §§ 60.122 and 60.123, together with proposed § 60.124. This change is designed to provide a clearer statement of the relationship between the favorable and potentially adverse conditions. The revised language makes it clear that all such conditions relate to isolation of the waste after permanent closure.

Proposed § 60.124 had specified ways to demonstrate that potentially adverse conditions would not "impair significantly" the isolation ability of the geologic repository. This has been modified so as to refer instead to "compromise" of such site suitability. This change is made to eliminate any question regarding the difference between the two terms. No such difference was intended. Both terms relate to conditions which would potentially preclude the Commission from finding that the geologic repository would achieve the performance objectives.

The rule now provides for evaluating the effect of the potentially adverse conditions on the "site" rather than the "geologic setting" or "disturbed zone." See *Siting Criteria*, above.

In the provision which states that potentially adverse conditions may be compensated by the presence of favorable conditions, the Commission has specified the standard for measuring the adequacy of such compensation—namely, achievement of the performance objectives relating to isolation of waste.

Section 60.122(b)(1) [§ 60.122(a)–(e)].

Proposed paragraphs 60.122 (a), (c), (d), and (e) have been consolidated for editorial reasons. Even if some of the cited processes might have an adverse affect on the geologic repository's ability to isolate the waste, the Commission intends that the other processes may nevertheless be treated as favorable conditions. The distinction between "tectonic" and "structural" processes is so "fine," as it was characterized by one commenter, that the final rule uses only the former term. The references to "the start of the Quaternary Period" have been removed because of the difficulties that might be involved in dating this point with precision; for present purposes, all that is important is that processes "operating during the Quaternary Period" be identified and evaluated, and this is reflected in the revised language. Note the fact that while the provision, as before, applies to favorable conditions in the "geologic setting," the broader definition of that term in the final rule recognizes that processes operating more remotely from the geologic repository must be taken into account.

Section 60.122(b)(2) [§ 60.122(f)].

The proposed rule included siting criteria applicable only to disposal in the saturated zone. This paragraph adapts the provision that dealt with hydrogeologic conditions in the host rock and is appropriately limited to the saturated zone option. The Commission no longer identifies "low groundwater content" as a favorable condition because it is the rate and direction of groundwater movement rather than the amount of groundwater present that is of primary significance; thus, instead, the final rule substitutes a reference to low permeability and downward hydraulic gradient. This change also addresses more clearly the prior consideration about inhibition of groundwater circulation in the host rock. Similarly, instead of referring to inhibition of groundwater flow between hydrogeologic units, the Commission specifies the properties which result in such inhibition, namely low vertical permeability and low hydraulic potential. Since the paragraph relates to the host rock, the reference to shafts, drifts, and boreholes was not fully appropriate and, in any event, is dealt with by identification of the pertinent properties.

The reference to groundwater travel time has been modified to conform with the language of the related performance objective. The proposed rule measured this property from the underground facility. However, the changes that may occur in the disturbed zone may negate the favorable condition in that part of the geologic setting and, accordingly, the final rule specifies that the travel time in question is to be measured from the disturbed zone to the accessible environment. There is no basis for identifying a particular number of years that will be deemed to be substantially in excess of 1,000 years. If for a particular site the value is sufficiently high to enhance the Commission's confidence that the performance objectives will be met, then it can appropriately be considered as a favorable condition.

Section 60.122(b)(3) [§ 60.122(g)].

Since the listed geochemical conditions may or may not occur simultaneously, yet since any of them may retard the transport of radionuclides, the paragraph has been stated in the disjunctive in the final rule (by substituting "or" in the place of "and").

Section 60.122(b)(4) [§ 60.122(h)].

This paragraph concerns transformation of "mineral assemblages" under thermal loading. It would be a favorable condition if changes left the capacity to inhibit radionuclide transport unaffected; the proposed rule, which spoke only of "increased" capacity, was too restrictive.

The paragraph is concerned primarily with the behavior of mineral assemblages which form coatings along the fracture paths along which radionuclides are anticipated to migrate; it would be incorrect, when referring to this surface zone, to adopt a commenter's suggestion that the Commission refers instead to "rock" or "geologic media."

Section 60.122(b)(5) [§ 60.122(i)].

This paragraph, relating to depth of emplacement, is unchanged. The purpose of the provision is to reflect the consideration that wastes buried at least 300 meters below the surface are less subject to disturbance, especially by human intrusion, than wastes closer to ground level would be. As in the case of other favorable conditions, it should be emphasized that the absence of a particular one or more of them does not rule out a site or even demand explanation; it simply means that other favorable conditions must be cited to show that the criterion set out in § 60.122(a)(1) has been satisfied. (The elevation being referred to is the altitude above mean sea level of the lowest point on the surface but the Commission perceives no need to express the concept, as one commenter had suggested, in such detail.)

Section 60.122(b)(6).

New. See *Population—Related Siting Criteria*, above.

Section 60.122(j)).

The proposed rule would have treated as a favorable condition "any local condition of the disturbed zone that contributes to isolation." This was criticized as being unduly general and vague. As the key favorable conditions appear to have been identified, the Commission has concluded that inclusion of such a "catch all" is unwarranted.

Section 60.122(c)(1) [§ 60.123(a) (1) and (8)].

This paragraph is adapted from two provisions of the proposed rule. Unlike most of the potentially adverse conditions, the prospect of flooding is of most concern prior to permanent closure. Even though criteria in § 60.133 provide that the underground facility be designed to handle water intrusion, the anticipated design features need not be sufficient to cope with massive inflows that could result from submersion of boreholes and shafts. Should such a situation develop, the ability of the geologic repository to achieve isolation of the wastes that had been emplaced could be compromised.

Because the concern relates to waste isolation, the paragraph has been rewritten so as to be limited to flooding of the underground facility. The design criteria for structures, systems, and components important to safety require that appropriate measures be taken to protect surface facilities against the consequences of flooding.

As there is no reason to differentiate between floods resulting from natural causes (i.e., from occupancy and modification of floodplains) and those resulting from failure of impoundments, the two pertinent paragraphs have been combined.

With respect to required investigations [§ 60.123(b)], see Section-by-Section Analysis, § 60.21(c)(1)(ii)(B).

Section 60.122(c)(2) [§ 60.123(a) (2) and (3)].

Two paragraphs related to the groundwater flow system have been consolidated. The conditions are to be regarded as potentially adverse if the activities in question are "foreseeable." This is more conservative than the original rule, which only identified "planned" activities. The proposed rule encompassed such activities with a potential to "significantly" affect groundwater flow. Any "adverse" effect should be treated as significant, and the final rule makes a change to reflect this.

Section 60.122(c)(3) [§ 60.123(a)(7)].

No substantive change from proposed rule.

Section § 60.122(c)(4) [§ 60.123(b)(8)].
[§ 60.123(b)(5)].
[§ 60.123(b)(6)].
[§ 60.123(b)(7)].

Structural deformation would have been regarded as a potentially adverse condition only if occurring within the disturbed zone during the Quaternary period. This approach was unduly limiting. Structural deformation in the geologic setting, whether or not of recent origin, is potentially adverse because of the effects which it may have upon the regional groundwater flow system. Of course, it is to be expected that structural deformation remote from the site, especially if ancient, can readily be found not to significantly affect the ability of the geologic repository to isolate the waste. Still, it is a potentially adverse condition and should be recognized as such.

Faulting is one kind of structural deformation. By including it here, the prior specific references to faulting can be eliminated.

Section 60.122(c)(5) [§ 60.123(b)(12)].

This paragraph is no longer restricted to the disturbed zone, but otherwise is unchanged in substance.

Section 60.122(c)(6) [§ 60.123(a)(9)].

The proposed rule referred to "expected climatic changes." Climatology is not sufficiently understood to enable us to limit our concern to "expected" changes, and the final rule therefore refers to characteristics of the geologic setting likely to be affected directly by reasonably foreseeable climatic change, viz. the hydrologic conditions.

Section 60.122(c)(7) [§ 60.123(b)(14)].

This paragraph referred to groundwater conditions that could "affect" solubility and chemical reactivity. The concern is not with effects *per se*, but rather with effects that increase the solubility or chemical reactivity of the engineered barrier system. This was not made explicit. In order to be more comprehensive, chemical composition of the host rock is added to the relevant groundwater conditions.

Section 60.122(c)(8) [§ 60.123(b)(15)].

Aside from the extension of this paragraph beyond the disturbed zone, there are no changes in substance. One clarifying addition, "of radionuclides," following "sorption" was made.

Section 60.122(c)(9) [§ 60.123(b)(13)].

This paragraph, related to non-reducing groundwater conditions, is only appropriate to disposal in the saturated zone.

Section 60.122(c)(10) [§ 60.123(b)(5)].

Dissolutioning will be treated as a potentially adverse condition throughout the geologic setting. Examples of the kinds of features that provide evidence of dissolutioning have been included so as to make it clear that the paragraph refers to processes that provide gross manifestations of their presence.

Section 60.122(c)(11) [§ 60.123(b)(8)].

No substantive changes.

Section 60.122(c)(12) [§ 60.123(a)(4)].
Section 60.122(c)(13) [§ 60.123(b)(10)].
Section 60.122(c)(14) [§ 60.123(b)(9)].
Section 60.122(c)(15) [§ 60.123(b)(11)].
Section 60.122(c)(16) [§ 60.123(b)(4)].

Extended from disturbed zone to the entire geologic setting, but otherwise unchanged.

Section 60.122(c)(17) [§ 60.123(b)(3)]

Consistent with the references to resources in the requirements for the content of the safety analysis report, § 60.21(c)(13), the presence on naturally occurring materials for which economic extraction is currently feasible or potentially feasible during the foreseeable future may give rise to a potentially adverse condition. The provision now applies to the site, rather that the disturbed zone, since it is the site that provides isolation of the waste.

Section 60.122(c)(18) [§ 60.123(b)(1)].

Extended from the disturbed zone to the site

Section 60.122(c)(19) [§ 60.123(b)(2)].

Extended from the disturbed zone to the site.

Section 60.122(c)(20) [§ 60.123(b)(18)].

The paragraph refers to "rock or groundwater" conditions that would require complex engineering measures. Although the engineering measures being referred to would be applied before permanent closure, the reason for having this criterion—as in the remainder of § 60.122(c)—stems from concerns about the ability of the geologic repository to satisfy the performance objectives with respect to isolation of the waste. Although complex engineering measures are not inherently unacceptable, their reliability must be carefully scrutinized in a licensing process. A geologic setting that requires the adoption of such complex engineering measures therefore can be viewed as exhibiting a potentially adverse condition. Although the final rule applies to the geologic setting instead of the disturbed zone, this paragraph would apply over only that part of the geologic setting that has features relevant to the selection of engineering measures.

Section 60.122(c)(21) [§ 60.123(b)(17)].

The criterion pertaining to stable underground openings is also unchanged in substance, except that it is no longer expressly limited to the disturbed zone. This is another criterion that pertains to the period of operations. However, like the preceding one, its underlying purpose is to assure that waste isolation objectives can be achieved. Failure of underground openings could result in the inability of the licensee to retrieve the wastes practicably, should such a course of action be found to be warranted. The consequence of this failure could be a transport of radionuclides to the accessible environment at levels exceeding the performance objectives.

Design Criteria for the Geologic Repository Operations Area

Section 60.130 Scope of design criteria for the geologic repository operations area. [§ 60.130(a)].

The separation of final § 60.130 from related sections is an editorial change.

As indicated in § 60.131, Subpart E is intended to specify site and design criteria. References to construction requirements are therefore inappropriate and have been deleted.

Section 60.131 General design criteria for the geologic repository operations area.

(a) Radiological protection. [§ 60.130(b)(1)].

Aside from editorial changes, the only revision relates to the design of the radiation alarm system; the language has been modified to conform to 10 CFR 72.74(b), and reference to radioactivity in effluents was deleted since this section has to do with radiation protection in restricted areas. Provisions for control of radioactivity in effluents are contained in § 60.131(b)(4), for emergency conditions, and in § 60.132(c), for normal operations.

(b) Structures, systems, and components important to safety.

(1) Protection against natural phenomena and environmental conditions. [§ 60.130(b)(2)].

The two proposed subparagraphs were duplicative and have been consolidated. The change of "site" to "geologic repository operations area" is appropriate because the concern being addressed is accident conditions at the HLW facility that could result in specified doses at the boundary. Similarly, "any relevant time period" has been deleted since this provision deals with the prevention or mitigation of accidents associated with waste storage and handling activities. Also, since it is accident conditions that are of concern, the provisions of the proposed rule dealing with operations, maintenance and testing were inappropriate and have been deleted. (The effects of natural phenomena and environmental conditions on waste isolation are addressed in § 60.122.)

(2) Protection against dynamic effects of equipment failure and similar events. [Section 60.130(b)(3)]

Editorial change, characterizing missile impacts as dynamic effects.

(3) Protection against fires and explosives. [Section 60.130(b)(4)]

The design criterion pertaining to continued operation during and after fires has been limited to such events as are "credible." This responds to comments that suggested that the proposed language could be interpreted to require protection against any fire or explosion that might be physically possible.

Because Subpart E is concerned with siting and design criteria, the Commission has not adopted a suggestion to incorporate, at this point, a requirement that explosives be excluded from areas containing radioactive materials. However, such a provision could be one of the license specifications found to be appropriate under § 60.43.

(4) Emergency capability [Section 60.130(b)(5)]

Provision has been made to require control of effluents during emergency conditions, see §§ 60.131(a). Otherwise unchanged.

(5) Utility services. [Section 60.130(b)]

Paragraph (i) has been clarified by inserting an explicit reference to systems "important to safety." Since the definition of "important to safety" refers to "accidents," the term "emergency conditions" has been changed to "accident conditions."

Proposed paragraph (iii) has been deleted because it was redundant with the general provision for inspection, testing, and maintenance.

Proposed paragraph (iv) [now (iii)] has been abbreviated. As proposed, it could have been interpreted as requiring systems, even if redundant, to be functional at all times. The intent was to assure that timely emergency power can be provided to structures, systems, and components important to safety. The provision has been modified accordingly. There is no need to state that emergency power be sufficient to allow safe conditions to be maintained, since this is implicit in the remainder of the text.

(6) Inspection, testing, and maintenance. [Section 60.130(b)(7)]

No change from proposed rule.

(7) Criticality control. [Section 60.130(b)(8)]

No change from proposed rule.

(8) Instrumentation and control systems. [Section 60.130(b)(9)]

The adjective "engineered" has been deleted, in reference to systems important to safety, so as to retain uniform terminology throughout the rule.

The provision for design "with sufficient redundancy to ensure that adequate margins of safety are maintained," which was criticized as being vague, has been deleted. The objective was to ensure that the design incorporate needed instrumentation and this has been accomplished more clearly by the amended language.

(9) Compliance with mining regulations. [Section 60.130(b)(10)]

No change from proposed rule. It should be noted that this provision is not intended to assert NRC authority over mining safety practices generally, but to the extent that the safety of workers is necessary for systems important to safety to perform their intended functions, the relevant design features are of legitimate concern to NRC.

(10) Shaft conveyances used in radioactive waste handling [Section 60.133(c)]

The specific criteria applicable to hoists important to safety have remained unchanged. The general requirement that shaft conveyances used to transport radioactive materials be designed to satisfy the requirements for systems, structures, and components important to safety has been deleted because it was unduly broad; to the extent that the shaft conveyances are in fact important to safety, the applicable design requirements will still apply.

Section 60.132 Additional design criteria for surface facilities in the geologic repository operations area. [Section 60.131]

(a) Facilities for receipt and retrieval of waste. [Section 60.131(a)]

This paragraph has been shortened by deleting redundant and unnecessary detail. The requirement for safe handling and storage implies provision for inspection, repair, and decontamination as appropriate. Similarly, it is not necessary to state that surface storage capacity need not be provided for all emplaced waste, there must be sufficient capacity, however, to allow safe handling and storage.

(b) Surface facility ventilation. [Section 60.131(b)]

The only change is the reference to § 60.111(a) by paragraph. This is not a substantive amendment, as this is the only part of the performance objectives relevant to ventilation.

(c) Radiation control and monitoring. [Section 60.131(c)]

The reference to emergency operations is omitted because that subject is covered by § 60.131(b)(4). Editorial changes have been made here for the same reasons as were discussed in connection with that paragraph.

(d) Waste treatment. [Section 60.131(d)]

No change from proposed rule.

(e) Consideration of decommissioning. [Section 60.131(e)]

See *Decommissioning* above. The term "decommissioning" has been retained in this context because surface facilities may continue to be used even after permanent closure. The requirement has been made more precise by specifying that the same standards apply here as to other activities licensed by NRC.

§ 60.133 Additional design criteria for the underground facility. [Section 60.132]

(a) General criteria for the underground facility. [Section 60.132(a)]

Proposed paragraphs (a)(1) and (a)(2) have been deleted because they were redundant.

The requirement that design features "enhance [containment and isolation of radionuclides] to the extent practicable at the site" has been changed to provide that the design shall "contribute" to such containment and isolation. As proposed, this provision could have been construed as imposing requirements substantially in excess of those needed to satisfy the performance objectives. This was not the intention. See also the discussion of *ALARA*, above.

The requirement to design the underground facility against the effects of disruptive events has been modified to apply to events occurring during the period of operations and to exclude water and gas intrusions to eliminate redundancy with other provisons of the rule. The requirement is also limited to consideration of *credible* disruptive events.

(b) Flexibility of design. [Section 60.132(b)]

The only change, in puncutation, is editorial.

(c) Retrieval of waste. [Section 60.132(d)]

Proposed paragraph (d)(2) has been deleted because it was redundant with proposed paragraph (d)(1) and was read to prohibit backfilling.

Proposed paragraph (d)(3) has been deleted because it is subsumed in the remaining text of the paragraph.

(d) Control of water and gas. [Section 60.132(g)]

Because of confusion about the meaning of the term "service water," the design requirement has been rephrased so as to refer more generally to "water or gas intrusion."

Additional proposed requirements have been deleted in response to comments regarding the level of detail in the rule. (See *Level of Detail*, above.) While each of the items that had been addressed will in all probability be needed, the remaining general design criterion for control of water and gas is adequate to ensure that each of the features will be incorporated in the design where necessary.

(e) Underground openings. [Section 60.132(e)]

This paragraph has been rewritten in functional terms so as to require design so that operations in the underground facility "can be carried out safely and the retrievability option maintained."

The requirement that the design reduce the potential for deleterious rock movement or fracturing of rock has been retained. The identification of considerations that must be taken into account has been deleted as being more appropriate for treatment in regulatory guides. The Commission anticipates, however, that each of the factors that had been listed would in fact have been included in complying with this paragraph.

(f) Rock excavation. [Section 60.132(f)]

The proposed rule required design to "limit damage to and fracturing of rock." The extent to which damage should be "limited" was not stated. Moreover, for some geologic media and sites, the requirement could be interpreted to prescribe particular excavation methods, which was not the intent. The paragraph has been rephrased to indicate that the design must reduce the potential for creating a preferential pathway to the accessible environment.

(g) Underground facility ventilation. [Section 60.132(h)]

The term "subsurface facility" has been eliminated, conforming to the caption of the section. Paragraph (g)(1) now refers to control within and from the "underground facility."

Proposed paragraph (h)(2), which would have required design to permit continuous occupany of all excavated areas through permanent closure, was excessively restrictive. Ventilation will need to be maintained, however, where normal operations are being carried out, so as to satisfy paragraph (g)(1).

Proposed paragraph (h)(3) was deleted. It is adequately covered by paragraph (g)(1).

As in some other contexts, reference is now made to "accident conditions" instead of "emergency conditions" (see discussion of § 60.131(b)(5) above). The requirement for design to assure continued function is retained, but the means for accomplishing this is left to the designer. Redundant equipment and fail-safe control systems would continue to be employed where necessary and appropriate.

(h) Engineered barriers. [Section 60.132(i)]

The proposed rule, in paragraph (i), would have specified several design requirements for the engineered barriers, including backfill and barriers at shafts. While the Commission continues to expect that such features will ordinarily be incorporated into the design, it has concluded that its earlier approach would have been unduly restrictive. The Commission has therefore left only the general functional statement that the engineered barriers shall be designed to assist the geologic setting in meeting long-term performance objectives.

(i) Thermal loads. [Section 60.132(k)]

This provision retains the substance of proposed paragraph (k)(1). The reference to the "ability of the natural or engineered barriers to retard radionuclide migration" is deleted because it is already covered by requiring that the performance objectives be met.

Proposed (k)(2), identifying factors to be taken into account in the design of waste loading and waste spacings, has been omitted as containing excessive detail.

Other omitted provisions. [Sections 60.132(c), 60.132(j)]

Proposed § 60.132(c), dealing with the modular concept, was excessively restrictive. The Commission recognizes that to some degree the concurrent conduct of excavation with waste emplacement could "impair" waste emplacement or retrieval operations. Concurrent excavation and waste emplacement would be acceptable, provided that all other applicable requirements are satisfied. The provision for trisulation of individual modules is not necessary, since paragraph (a)(3) requires that the design limit the effects of disruptive events and paragraph (g)(2) provides that the design assure continued function of ventilation systems under accident conditions. Section 60.131(a), including the design requirement to control the dispersal of radioactive contamination, is also relevant.

Proposed § 60.132(j) would have specified fail-safe designs in systems for handling, transporting, and emplacing wastes. This too was excessively restrictive. What protective measures are needed will be determined in the light of a range of factors, including the probability and consequences of mishaps and the costs of alternative means for dealing with them. Similarly, the final rule does not require that handling systems "minimize the potential for operator error;" specifications for such systems will depend upon an evaluation of the particular risks involved. Where protective measures are needed, particularly insofar as they relate to radiological consequences, the remaining design requirements suffice.

Section 60.134 Construction specifications for surface and subsurface facilities

The proposed rule contained a section on construction specifications that was not appropriate, since (under § 60.21(a)(2)), the scope of Subpart E was limited to site and design criteria.

Although the section has therefore been deleted, this does not mean that construction procedures are not of vital significance. As stated in § 60.31(a)(1)(iv), the Commission will consider whether DOE has adequately described construction procedures which may affect the capability of the geologic repository to serve its intended function. Appropriate provisions will be included in a construction authorization, as provided in § 60.32.

Proposed § 60.134(c), dealing with construction records, has been retained, with minor modifications. It now appears as § 60.72, and is discussed in the analysis of that section.

Section 60.134 Design of seals for shafts and boreholes. [§ 60.133]

The proposed rule contained a number of provisions which commenters criticized as being unachievable, or at least incapable of being demonstrated. Specifically, there was objection to the requirements that shaft and seal design not create preferential pathways and that sealed shafts and boreholes inhibit radionuclide transport to, at the least, the same degree as the undisturbed rock. The Commission acknowledges that in some cases a pathway may be created that may be preferential in relation to the undisturbed rock. Whether or not this is acceptable will depend upon the characteristics of the rock in question, the quality of the seal under projected conditions, the age, nature, and location of the waste, and the design of the underground facility. The important thing is that the seals not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period relating to isolation of the waste. This concept now appears as § 60.134(a).

Additionally, although the Commission's general approach has been to avoid ALARA-type concepts, it has in this instance specified that materials and placement methods for seals be selected to reduce to the extent practicable, the potential for creating a preferential pathway or the migration of radionuclides through existing pathways. This approach is based upon a concern that significant deficiencies in seal design could largely, or entirely, eliminate the contribution to waste isolation which is to be provided by the geologic setting. By insisting that seal design reduce preferential pathways to the extent practicable, the Commission ensures that the design will facilitate its arriving at licensing decisions.

Proposed § 60.132(L)(1) provided that shafts and boreholes be sealed as soon as possible after they have served their operational purpose. As in the other portions of the section, the objective was to address the question of long-term isolation. Early sealing can prevent deformations that might otherwise develop prior to permanent closure. Such events could make it more difficult or impractical to achieve maximum integrity of the permanent seals when they are put into place. To the extent that this is an important concern, it too is covered under the text of the final § 60.134.

Design Criteria for the Waste Package

Section 60.135 Criteria for the waste package and its components.

A geologic repository operations area, by definition, is a facility that may be used for the disposal of high-level radioactive waste. The rule must therefore address matters related to HLW, including as appropriate requirements as to HLW waste form and waste package. Whether or not other radioactive materials are emplaced in the facility is speculative, and even if this should occur, the quantities, specific activity, half-lives and other relevant factors may be so variable as to make it impossible at this time to establish reasonable rules. The final rule accordingly expressly limits the applicability of the requirements of this section to high-level radioactive waste. Nonradioactive wastes are not addressed at all. The Commission defers for later consideration, should the occasion arise, an examination of the legal and technical questions that would be presented if the disposal of nonradioactive wastes in a geologic repository operations area were to be proposed.

Section 60.135(a) High-level waste package design in general.

This paragraph has been revised editorially. It is now limited to HLW packages, but is otherwise unchanged in substance from the proposed rule.

Section 60.135(b) Specific criteria for HLW package design [§ 60.135(c)]

Two paragraphs relate to contents of the waste package—one dealing with explosive, pyrophoric, and chemically reactive materials and a second dealing with free liquids. Editorial changes have been made so as to provide parallel language. Insofar as the period of operations is concerned, this is done by adopting the proposed language that has applied to free liquids. Insofar as waste isolation is concerned, both paragraphs are related to the relevant performance objective, adapting for this purpose the proposed provisions on explosive, pyrophoric, and chemically reactive materials.

Also, as revised, the provision pertaining to explosive, pyrophoric, and chemically reactive materials avoids the possible interpretation that insignificant quantities of such materials may not be incorporated in waste packages.

Other changes are merely editorial.

Section 60.135(c) Waste form criteria for HLW. [§ 60.135(b)].

The portion of this paragraph that deals with combustibles has been modified so as to specify that a fire involving waste packages containing combustibles will not affect the integrity of other waste packages, adversely affect any structures, systems or components important to safety, or compromise the ability of the underground facility to contribute to waste isolation. This parallels the corresponding changes in the waste package design criteria.

The reference to structures, systems, or components is modified by the defined term "important to safety" rather than the undefined adjective "safety-related."

Section 60.135(d) Design criteria for other radioactive wastes.

This paragraph is new. Its purpose is described in the introductory analysis for this section.

Performance Confirmation Requirements

Section 60.137 General requirements for performance confirmation.

Unchanged from proposed rule.

Subpart F—Performance Confirmation Program

Section 60.140 General requirements

The proposed rule would have specified that the performance confirmation program "ascertain" certain data. While achievement of that goal would be desirable, it is more accurate to state that the program is to "provide data which indicates, where practicable," whether conditions are within assumed limits and systems are functioning as intended.

The proposed requirement that the confirmation program be implemented so as not to "adversely affect" the natural and engineered barriers, § 60.140(d)(1), also needed to be qualified. The Commission's intention was not to prohibit useful tests that would have trivial impacts upon the repository's performance. Instead, it wishes to assure that significant potentially adverse effects are taken into account in designing the performance confirmation program. The paragraph has been modified accordingly.

See also the amendment to § 60.74, which provides for the conduct of the performance confirmation program.

Section 60.141 Confirmation of geotechnical and design parameters.

Unchanged from proposed rule.

Section 60.142 Design testing

Unchanged from proposed rule.

Section 60.143 Monitoring and testing waste packages.

The ambiguous term "repository" has been replaced by the defined terms "geologic repository operations area" or "underground facility," as appropriate. Other changes are editorial in nature.

Subpart G—Quality Assurance

Section 60.150 Scope.

This section has been revised to correspond to the counterpart provision of 10 CFR Part 50, Appendix B. Where the same term (here, "quality assurance") is employed in related contexts, it is generally desirable to use a common definition. For this reason, the Commission has declined to substitute "reasonable assurance" for "adequate confidence" as the measure of satisfactory performance.

Section 60.151 Applicability

The final rule defines "important to safety" in a manner related to the period of operations. Because quality assurance requirements must be applied with a view to long-term performance, Subpart G is also made applicable to those elements of the geologic repository that must function in a prescribed manner so as to satisfy the performance objectives for the period after permanent closure. The proposed rule's reference to "events that could cause an undue risk to the health and safety of the public" has been deleted because of the inclusion of the more definite standards that are referred to in the revised first sentence of the section.

Further, the Commission has adopted a suggestion to revise the list of activities to which Subpart G pertains so as to correspond more closely with the structure of the rule.

Section 60.152 Implementation.

Unchanged from proposed rule.

[Section 60.153 Quality assurance for performance confirmation.]

This section of the proposed rule has been deleted because performance confirmation is now made subject, by § 60.151(b), to explicit requirement for the conduct of performance confirmation.

Subpart H—Training and Certification of Personnel

Provisions for training and Certification of Personnel are unchanged in substance from the proposed rule. The rule has been clarified by replacing the undefined term "operations important to safety" with the phrase "operations of systems and components important to safety." Other changes are merely editorial.

Subpart I—Emergency Planning Criteria

Section 60.31(a) provides that one of the considerations bearing upon the issuance of a construction authorization is whether DOE's emergency plan complies with the criteria contained in Subpart I. The proposed technical criteria were silent with respect to Subpart I, and the contents of that subpart here continue to be reserved.

Environmental Impact

Pursuant to Section 121(c) of the Nuclear Waste Policy Act of 1982, the promulgation of these criteria shall not require the preparation of an environmental impact statement under Section 102(2)(C) of the National Environmental Policy Act of 1969 or any environmental review under subparagraph (E) or (F) of Section 102(2) of such Act.

Paperwork Reduction Act

This rule contains no new or amended recordkeeping, reporting, or application requirement, or any other type of information collection requirement, subject to the Paperwork Reduction Act (Pub. L. 96-511).

Regulatory Flexibility Act Certification

As required by the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Commission certifies that this rule, if adopted, will not have a significant economic impact upon a substantial number of small entities. The only entity subject to regulation under this rule is the U.S. Department of Energy.

List of Subjects in 10 CFR Part 60

High-level waste, Nuclear power plants and reactors, Nuclear materials, Penalty, Reporting requirements, Waste treatment and disposal.

Issuance

For the reasons set out in the preamble and under the authority of the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, the Nuclear Waste Policy Act of 1982, and 5 U.S.C. 553, the Nuclear Regulatory Commission is adopting the following amendments to 10 CFR Part 60.

PART 60—DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

1. The Table of Contents for Part 60 is revised to read as follows:

Subpart A—General Provisions

Sec.
60.1 Purpose and scope.
60.2 Definitions.
60.3 License required.
60.4 Communications.
60.5 Interpretations.
60.6 Exemptions.
60.7 License not required for certain preliminary activities.
60.8 Reporting, recordkeeping, and application requirements: OMB approval not required.
60.9 Employment protection.

Subpart B—Licenses

Preapplication Review

60.10 Site characterization.
60.11 Site characterization report.

License Applications

60.21 Content of application.
60.22 Filing and distribution of application.
60.23 Elimination of repetition.
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Construction Authorization

60.31 Construction authorization.
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License Issuance and Amendment

60.41 Standards for issuance of a license.
60.42 Conditions of license.
60.43 License specification.
60.44 Changes, tests, and experiments.
60.45 Amendment of license.
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Permanent Closure

60.51 License amendment for permanent closure.
60.52 Termination of license.

Subpart C—Participation by State Governments and Indian Tribes

60.61 Site review.
60.62 Filing of proposals for State participation.
60.63 Approval of proposals.
60.64 Participation by Indian tribes.
60.65 Coordination.

Subpart D—Records, Reports, Tests, and Inspections

60.71 General recordkeeping and reporting requirements.
60.72 Construction records.
60.73 Reports of deficiencies.
60.74 Tests.
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Subpart E—Technical Criteria

Sec.
60.101 Purpose and nature of findings.
60.102 Concepts.

Performance Objectives

60.111 Performance of the geologic repository operations area through permanent closure.
60.112 Overall system performance objective for the geologic repository after permanent closure.
60.113 Performance of particular barriers after permanent closure.

Land Ownership and Control

60.121 Requirements for ownership and control interests in land.

Siting Criteria

60.122 Siting criteria.

Design Criteria for the Geological Repository Operations Area

60.130 Scope of design criteria for the geologic repository operations area.
60.131 General design criteria for the geologic repository operating area.
60.132 Additional design criteria for surface facilities in the geologic repository operations area.
60.133 Additional design criteria for the underground facility.
60.134 Design of seals for shafts and boreholes.

Design Criteria for the Waste Package

60.135 Criteria for the waste package and its components.

Performance Confirmation Requirements

60.137 General requirements for performance confirmation.

Subpart F—Performance Confirmation Program

60.140 General requirements.
60.141 Confirmation of geotechnical and design parameters.
60.142 Design testing.
60.143 Monitoring and testing waste packages.

Subpart G—Quality Assurance

60.150 Scope.
60.151 Applicability.
60.152 Implementation.

Subpart H—Training and Certification of Personnel

60.160 General requirements.
60.161 Training and certification program.
60.162 Physical requirements.

Subpart I—Emergency Planning Criteria [Reserved]

2. The authority citation for Part 60 is revised to read as follows:

Authority: Secs. 51, 53, 62, 63, 65, 81, 161, 182, 183, 68 Stat. 929, 930, 932, 933, 935, 948, 953, 954, as amended (42 U.S.C. 2071, 2073, 2092, 2093, 2095, 2111, 2201, 2232, 2233); secs. 202, 206, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846); secs. 10 and 14, Pub. L. 95-601, 92 Stat. 2951 (42 U.S.C. 2021a and 5851); sec. 102, Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332); sec. 121, Pub. L. 97-425, 96 Stat. 2228 (42 U.S.C. 10141).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), §§ 60.71 to 60.75 are issued under sec. 161o, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

3. Section 60.2 is revised to read as follows:

§ 60.2 Definitions.

As used in this part—

"Accessible environment" means: (1) The atmosphere, (2) the land surface, (3) surface water, (4) oceans, and (5) the portion of the lithosphere that is outside the controlled area.

"Anticipated processes and events" means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved. To the extent reasonable in the light of the geologic record, it shall be assumed that those processes operating in the geologic setting during the Quaternary Period continue to operate but with the perturbations caused by the presence of emplaced radioactive waste superimposed thereon.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Candidate area" means a geologic and hydrologic system within which a geologic repository may be located.

"Commencement of construction" means clearing of land, surface or subsurface excavation, or other substantial action that would adversely affect the environment of a site, but does not include changes desirable for the temporary use of the land for public recreational uses, site characterization activities, other preconstruction monitoring and investigation necessary to establish background information related to the suitability of a site or to the protection of environmental values, or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Controlled area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the accessible environment.

"Disturbed zone" means that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered barrier system" means the waste packages and the underground facility.

"Geologic repository" means a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes: (1) The geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste.

"Geologic repository operations area" means a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

"High-level radioactive waste" or "HLW" means: (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

"HLW facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat 1244) [1]

"Host rock" means the geologic medium in which the waste is emplaced.

"Important to safety," with reference to structures, systems, and components means those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure.

"Indian tribe" means an Indian tribe as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93-638).

"Isolation" means inhibiting the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

"Permanent closure" means final backfilling of the underground facility and the sealing of shafts and boreholes.

"Performance confirmation" means the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met.

"Public Document Room" means the place at 1717 H Street N.W., Washington, D.C., at which records of the Commission will ordinarily be made available for public inspection and any other place, the location of which has been published in the Federal Register, at which public records of the Commission pertaining to a particular geologic repository are made available for public inspection.

"Radioactive waste" or "waste" means HLW and other radioactive materials other than HLW that are received for emplacement in a geologic repository.

"Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

"Retrieval" means the act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal.

"Saturated zone" means that part of the earth's crust beneath the deepest water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

"Site" means the location of the controlled area.

"Site characterization" means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic repository, but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken.

"Tribal organization" means a tribal organization as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93-638).

"Unanticipated processes and events" means those processes and events affecting the geologic setting that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which are nevertheless sufficiently credible to warrant consideration. Unanticipated processes and events may be either natural processes or events or processes and events initiated by human activities other than those activities licensed under this part. Processes and events initiated by human activities may only be found to be sufficiently credible to warrant consideration if it is assumed that: (1) The monuments provided for by this part are sufficiently permanent to serve their intended purpose; (2) the value to future generations of potential resources within the site can be assessed adequately under the applicable provisions of this part; (3) an understanding of the nature of radioactivity, and an appreciation of its hazards, have been retained in some functioning institutions; (4) institutions are able to assess risk and to take remedial action at a level of social organization and technological competence equivalent to, or superior to, that which was applied in initiating the processes or events concerned; and (5) relevant records are preserved, and remain accessible, for several hundred years after permanent closure.

"Underground facility" means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

[1] These are DOE "facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such Act [the Atomic Energy Act]" and "Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive wastes generated by [DOE], which are not used for, or are part of, research and development activities."

"Unrestricted area" means any area, access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

"Waste form" means the radioactive waste materials and any encapsulating or stabilizing matrix.

"Waste package" means the waste form and any containers, shielding, packing and other absorbent materials immediately surrounding an individual waste container.

"Water table" means that surface in a groundwater body at which the water pressure is atmospheric.

4. Section 60.10 is amended by revising paragraph (a) and adding a new paragraph (d) to read as follows:

§ 60.10 Site characterization.

(a) Prior to submittal or an application for a license to be issued under this part DOE shall conduct a program of site characterization with respect to the site to be described in such application.

* * * * *

(d) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted in such a manner as to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

(2) The number of exploratory boreholes and shafts shall be limited to the extent practical consistent with obtaining the information needed for site characterization.

(3) To the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for underground facility construction and operation or where large unexcavated pillars are planned.

(4) Subsurface exploratory drilling, excavation, and in situ testing before and during construction shall be planned and coordinated with geologic repository operations area design and construction.

5. Section 60.11 is amended by revising paragraph (a) to read as follows:

§ 60.11 Site characterization report.

(a) As early as possible after commencement of planning for a particular geologic repository operations area, and prior to site characterization, DOE shall submit to the Director a Site Characterization Report. The report shall include [8] (1) A description of the site to be characterized; (2) the criteria used to arrive at the candidate area; (3) the method by which the site was selected for site characterization; (4) identification and location of alternative media and sites at which DOE intends to conduct site characterization and for which DOE anticipates submitting subsequent Site Characterization Reports; (5) a description of the decision process by which the site was selected for characterization, including the means used to obtain public, Indian tribal and State views during selection; (6) a description of the site characterization program including: (i) The extent of planned excavation and plans for in situ testing, (ii) a conceptual design of a geologic repository operations area appropriate to the named site in sufficient detail to allow assessment of the site characterization program, with respect to investigation activities which address the ability of the site to host a geologic repository and isolate radioactive waste, or which may affect such ability, and (iii) provisions to control any adverse, safety-related effects from site characterization, including appropriate quality programs; (7) a description of the quality assurance program to be applied to data collection; and (8) any issues related to site selection, alternative candidate areas, or other sites, or design of the geologic repository operations area which the DOE wishes the Commission to review. Also included shall be a description of the research and development activities being conducted by DOE which deal with the waste form and packaging which may be considered appropriate for the site to be characterized, including research planned or underway to evaluate the performance of such waste forms and packaging.

* * * * *

6. Section 60.21 is amended by revising paragraphs (c)(1), (c)(3), (c)(4), (c)(8), (c)(9), (c)(11), (c)(13), (c)(14), and (c)(15) to read as follows:

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include—

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

(ii) The assessment shall contain—

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they affect isolation within the controlled area.

(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of

[8] To the extent that the information indicated in items 3 through 5 appears in an Environmental Impact Statement prepared by DOE for site characterization of the named site, it may be incorporated into DOE's Site Characterization Report by reference.

releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(E) An analysis of the performance of the major design structures, systems, and components, both surface and subsurface, to identify those that are important to safety. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, in situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. This analysis shall consider—(i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

(4) A description of the quality assurance program to be applied to the structures, systems, and components important to safety and to the engineered and natural barriers important to waste isolation.

* * * * *

(8) A description of the controls that the applicant will apply to restrict access and to regulate land use at the site and adjacent areas, including a conceptual design of monuments which would be used to identify the controlled area after permanent closure.

(9) Plans for coping with radiological emergencies at any time prior to permanent closure and decontamination or dismantlement of surface facilities.

* * * * *

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

* * * * *

(13) An identification and evaluation of the natural resources of the geologic setting, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the geologic repository to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscoverd deposits, shall be conducted for the site and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The estimate of net value shall take into account current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

(14) An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, which require research and development to confirm the adequacy of design. For structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

(15) The following information concerning activities at the geologic repository operations area:

(i) The organizational structure of DOE as it pertains to construction and operation of the geologic repository operations area including a description of any delegations of authority and assignments of responsibilities, whether in the form of regulations, administrative directives, contract provisions, or otherwise.

(ii) Identification of key positions which are assigned responsibility for safety at and operation of the geologic repository operations area.

(iii) Personnel qualifications and training requirements.

(iv) Plans for startup activities and startup testing.

(v) Plans for conduct of normal activities, including maintenance, surveillance, and periodic testing of structures, systems, and components of the geologic repository operation area.

(iv) Plans for permanent closure and plans for the decontamination or dismantlement of surface facilities.

(vii) Plans for any uses of the geologic repository operations area for purposes other than disposal of radioactive wastes, with an analysis of the effects, if any, that such uses may have upon the operation of the structures, systems, and components important to safety and the engineered and natural barriers important to waste isolation.

7. Section 60.22 is amended by revising paragraphs (a) and (d) to read as follows:

§ 60.22 Filing and distribution of application.

(a) An application for a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area at a site which has been characterized, and an accompanying environmental report, and any amendments thereto, shall be filed in triplicate with the Director and shall be signed by the Secretary of Energy or the Secretary's authorized representative.

* * * * *

(d) At the time of filing of an application and environmental report, and any amendments thereto, one copy shall be made available in an appropriate location near the proposed geologic repository operations area (which shall be a public document room, if one has been established) for inspection by the public and updated as amendments to the application or environmental report are made. An updated copy shall be produced at any public hearing on the application for use by any parties to the proceedings.

* * * * *

8. Section 60.31 is amended by revising paragraphs (a)(1) and (a)(2) to read as follows:

§ 60.31 Construction authorization.

* * * * *

(a) *Safety.* That there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository operations area of the design proposed without unreasonable risk to the health and safety of the public. In arriving at this determination, the Commission shall consider whether:

(1) DOE has described the proposed geologic repository including but not limited to: (i) The geologic, geophysical, geochemical and hydrologic characteristics of the site; (ii) the kinds and quantities of radioactive waste to be received, possessed, stored, and disposed of in the geologic repository operations area; (iii) the principal architectural and engineering criteria for the design of the geologic repository operations area; (iv) construction procedures which may affect the capability of the geologic repository to serve its intended function; and (v) features or components incorporated in the design for the protection of the health and safety of the public.

(2) The site and design comply with the performance objectives and criteria contained in Subpart E of this part.

* * * * *

9. Section 60.32 is amended by revising paragraphs (b) and (c) to read as follows:

§ 60.32 Conditions of construction authorization.

* * * * *

(b) The Commission will incorporate in the construction authorization provisions requiring DOE to furnish periodic or special reports regarding: (1) Progress of construction, (2) any data about the site obtained during construction which are not within the predicted limits upon which the facility design was based, (3) any deficiencies in design and construction which, if uncorrected, could adversely affect safety at any future time, and (4) results of research and development programs being conducted to resolve safety questions.

(c) The construction authorization will include restrictions on subsequent changes to the features of the geologic repository and the procedures authorized. The restrictions that may be imposed under this paragraph can include measures to prevent adverse effects on the geologic setting as well as measures related to the design and construction of the geologic repository operations area. These restrictions will fall into three categories of descending importance to public health and safety as follows: (1) Those features and procedures which may not be changed without (i) 60 days prior notice to the Commission (ii) 30 days notice of opportunity for a prior hearing, and (iii) prior Commission approval; (2) those features and procedures which may not be changed without (i) 60 days prior notice to the Commission, and (ii) prior Commission approval; and (3) those features and procedures which may not be changed without 60 days notice to the Commission. Features and procedures falling in paragraph (c)(3) of this section may not be changed without prior Commission approval if the Commission, after having received the required notice, so orders.

* * * * *

10. Section 60.43 is amended by revising paragraphs (b)(3) and (b)(5) to read as follows:

§ 60.43 License specifications.

* * * * *

(b) License conditions shall include items in the following categories—

* * * * *

(3) Restrictions as to the amount of waste permitted per unit volume of storage space considering the physical characteristics of both the waste and the host rock.

* * * * *

(5) Controls to be applied to restricted access and to avoid disturbance to the controlled area and to areas outside the controlled area where conditions may affect isolation within the controlled area.

* * * * *

11. Section 60.46 is amended by revising paragraphs (a)(3) and (a)(6) and adding (a)(7) to read as follows:

§ 60.46 Particular activities requiring license amendment.

(a) Unless expressly authorized in the license, an amendment of the license shall be required with respect to any of the following activities—

* * * * *

(3) Removal or reduction of controls applied to restrict access to or avoid disturbance of the controlled area and to areas outside the controlled area where conditions may affect isolation within the controlled area.

* * * * *

(6) Permanent closure.

(7) Any other activity involving an unreviewed safety question.

* * * * *

12. Section 60.51 is amended by changing the undesignated center heading immediately preceding the section from "Decommissioning" to "Permanent Closure" and by revising paragraphs (a)(1), (2), (4), (5) and (6), and paragraph (b).

§ 60.51 License amendment for permanent closure.

(a) DOE shall submit an application to amend the license prior to permanent closure. The application shall consist of an update of the license application and environmental report submitted under §§ 60.21 and 60.22, including:

(1) A description of the program for post-permanent closure monitoring of the geologic repository.

(2) A detailed description of the measures to be employed—such as land use controls, construction of monuments, and preservation of records—to regulate or prevent activities that could impair the long-term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for the use of future generations. As a minimum, such measures shall include—

(i) Identification of the controlled area and geologic repository operations area by monuments that have been designed, fabricated, and emplaced to be as permanent as is practicable; and

(ii) Placement of records in the archives and land record systems of local State, and Federal government agencies, and archives elsewhere in the world, that would be likely to be consulted by potential human intruders—such records to identify the location of the geologic repository operations area, including the underground facility, boreholes and shafts, and the boundaries of the controlled area, and the nature and hazard of the waste.

* * * * *

(4) The results of tests, experiments, and any other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with the host rock, and any other tests, experiments, or analyses pertinent to the long-term isolation of emplaced wastes within the geologic repository.

(5) Any substantial revision of plans for permanent closure.

(6) Other information bearing upon permanent closure that was not available at the time a license was issued.

(b) DOE shall update its environmental report in a timely manner so as to permit the Commission to review, prior to issuance of an amendment, substantial changes in the permanent closure activities proposed to be carried out or significant new information regarding the environmental impacts of such permanent closure.

13. Section 60.52 is amended by revising paragraphs (a) and (c)(2) to read as follows.

§ 60.52 Termination of license.

(a) Following permanent closure and the decontamination or dismantlement of surface facilities, DOE may apply for an amendment to terminate the license.

* * * * *

(c) A license shall be terminated only when the Commission finds with respect to the geologic repository—

(1) * * *

(2) That the final state of the geologic repository operations area conforms to DOE's plans for permanent closure and DOE's plans for the decontamination or dismantlement of surface facilities, as amended and approved as part of the license.

* * * * *

14. Subpart D is revised to read as follows:

Subpart D—Records, Reports, Tests, and Inspections

§ 60.71 General recordkeeping and reporting requirements.

(a) DOE shall maintain such records and make such reports in connection with the licensed activity as may be required by the conditions of the license or by rules, regulations, and orders of the Commission as authorized by the Atomic Energy Act and the Energy Reorganization Act.

(b) Records of the receipt, handling, and disposition of radioactive waste at a geologic repository operations area shall contain sufficient information to provide a complete history of the movement of the waste from the shipper through all phases of storage and disposal.

§ 60.72 Construction records.

(a) DOE shall maintain records of construction of the geologic repository operations area.

(b) The records required under paragraph (a) shall include at least the following—

(1) Surveys of the underground facility excavations, shafts, and boreholes referenced to readily identifiable surface features or monuments;

(2) A description of the materials encountered;

(3) Geologic maps and geologic cross sections;

(4) Locations and amount of seepage;

(5) Details of equipment, methods, progress, and sequence of work;

(6) Construction problems;

(7) Anomalous conditions encountered;

(8) Instrument locations, readings, and analysis;

(9) Location and description of structural support systems;

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

§ 60.73 Reports of deficiencies.

DOE shall promptly notify the Commission of each deficiency found in the characteristics of the site, and design and construction of the geologic repository operations area which, were it to remain uncorrected, could: (a) Be a substantial safety hazard, (b) represent a significant deviation from the design criteria and design bases stated in the application, or (c) represent a deviation from the conditions stated in the terms of a construction authorization or the license, including license specifications. The notification shall be in the form of a written report, copies of which shall be sent to the Director and to the appropriate Nuclear Regulatory Commission Regional Office listed in Appendix D of Part 20 of this chapter.

§ 60.74 Tests.

(a) DOE shall perform, or permit the Commission to perform, such tests as the Commission deems appropriate or necessary for the administration of the regulations in this part. These may include tests of: (1) Radioactive waste, (2) the geologic repository including its structures, systems, and components, (3) radiation detection and monitoring instruments, and (4) other equipment and devices used in connection with the receipt, handling, or storage of radioactive waste.

(b) The tests required under this section shall include a performance confirmation program carried out in accordance with Subpart F of this part.

§ 60.75 Inspections.

(a) DOE shall allow the Commission to inspect the premises of the geologic repository operations area and adjacent areas to which DOE has rights of access.

(b) DOE shall make available to the Commission for inspection, upon reasonable notice, records kept by DOE pertaining to activities under this part.

(c)(1) DOE shall upon requests by the Director, Office of Inspection and Enforcement, provide rent-free office space for the exclusive use of the Commission inspection personnel. Heat, air-conditioning, light, electrical outlets and janitorial services shall be furnished by DOE. The office shall be convenient to and have full access to the facility and shall provide the inspector both visual and acoustic privacy.

(2) The space provided shall be adequate to accommodate a full-time inspector, a part-time secretary and transient NRC personnel and will be generally commensurate with other office facilities at the geologic repository operations area. A space of 250 square feet either within the geologic repository operations area's office complex or in an office trailer or other onsite space at the geologic repository operations area is suggested as a guide. For locations at which activities are carried out under licenses issued under other parts of this chapter, additional space may be requested to accomodate additional full-time inspectors. The Office space that is provided shall be subject to the approval of the Director, Office of Inspection and Enforcement. All furniture, supplies and communication equipment will be furnished by the Commission.

(3) DOE shall afford any NRC resident inspector assigned to that location, or other NRC inspectors identified by the Regional Administrator as likely to inspect the facility, immediate unfettered access, equivalent to access provided regular employees, following proper identification and compliance with applicable access control measures for security, radiological protection and personal safety.

15. Subparts E, F, G, H, and I are added to read as follows:

Subpart E—Technical Criteria

§ 60.101 Purpose and nature of findings.

(a)(1) Subpart B of this part prescribes the standards for issuance of a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area. In particular, § 60.41(c) requires a finding that the issuance of a license will not constitute an unreasonable risk to the health and safety of the public. The purpose of this subpart is to set out performance objectives and site and design criteria which, if satisfied, will support such a finding of no unreasonable risk.

(2) While these performance objectives and criteria are generally stated in unqualified terms, it is not expected that complete assurance that they will be met can be presented. A reasonable assurance, on the basis of the record before the Commission, that the objectives and criteria will be met is the general standard that is required. For § 60.112, and other portions of this subpart that impose objectives and criteria for repository performance over long times into the future, there will inevitably be greater uncertainties. Proof of the future performance of engineered barrier systems and the geologic setting over time periods of many hundreds or many thousands of

years is not to be used in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with those objectives and criteria. Demonstration of compliance with such objectives and criteria will involve the use of data from accelerated tests and predictive models that are supported by such measures as field and laboratory tests, monitoring data and natural analog studies.

(b) Subpart B of this part also lists findings that must be made in support of an authorization to construct a geologic repository operations area. In particular, § 60.31(a) requires a finding that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository operations area of the design proposed without unreasonable risk to the health and safety of the public. As stated in that paragraph, in arriving at this determination, the Commission will consider whether the site and design comply with the criteria contained in this subpart. Once again, while the criteria may be written in unqualified terms, the demonstration of compliance may take uncertainties and gaps in knowledge into account, provided that the Commission can make the specified finding of reasonable assurance as specified in paragraph (a) of this section.

§ 60.102 Concepts.

This section provides a functional overview of Subpart E. In the event of any inconsistency with definitions found in § 60.2, those definitions shall prevail.

(a) *The HLW facility.* NRC exercises licensing and related regulatory authority over those facilities described in section 202 (3) and (4) of the Energy Reorganization Act of 1974. Any of these facilities is designated a *HLW facility.*

(b) *The geologic repository operations area.* (1) This part deals with the exercise of authority with respect to a particular class of HLW facility—namely a *geologic repository operations area.*

(2) *A geologic repository operations area* consists of those surface and subsurface areas that are part of a geologic repository where radioactive waste handling activities are conducted. The underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals, is designated the *underground facility.*

(3) The exercise of Commission authority requires that the geologic repository operations area be used for *storage* (which includes *disposal*) of *high-level radioactive wastes (HLW).*

(4) HLW includes irradiated reactor fuel as well as reprocessing wastes. However, if DOE proposes to use the geologic repository operations area for storage of *radioactive waste* other than HLW, the storage of this radioactive waste is subject to the requirements of this part.

(c) *Areas related to isolation.* Although the activities subject to regulation under this part are those to be carried out at the geologic repository operations area, the licensing process also considers characteristics of adjacent areas that are defined in other ways. There is to be an area surrounding the underground facility referred to above, which is designated the *controlled area*, within which DOE is to exercise specified controls to prevent adverse human actions following permanent closure. The location of the controlled area is the *site.* The *accessible environment* is the atmosphere, land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area. There is an area, designated the *geologic setting*, which includes the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located. The geologic repository operations area plus the portion of the geologic setting that provides isolation of the radioactive waste make up the *geologic repository.*

(d) *Stages in the licensing process.* There are several stages in the licensing process. The *site characterization* stage, though begun before submission of a license application, may result in consequences requiring evaluation in the license review. The *construction stage* would follow, after issuance of a construction authorization. A *period of operations* follows the issuance of a license by the Commission. The period of operations includes the time during which *emplacement* of wastes occurs; any subsequent period before permanent closure during which the emplaced wastes are *retrievable*; and *permanent closure*, which includes sealing of shafts. Permanent closure represents the end of active human intervention with respect to the engineered barrier system.

(e) *Isolation of waste.* (1) During the first several hundred years following permanent closure of a geologic repository, when radiation and thermal levels are high and the uncertainties in assessing repository performance are [illegible] special emphasis is placed upon the ability to contain the wastes by waste packages within an *engineered barrier system.* This is known as the *containment period.* The *engineered barrier system* includes the waste packages and the underground facility. A *waste package* is composed of the waste form and any containers, shielding, packing, and absorbent materials immediately surrounding an individual waste container. The *underground facility* means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

(2) Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. The engineered barrier system works to control the release of radioactive material to the geologic setting and the geologic setting works to control the release of radioactive material to the accessible environment. *Isolation* means inhibiting the transport of radioactive material so that amounts and concentrations of the materials entering the accessible environment will be kept within prescribed limits.

Performance Objectives

§ 60.111 Performance of the geologic repository operations area through permanent closure.

(a) *Protection against radiation exposures and releases of radioactive material.* The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) *Retrievability of waste.* (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a preformance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§ 60.112 Overall system performance objective for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure.

(a) *General provisions.* (1) *Engineered barrier system.* (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analysed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in § 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) *Geologic setting.* The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement groundwater travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are—

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and groundwater; and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

Land Ownership and Control

§ 60.121 Requirements for ownership and control of interests in land.

(a) *Ownership of land.* (1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use.

(2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) Rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Additional controls.* Appropriate controls shall be established outside of the controlled area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) *Water rights.* (1) DOE shall also have obtained such water rights as may be needed to accomplish the purpose of the geologic repository operations area.

(2) Water rights are included in the additional controls to be established under paragraph (b) of this section.

Siting Criteria

§ 60.122 Siting criteria.

(a)(1) A geologic setting shall exhibit an appropriate combination of the conditions specified in paragraph (b) of this section so that, together with the engineered barriers system, the favorable conditions present are sufficient to provide reasonable assurance that the performance objectives relating to isolation of the waste will be met.

(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository the following must be demonstrated:

(i) The potentially adverse human activity or natural condition has been adequately investigated, including the present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect; and

(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to isolation of the waste, or

(B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics so that the performance objectives relating to isolation of the waste are met, or

(C) The potentially adverse human activity or natural condition can be remedied.

(b) *Favorable conditions.* (1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide—

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and immediately surrounding hydrogeologic units; and

(iii) Low vertical permeability and low hydraulic potential between the host rock and surrounding hydrogeologic units; or

(iv) Pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years.

(3) Geochemical conditions that—(i) Promote precipitation or sorption of radionuclides; (ii) Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) Inhibit the transport of radionuclides by particulates, colloids, and complexes.

(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(6) A low population density within the geologic setting and a controlled area that is remote from population centers.

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(9) For disposal in the saturated zone, groundwater conditions in the host rock that are not reducing.

(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

(15) Evidence of igneous activity since the start of the Quaternary Period.

(16) Evidence of extreme erosion during the Quaternary Period.

(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(18) Evidence of subsurface mining for resources within the site.

(19) Evidence of drilling for any purpose within the site.

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

Design Criteria for the Geologic Repository Operations Area

§ 60.130 Scope of design criteria for the geologic repository operations area.

Sections 60.131 through 60.134 specify minimum criteria for the design of the geologic repository operations area. These design criteria are not intended to be exhaustive, however. Omissions in §§ 60.131 through 60.134 do not relieve DOE from any obligation to provide such safety features in a specific facility needed to achieve the performance objectives. All design bases must be consistent with the results of site characterization activities.

§ 60.131 General design criteria for the geologic repository operations area.

(a) *Radiological protection.* The geologic repository operations area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in restricted areas within the limits specified in Part 20 of this chapter. Design shall include—

(1) Means to limit concentrations of radioactive material in air;

(2) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(3) Suitable shielding;

(4) Means to monitor and control the dispersal of radioactive contamination;

(5) Means to control access to high radiation areas or airborne radioactivity areas; and

(6) A radiation alarm system to warn of significant increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability.

(b) *Structures, systems, and components important to safety. (1) Protection against natural phenomena and environmental conditions.* The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

(2) *Protection against dynamic effects of equipment failure and similar events.* The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts, that could result from equipment failure, and similar events and conditions that could lead to loss of their safety functions.

(3) *Protection against fires and explosions.* (i) The structures, systems, and components important to safety shall be designed to perform their safety fuctions during and after credible fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

(4) *Emergency capability.* (i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(5) *Utility services.* (i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and accident conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(iii) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely emergency power can be provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety.

(6) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(7) *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(8) *Instrumentation and control systems.* The design shall include provisions for instrumentation and control systems to monitor and control the behavior of systems important to safety over anticipated ranges for normal operation and for accident conditions.

(9) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

(10) *Shaft conveyances used in radioactive waste handling.* (i) Hoists important to safety shall be designed to preclude cage free fall.

(ii) Hoists important to safety shall be designed with a reliable cage location system.

(iii) Loading and unloading systems for hoists important to safety shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(iv) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place and ready for transfer.

§ 60.132 Additional design criteria for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111(a).

(1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objections of § 60.111(a).

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.

§ 60.133 Additional design criteria for the underground facility.

(a) *General criteria for the underground facility.* (1) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(2) The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as flooding, fires and explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Retrieval of waste.* The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of § 60.111.

(d) *Control of water and gas.* The design of the underground facility shall provide for control of water or gas intrusion.

(e) *Underground openings.* (1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) *Rock excavation.* The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment.

(g) *Underground facility ventilation.* The ventilation system shall be designed to—(1) Control the transport of radioactive particulates and gases within and releases from the underground facility in accordance with the performance objectives of § 60.111(a).

(2) Assure continued function during normal operations and under accident conditions; and

(3) Separate the ventilation of excavation and waste emplacement areas.

(h) *Engineered barriers.* Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

(i) *Thermal loads.* The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, and surrounding strata, groundwater system.

§ 60.134 Design of seals for shafts and boreholes.

(a) *General design criterion.* Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives or the period following permanent closure.

(b) *Selection of materials and placement methods.* Materials and placement methods for seals shall be selected to reduce, to the extent practicable: (1) The potential for creating a preferential pathway for groundwater; or (2) radioactive waste migration through existing pathways.

Design Criteria for the Waste Package

§ 60.135 Criteria for the waste package and its components.

(a) *High-level-waste package design in general.* (1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) *Specific criteria for HLW package design.* (1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials in an amount that could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives.

(2) *Free liquids.* The waste package shall not contain free liquids in an amount that could compromise the ability of the waste packages to achieve the performance objectives relating to containment of HLW (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure.

(3) *Handling.* Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) *Unique identification.* A label or other means of identification shall be provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

(c) *Waste form criteria for HLW. High-level radioactive waste that is emplaced in the underground facility shall be designed to meet the following criteria:*

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall be consolidated (for example, by incorporation into an encapsulating matrix) to limit the

bility and generation o[f]
ulates.

Combustibles. All combustible
ictive wastes shall be reduced to a
mbustible form unless it can be
istrated that a fire involving the
packages containing combustibles
ot compromise the integrity of
waste packages, adversely affect
ructures, systems, or components
tant to safety, or compromise the
of the underground facility to
bute to waste isolation.

*Design criteria for other
ictive wastes.* Design criteria for
types other than HLW will be
ssed on an individual basis if and
they are proposed for disposal in a
gic repository.

mance Confirmation
rements

**[§ 60.13]7 General requirements for
mance confirmation.**

geologic repository operations
hall be designed so as to permit
nentation of a performance
mation program that meets the
ements of Subpart F of this part.

[Subpa]rt F—Performance Confirmation [Progr]am

[§ 60.14]0 General requirements.

The performance confirmation
im shall provide data which
tes, where practicable, whether—
Actual subsurface conditions
ntered and changes in those
ions during construction and
emplacement operations are
the limits assumed in the
ing review; and
Natural and engineered systems
omponents required for repository
tion, or which are designed or
ed to operate as barriers after
nent closure, are functioning as
led and anticipated.
The program shall have been
[...] site characterization and
continue until permanent closure.
The program shall include in situ
oring, laboratory and field testing,
situ experiments, as may be
priate to accomplish the objective
ted above.
The program shall be implemented
t:
t does not adversely affect the
of the natural and engineered
nts of the geologic repository to
he performance objectives.
t provides baseline information
alysis of that information on
parameters and natural processes
ning to the geologic setting that
e changed by site [...] and
operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements [...] began.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the geologic repository operations area for monitoring the condition of the waste packages. Waste packages chosen for the program shall be representative of those to be emplaced in the underground facility.

(b) Consistent with safe operation at the geologic repository operations area, the environment of the waste packages selected for the waste package monitoring program shall be representative of the environment in which the wastes are to be emplaced.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the underground facility during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

Subpart G—Quality Assurance

§ 60.150 Scope.

As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the geologic repository and its subsystems or components will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety, to design and characterization of barriers important to waste isolation and to activities related thereto. These activities include: site characterization, facility and equipment construction, facility operation, performance confirmation, permanent closure, and surface facilities.

§ 60.152 Implementation.

DOE shall implement a quality assurance program based on the criteria of Appendix B of 10 CFR Part 50 as applicable, and appropriately supplemented by additional criteria as required by § 60.151.

Subpart H—Training and Certification of Personnel

§ 60.160 General requirements.

Operations of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety must also be certified in such operations.

§ 60.161 Training and certification program.

DOE shall establish a program for training, proficiency testing, certification and requalification of operating and supervisory personnel.

§ 60.162 Physical requirements.

The physical condition and the general health of personnel certified for operations that are important to safety shall not be such as might cause operational errors that could endanger the public health and safety. Any condition which might cause impaired judgment or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, so long as appropriate provisions are made to accommodate such conditions.

Subpart I—Emergency Planning Criteria [Reserved]

Dated at Washington, D.C., this 13th day of June 1983.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 83-16719 Filed 6-20-83; 8:45 am]

BILLING CODE 7590-01-M

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12 CFR Parts 207, 220, 221 and 224

Regulations G, T, U and X; Securities Credit Transactions

AGENCY: Board of Governors of the Federal Reserve System.

ACTION: Final rule; correction.

SUMMARY: This document corrects a previous Federal Register document, FR Doc. 83-15384 (List of OTC Margin Stocks), which was published at page 26587 of the issue for Thursday, June 9, 1983, to be effective June 20, 1983.

FOR FURTHER INFORMATION CONTACT: Jamie Lenoci, Financial Analyst, Division of Banking Supervision and Regulation, Board of Governors of the Federal Reserve System, Washington, D.C. 20551, (202) 452-2781.

SUPPLEMENTARY INFORMATION: Based upon corrected information received from the Company, the stock of Chemical Leaman Corporation, $2.50 par common, should remain on the List of OTC Margin Stocks. The stock of The Central Bancorporation, Inc., $5.00 par common was inadvertently omitted from the printed copy of the complete List of OTC Margin Stocks although it was not listed as a deletion from the list.

Accordingly, in accordance with § 207.2(f)(2) of Regulation G, § 220.2(e)(2) of Regulation T, and § 221.3(d)(2) of Regulation U the stock of Chemical Leaman Corporation, $2.50 par common, is removed from the list of deletions from the Board's List and is added to the complete List of OTC Margin Stocks on file at the Office of the Federal Register; and the stock of the Central Bancorporation, Inc., $5.00 par common, is added to the complete List on file at the Office of the Federal Register.

By order of the Board of Governors of the Federal Reserve System, June 16, 1983.

James McAfee,

Associate Secretary of the Board.

[FR Doc. 83-16608 Filed 6-16-83; 4:08 pm]

BILLING CODE 6210-01-M

CONSUMER PRODUCT SAFETY COMMISSION

16 CFR Part 1406

Provision of Performance and Technical Data for Coal and Wood Burning Appliances

AGENCY: Consumer Product Safety Commission.

ACTION: Final rule.

SUMMARY: The Commission amends a rule which requires that coal and wood burning stoves, freestanding fireplaces, and similar appliances bear a label stating that furnishings and other combustibles should be kept a "considerable distance away" from the appliance. The amendment would allow the use of alternate language stating that such objects should be kept "far away" from the appliance. This change is made to allow manufacturers to use a shorter statement to convey the safety message.

EFFECTIVE DATES: This amendment shall become effective October 17, 1983, which is also the effective date of the rule.

ADDRESSES: All materials that the Commission has that are relevant to this proceeding may be seen in, or copies obtained from, the Office of the Secretary, 8th Floor, 1111 18th Street NW., Washington, D.C. 20207.

FOR FURTHER INFORMATION CONTACT: Wade Anderson, Directorate for Compliance and Administrative Litigation, Consumer Product Safety Commission, Washington, D.C. 20207, phone (301) 492-6400.

SUPPLEMENTARY INFORMATION: On May 16, 1983, the Commission published a final rule in the Federal Register that requires that certain performance and technical data be supplied with coal and wood burning stoves, freestanding fireplaces, and similar appliances in order that consumers will be aware of important safety information concerning the installation, operation, and maintenance of these appliances. 16 CFR Part 1406, 48 FR 21898. Part of the data required by this rule is to be in the form of labeling on the device, and the rule also requires that complete installation, operation, and maintenance directions be provided with the appliance. Sales catalogs and other point of sale literature are required to state certain minimum clearance distances to combustibles and to refer to the possibility of other installation restrictions.

Section 1406.4(a)(1)(ix) of the rule requires that the label contain a "statement that furnishings and other combustible materials should be kept a considerable distance from the appliance." This requirement is intended to help prevent fires that can occur if furnishings or other combustible materials are placed too close to the appliance.

After the Commission had voted on the present language of § 1406.4(a)(1)(ix), a stove manufacturer wrote to the Commission, suggesting that the requirement be changed so that

APPENDIX C

NUCLEAR REGULATORY COMMISSION

10 CFR Part 60

Disposal of High-Level Radioactive Wastes in Geologic Repositories

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The NRC is publishing proposed amendments which specify technical criteria for disposal of high-level radioactive wastes (HLW) in geologic respositories. The proposed criteria address siting, design, and performance of a geologic repository, and the design and performance of the package which contains the waste within the geologic repository. Also included are criteria for monitoring and testing programs, performance confirmation, quality assurance, and personnel training and certification. The proposed criteria are necessary for the NRC to fulfill its statutory obligations concerning the licensing and regulating of facilities used for the receipt and storage of high-level radioactive waste.

DATE: Comments received after November 5, 1981 will be considered if it is practical to do so, but assurance of consideration cannot be given except for comments received on or before this date.

ADDRESS: Written comments or suggestions on the proposed amendments should be sent to the Secretary of the Nuclear Regulatory Commission, Washington, D.C. 20555, [illegible] examined in the U.S. Nuclear Regulatory Commission Public Document Room, 1717 H Street NW, Washington, D.C. Comments may also be delivered to Room 1121, 1717 H Street NW, Washington, D.C., between 8 15 a.m. and 5.00 p.m.

FOR FURTHER INFORMATION CONTACT: Frank J. Arsenault, Director of the Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone (301) 427-4350.

SUPPLEMENTARY INFORMATION:

Background

On December 6, 1979 the Nuclear Regulatory Commission (Commission or NRC) published for comment proposed procedures for licensing geologic disposal of high-level radioactive wastes. The licensing procedures were published in final form on February 25, 1981 (46 FR 13971). On May 13, 1980 (45 FR 31393) the Commission published for comment an Advance Notice of Proposed Rulemaking (ANPR) concerning technical criteria for regulating disposal of high-level radioactive wastes (HLW) in geologic respositories. Included with the advance notice was a draft of the technical criteria under development by the staff. The public was asked to provide comment on several issues discussed in the advance notice and to reflect on the draft technical criteria in light of that discussion. The comments received were numerous and covered the full range of issues related to the technical criteria. The technical criteria being proposed here are the culumination of a number of drafts, and were developed in light of the comments received on the ANPR. It is the Commissions's belief that the regulation proposed here is one which is both practical for licensing and this notice provides a flexible vehicle for accommodating comments in that it points out alternatives and calls for comment in a number of critical plans. The Commission has prepared an analysis of the comments which explains the changes made from the ANPR, and intends to publish soon the comments and the analysis as a NUREG document. A draft of this NUREG has been placed in the Commission's Public Document Room for review. In addition, the staff has begun a program to develop guidance as to the methods that it regards as satisfactory for demonstrating compliance with the requirements of the proposed rule.

ere as proposed rulemaking are a result f the Commission's further effort in egulating geologic disposal of HLW by e Department of Energy (DOE). The ationale for the performance objectives nd the Environmental Impact assessment supporting this rulemaking re also being published separately and re available free of charge upon written equest to Frank Arsenault at the above ddress. In developing these criteria we ave not reexamined DOE's rogrammatic choice of disposal echnology resulting from its Generic Environmental Impact Statement, nasmuch as the Commission has xpressly reserved until a later time ossible consideration of matters within he scope of that generic statement (44 FR 70408). Accordingly, the technical riteria apply only to disposal in eologic respositories and do not ddress other possible or potential lisposal methods. Similarly, in that DOE's current plans call for dispoal at ufficient depth to be in the area termed he saturated zone, these criteria were leveloped for disposal in saturated nedia. Additional or alternative criteria nay need to be developed for regulating disposal in the unsaturated or vadose zone.

Authority

Sections 202 (3) and (4) of the Energy Reorganization Act of 1974, as amended, provide the Commission with licensing and regulatory authority regarding DOE facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under the Atomic Energy Act and certain other long-term HLW storage facilities of DOE. Pursuant to that authority, the Commission is developing criteria appropriate to regulating geologic disposal of HLW by DOE. The requirements and criteria contained in this proposed rule are a result of that effort.

Relation to Generally Applicable Standards for Radiation in the Environment Established by the Environmental Protection Agency

The Environmental Protection Agency (EPA) has the authority and responsibility for setting generally applicable standards for radiation in the environment. It is the responsibility of the NRC to implement those standards in its licensing actions and assure that public health and safety are protected. Although no EPA standard for disposal of HLW yet exists, these proposed technical criteria for regulating geologic disposal of HLW have been developed to be compatible with a generally applicable environmental standard. Specifically, the performance objectives and criteria speak to the functional elements of geologic disposal of HLW and the analyses required to give confidence that these functional elements will perform as intended.

Disruptive Processes and Events

The NRC's implementing regulations assume that licensing decisions will be based, in part, on the results of analysis of the consequences of processes and events which potentially could disrupt a repository. Thus, throughout the criteria are requirements that the design basis take into account processes and events with the potential to disrupt a geologic repository. If the process or event is anticipated, i.e., likely, then the design basis requires barriers which would not fail in a way that would result in the repository not meeting the performance objectives. Anticipated processes and events would include such items as waste/rock interactions that result from emplacement of the wastes or the gradual deterioration of borehole seals. If the process or event is unlikely, then the overall system must still limit the release of radionuclides consistent with the EPA standard as applied to such events. An example of an unlikely event would be reactivation of a fault within the geologic setting which had not exhibited movement since the start of the Quaternary Period. In general, both likely and unlikely processes and events are expected to be site and design specific end would be identified by DOE in its license application.

Multiple Barriers

The proposed technical criteria were developed not only with the understanding that EPA's generally applicable environmental standard would need to be implemented, at least in part, by performing calculations to predict performance, but also with the knowledge that some of those calculations would be complex and uncertain. Natural systems are difficult to characterize and any understanding of the site will have significant limitations and uncertainties. Those properties which pertain to isolation of HLW are difficult to measure and the measurements which are made will be subject to several sources of error and uncertainty. The physical and chemical processes which isolate the wastes are themselves varied and complex. Further, those processes are especially difficult to understand in the area close to the emplaced wastes because that area is physically and chemically disturbed by the heat generated by those wastes. The repository consists of engineered features as well as the natural geologic environment. Any evaluation of repository performance, therefore, will consider the waste form and other engineering factors which are elemental to the performance of the repository as a system. By partitioning the engineered system into two major barriers, the waste package and the underground facility, and establishing performance objectives for each, the Commission has sought to exploit the ability to design the engineered features to meet specific performance objectives as a means of reducing some of the uncertainties in the calculations of overall repository performance.

In addition, the requirements for containment, controlled release rate, and 1,000-year groundwater transit time are three criteria which act independently of the overall repository performance to provide confidence that the wastes will be isolated at least for as long as they are most hazardous.

Containment and Isolation

During the first several hundred years following emplacement of the wastes, both the radiation from and the heat generated by the wastes are attributable mainly to the decay of the shorter-lived nuclides, primarily fission products. At about 1,000 years after emplacement both the radiation from and heat generated by decay of the wastes have diminished by about 3 orders of magnitude. As the decay of the longer-lived nuclides, primarily actinides, begins to dominate, both the radiation from and thermal output of the wastes continue to fall until almost 100,000 to 1,000,000 years after emplacement. By that time both have diminished by about 5 orders of magnitude and both heat and radiation become roughly constant due to the ingrowth of daughter nuclides, primarily Ra-225, Ra-226 and their decay products.

The technical criteria would require the engineered system to be designed so that the wastes are contained within the waste package for the first thousand years following emplacement. Following this period, containment is no longer assumed and the function of the waste package and underground facility is to control the release of radionuclides from the underground facility. By requiring containment during the period when the thermal conditions around the waste packages are most severe, evaluation of repository performance is greatly simplified to considerations of the degree of conservatism in the containment design relative to events period.

Although both the radiation from and heat generated by the decay of the wastes have diminished about 3 orders of magnitude during the containment period, the area surrounding the emplaced wastes will not return to temperatures near those before the wastes were emplaced until after about 10,000 years. As mentioned earlier, the thermal disturbance of the area near the emplaced wastes adds significantly to the uncertainties in the calculation of the transport of the radionuclides through the geologic environment. The technical criteria are intended to compensate for uncertainties by imposing further design requirements on the waste package and underground facility, thereby limiting the source term by controlling the release rate.

Role of the Site

The Commission neither intends nor expects either containment to be lost completely at 1,000 years following emplacement or the engineered system's contribution to the control of the release of wastes to cease abruptly at some later time. However, the Commission recognizes that at some point the design capabilities of the engineered system will be lost and that the geologic setting—the site—must provide the isolation of the wastes from the environment, and has translated this requirement into a performance objective for the geologic setting. The Commission also recognizes that isolation is, in fact, a controlled release to the environment which could span many thousands of years, and that the release of radionuclides and the potential exposures to individuals which could result, should be addressed in the evaluation of a repository. A complement to the evaluation of the effects of design basis processes and events which might disrupt the repository is a projection of how the repository, unperturbed by discrete external events, will evolve through the centuries as a result of the geologic processes operating at the site. Hence, an amendment is being proposed to that portion of Subpart B of 10 CFR Part 60 which describes the contents of the Safety Analysis Report of DOE's application for geologic disposal of HLW which would require DOE to project the expected performance of the proposed geologic repository noting the rates and quantities of expected releases of radionuclides to the accessible environment as a function of time.

Part 60 were written assuming that there would be a program of testing and measurement of the thermal, mechanical, and chemical properties of the major engineered barriers to confirm their expected performance. The Commission would like to tie the requirement for retrievability of the wastes to the expected time needed to execute the performance confirmation program. However, at present it appears to the Commission that neither the specific nature nor the period needed for execution of the performance confirmation program will be certain until construction of the repository is substantially complete; that is, until the actual licensing to receive wastes at a geologic repository. Hence it is difficult at this time to use the performance confirmation program as a basis for establishing a period of retrievability. Nonetheless, DOE is now making critical decisions regarding the design of geologic repositories which will have a direct effect upon how long the optio to retrieve wastes can be maintained, and upon the difficulty which will be encounted in exercising that option, should that be necessary for protection of public health and safety. Therefore, to provide a suitable objective in this regard, the proposed rule sets forth a requirement that the engineered system be designed so that the option to retrieve the waste can be preserved for up to fifty years following completion of emplacement. Thus, the waste package and the underground facility would be designed so that the period of retrievability would not be the determinant of when the Commission would decide to permit closure of the repository. Rather, the Commission would be assured of the option to let the conduct of the performance confirmation program indicate when it is appropriate to make such a decision. In particular, the Commission is concerned that the thermo-mechanical design of the underground facility be such that access can be maintained until the Commission either decides to permit permanent closure of the repository or to take corrective action, which may include retrieval.

As it is now structured, the rule would require in effect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years. The components of this total period are as follows: the first waste packages to go in the repository are likely to be in place about thirty years before all wastes are in place; thereafter, a 50-year period is required

the original construction plus emplacement operations—another 30-odd years. Since it is probably not practical to adjust the retrievability design aspects of the repository according to the order of emplacement of the waste packages, the 110-year requirement will apply to all of the waste. The Commission is particularly interested in comments on the degree to which this requirement will govern the thermal and mechanical design of the repository and on whether some shorter period would be adequate or whether there are other ways than an overall retrievability requirement to preserve options before permanent closure. The Commission does not want to approve construction of a design that will foreclose unnecessarily options for future decisionmakers, but it is also concerend that retrievability requirements not unnecessarily complicate or dominate repository design.

The retrievability requirement does not specify the form in which the wastes are to be retrievable or that wastes are "readily retrievable." The requirement is simply that all the wastes be retrievable during a period equal to the period of construction and emplacement. DOE's plans for retrieval are specifically requested as part of its license application and the practicability of its proposal will be considered by the Commission. Waste may be retrieved upon NRC approval of a DOE application or upon order by NRC, or otherwise, where authorized by DOE's license.

Human Intrusion

Some concern has been raised on the issue of human intrusion into a geologic repository. Human intrusion could conceivably occur either inadvertently or deliberately. Inadvertent intrusion is the accidental breaching of the repository in the course of some activity unrelated to the existence of the repository, e.g., exploration for or development of resources. For inadvertent intrusion to occur, the institutional controls, site markers, public records, and societal memory of the repository's existence must have been ineffective or have ceased to exist. Deliberate or intentional intrusion, on the other hand, assumes a conscious decision to breach the repository; for example, in order to recover the high-level waste itself, or exploit a mineral associated with the site.

Historical evidence indicates that there is substantial continuity of information transfer over time. There are numerous examples of knowledge, including complex information, being preserved for thousands of years. This has occurred even in the absence of printing and modern information transfer and storage systems. Furthermore, this information transfer has survived disruptive events, such as wars, natural disasters, and dramatic changes in the social and political fabric of societies. The combination of the historical record of information transfer, provisions for a well-marked and extensively documented site location, and the scale and technology of the operation needed to drill deeply enough to penetrate a geologic repository argue strongly that inadvertent intrusion as described above is highly improbable, at least for the first several hundred years during which time the wastes are most hazardous. Selecting a site for a repository which is unattractive with respect to both resource value and scientific interest further adds to the improbability of inadvertent human intrusion. It is also logical to assume that any future generation possessing the technical capability to locate and explore for resources at the depth of a repository would also possess the capability to assess the nature of the material discovered, to mitigate consequences of the breach and to reestablish administrative control over the area if needed. Finally, it is inconsistent to assume the scientific and technical capability to identify and explore an anomalous heat source several hundred meters beneath the Earth's surface and not assume that those exploring would have some idea of either what might be the cause of the anomaly or what steps to take to mitigate any untoward consequence of that exploration.

The above arguments do not apply to the case of deliberate intrusion. The repository itself could be attractive and invite intrusion simply because of the resource potential of the wastes themselves. Intrusion to recover the wastes demands (1) knowledge of the existence and nature of the repository, and (2) effort of the same magnitude as that undertaken to emplace the wastes. Hence intrusion of this sort can only be the result of a conscious, collective societal decision to recover the wastes.

Intrusion for the purpose of sabotage or terrorism has also been mentioned as a possibility. However, due to the nature of geologic disposal, there seems to be very little possibility that terrorists or saboteurs could breach a repository. Breach of the repository would require extensive use of machinery for drilling and excavating over a considerable period of time. It is highly improbable that a terrorist group could accomplish this covertly.

In light of the above, the Commission adopted the position that commonsense dictates that everything that is reasonable be done to discourage people from intruding into the repository. Thus, the proposed technical criteria are written to direct site selection towards selection of sites of little resource value and for which there does not appear to be any attraction for future societies. Further, the proposed criteria would require reliable documentation of the existence and location of the repository and the nature of the wastes emplaced therein, including marking the site with the most permanent markers practical. However, once the site is selected, marked, and documented, it does no use to argue over whether these measures will be adequate in the future, or to speculate on the virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard. Of course, the Commission recognizes that there are alternative approaches to the Human Intrusion question. Accordingly, comment on this and alternative approaches is welcome.

Relation to Other Parts of NRC Regulations

The proposed rule contemplates that DOE activities at a geologic repository operations area may in appropriate cases be licensed under other parts of NRC regulations and would then not be governed by these technical criteria. We note, in this connection, that the scope section of the procedural rule specifically provides that Part 60 shall not apply to any activity licensed under another part. This allows an independent spent fuel storage installation to be licensed under Part 72, even though located at a geologic repository operations area (provided, of course, it is sufficiently separate to be classified as "independent"). Other DOE activities of the geologic repository operations area could be licensed under Parts 30 or 70 if an exemption from Part 60 is determined to be appropriate.

Alternative Approach

In the course of the Commission's deliberation, it becomes evident that in order to have confidence in the ability of a geological repository to contain and isolate the wastes for an extended period of time, the repository must consist of multiple barriers. In view of the uncertainties that attach to reliance on the geologic setting alone, the Commission believes that a repository [illegible] barriers (waste packages and underground facility) in addition to the natural barrier provided by the geological setting. The Commission is emphasizing these elements to take advantage of the opportunity to attain greater confidence in the isolation of the waste. Having reached these conclusions, the Commission considers next whether or not and to what level of detail the performance criteria for a geological repository should be prescribed. In this regard, the Commission considers the following 3 alternatives:[5]

1. Prescribe a single overall performance standard that must be met. The standard in this case would be the EPA standard;

2. Prescribe minimum performance standards for each of the major elements, in addition to requiring the overall system to meet the EPA standards; and

3. Prescribe detailed numerical criteria on critical engineering attributes of the repository system.

Alternative 3 is considered overly restrictive on the design flexibility and judged to be inappropriate at this stage of technological development. Therefore, this alternative is quickly eliminated as a viable regulatory approach.

Alternative 1 has as its principal advantage the fact that it provides maximum flexibility in apportioning credit for containment and isolation to the several elements of the repository. It also allows the designer to incorporate and apply new technological developments and knowledge from the site characterization phase to the repository design. Notwithstanding, some concern over its practicality in the regulatory framework, the Commission cannot at this time eliminate it from further consideration. The Commission is, therefore, specifically requesting the general public, particularly those from the technical communities, to comment on this point. In addition, the Commission requests commentors espousing this alternative to address specifically ways in which the Commission might find reasonable assurance that the ultimate standards

[5] Detailed discussions on the advantages and disadvantages of each of these alternatives are given in Appendix J to Commission Paper SECY-81-287, April 27, 1981, "Rationale for Performance Objectives and Required Characteristics of the Geologic Setting." This appendix is being published separately and is available without charge on request to the Commission's Public Document Room, 1717 H St. NW, Washington, D.C. 20555.

met without prescribing standards the major elements of a repository. relation to the first and the third matives that are briefly discussed ve, Alternative 2 appears to offer a onable and practical compromise. In ition to retaining the single overall ormance standard in Alternative 1 he final performance objective, this roach establishes the minimum ormance objectives for each of the 3 or barriers of the repository. While approach limits the repository igner's flexibility, it is clear that ting these minimum design goals ld substantially enhance the nmission's confidence that the final standard will be met. Therefore, Commission prefers a technical rule iblished upon this approach.

should be noted that, in the event the Commission decides to adopt Alternate 1 approach in the final making, portions of the proposed (e.g., the section on requirements for geological setting) would have to be her studied and possibly revised. In ition, it is possible that further public iments would have to be sought.

or Features of the Proposed Rule

Overall Description. The proposed nical criteria have been written to ress the following: performance ectives and requirements for siting, ign and construction of the ository, the waste package, firmation of repository performance, lity assurance, and the training and ification of personnel. As ropriate, these topics are divided in to address separately requirements ch apply during construction, waste placement, and after permanent sure (decommissioning) of the ository. Although the licensing cedures indicate that there would be arate subparts for siting and design uirements, viz. Subparts E and F, pectively (cf. § 60.31(a)(2)), the NRC ... that the site and design so interdependent that such a inction is artificial and misleading. example, although the requirement lace the underground facility at a imum depth of 300 meters is clearly esign requirement, it is manifested as ting requirement since unless the site a host rock of sufficient thickness at ficient depth, the above design uirement cannot be met. Hence the posed Subpart E to 10 CFR Part 60 tains both site and design uirements.

o enable the Commission to reach a ling as to whether the generally licable environmental standard for osal of HLW is met and that public lth and safety will be protected, a careful and exhaustive analysis of all the features of the repository will be needed. That analysis necessarily must be both qualitative and quantitative although the analysis can and will be largely quantitative during the period that greatest reliance can be placed upon the engineered system. Thereafter, although the issues of concern, and certainly the physics of a repository itself, do not change, the numerical uncertainties begin to become so large that calulations become a weak indicator of expected repository performance.

In sum, the technical criteria perform two tasks. First they serve to guide DOE in siting, designing, constructing, and operating a repository in such a manner that there can be reasonable confidence that public health and safety will be protected. Second, they serve to guide DOE in those same areas in such a manner that there can be reasonable confidence that the analyses, needed to determine whether public health and safety is protected, can be performed.

2. *Performance Objectives.* The design and operation of the repository are prescribed to be such that during the period that wastes are being emplaced and performance assessed, exposure to workers and releases of radioactivity to the environment must be within limits set by the Commission and the EPA. Further, the repository is to be designed so that the option can be preserved to retrieve the emplaced wastes beginning at anytime up to 50 years following completion of emplacement. Following permanent closure, the repository must perform so that releases are within the limits prescribed by the generally applicable environmental standard which will be set by the EPA. Further, the design of the repository must include a waste package and an underground facility, as well as the site, as barriers to radionuclide migration.

The performance of the engineered system (waste package and underground facility) following permanent closure is specified to require containment of the wastes within the waste package for at least 1000 years following closure, when temperatures in the repository are substantially elevated, and control of the release of nuclides to the geologic environment thereafter.

Transuranic waste (TRU) may be disposed of in a geologic repository. Since transuranic waste does not generate significant amounts of heat, there is no advantage to containment for any specified period. Hence, the requirement for TRU waste is simply a controlled release equivalent to that for HLW, provided they are physically separated from the HLW so that they will not experience a significant increase in temperature.

Although a minimum 1,000-year containment and a maximum one part in 100,000 release rate will satisfy these criteria, the Commission considers it highly desirable that wastes be contained as long thereafter as is reasonably achievable, and that release rates be as far below one part in 100,000 as is reasonably achievable.

3. *Siting Requirements.* Although no specific site suitability or exclusion requirements are given in the criteria, stability and minimum groundwater travel times are specified as required site characteristics. ALARA (as low as reasonably achievable) principles have not been applied to the natural features of a site because they are not amenable to modification once a site is chosen. However, the technical criteria do identify site characteristics considered favorable for a repository as well as characteristics which, if present at the site, may compromise site suitability and which will require careful analysis and such measures as may be necessary to compensate for them adequately. The impact of these characteristics on overall performance would be site specific. Thus, the Commission has judged that these should not be made absolute requirements. Presence of all the favorable characteristics does not lead to the conclusion that the site is suitable to host a repository. Neither is the presumption of unsuitability because of the presence of an unfavorable characteristic incontrovertible. Rather, the Commission's approach requires a sufficient combination of conditions at the selected site to provide reasonable assurance that the performance objectives will be achieved. If adverse conditions are identified as being present, they must be thoroughly charaterized and analyzed and it must be demonstrated that the conditions are compensated for by repository design or by favorable conditions in the geologic setting.

The Commission has not included any siting requirements which directly deal with population density or proximity to population centers. Rather, the issue has been addressed indirectly through consideration of resources in the geologic setting. The Commission believes this to be a more realistic approach given the long period of time involved with geologic disposal. Nonetheless, the Commission invites comment on whether population related siting requirements should be included in the final rule and how they might be implemented.

4. *Design and Construction.* In addition to the requirements on designing for natural phenomena, criticality control, radiation protection, and effluent control, the proposed technical criteria require the design of the repository to accommodate potential interaction of the waste, the underground facility, and the site. Requirements are also placed upon the design of the equipment to be used for handling the wastes, the performance and purpose of the backfill material, and design and performance of borehole and shaft seals. Further, there are requirements related to the methods of construction. The Commission believes such requirements are necessary to assure that the ability of the repository to contain and isolate the wastes will not be compromised by the construction of the repository.

The proposed technical criteria would require that the subsurface facility be designed so that it could be constructed and operated in accordance with relevant Federal mining regulations, which specify design requirements for certain items of electrical and mechanical equipment and govern the use of explosives.

These criteria are a blend of general and detailed prescriptive requirements. They have been developed from Commission experience and practice in the licensing of other nuclear facilities such as power plants and fuel cycle facilities. While there are differences in the systems and components addressed by these criteria from those of power plants or fuel cycle facilities, and the criteria have been written to be appropriate for a geologic repository, the proposed criteria represent a common practice based on experience which has shown that the above items need to be regulated. The level of detail of these criteria reflects the Commission's current thinking on how to regulate effectively geologic disposal of HLW. However, the Commission continues to examine other possibilities for promulgating the more detailed of these requirements. Comments are invited on formulations for the design and construction criteria in the rule, perhaps in a more concise form; these may be supplemented, of course, with more details in staff guidance documents such as Regulatory Guides.

5. *Waste Package.* The proposed requirements for the design of the waste package emphasize its role as a key component of the overall engineered system. Besides being required to contribute to the engineered system's meeting containment and controlled release performance objectives, both compatibility with the underground facility and the site and a method of unique identification are required of the waste package. Included in the section of the proposed technical criteria which deals with the waste package are requirements that the waste form itself contained within the package be consolidated and non-pyrophoric.

6. *Performance Confirmation.* The proposed technical criteria include requirements for a program of testing and measurement (Subpart F). The main purpose of this program is to confirm the assumptions, data, and analyses which led to the findings that permitted construction of the repository and subsequent emplacement of the wastes. Further, the performance confirmation program includes requirements for monitoring of key geologic and hydrologic parameters throughout site characterization, construction, and emplacement to detect any significant changes in the conditions which supported the above findings during, or due to operations at the site. Also included in the program would be tests of the effectiveness of borehole and shaft seals and of backfill placement procedures.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Commission hereby certifies that this rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. This proposed rule affects only the Department of Energy, and does not fall within the purview of the Act.

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, the National Environmental Policy Act of 1969, as amended, and sections 552 and 553 of title 5 of the United States Code, notice is hereby given that adoption of the following amendments to Title 10, Chapter I, Code of Federal Regulations is contemplated.

PART 60—DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

1. The authority citation for Part 60 reads as follows:

Authority: Secs. 51, 53, 62, 63, 65, 81, 161b., i., o., p., 182, 183, Pub. L. 83-703, as amended, 68 Stat. 929, 930, 932, 933, 935, 948, 953, 954, as amended (42 U.S.C. 2071, 2073, 2092, 2093, 2095, 2111, 2201, 2232, 2233); Secs. 202, 206, Pub. L. 93-438, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846); Sec. 14, Pub. L. 95-601 (42 U.S.C. 2021a); Sec. 102(2)(c), Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332)

2. Section 60.2 is revised to read as follows:

§ 60.2 Definitions.

For the purposes of this Part—

"Accessible Environment" means those portions of the environment directly in contact with or readily available for use by human beings.

"Anticipated Processes and Events" means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Candidate area" means a geologic and hydrologic system within which a geologic repository may be located.

"Commencement of construction" means clearing of land, surface or subsurface excavation, or other substantial action that would adversely affect the environment of a site, but does not include changes desirable for the temporary use of the land for public recreational uses, site characterization activities, other preconstruction monitoring and investigation necessary to establish background information related to the suitability of a site or to the protection of environmental values, or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Decommissioning," or "permanent closure," means final backfilling of subsurface facilities, sealing of shafts, and decontamination and dismantlement of surface facilities.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the biosphere.

"Disturbed zone" means that portion of the geologic setting that is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered system" means the waste packages and the underground facility.

"Far field" means the portion of the geologic setting that lies beyond the disturbed zone.

"Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands and including at a minimum that area subject to a one percent or greater chance of flooding in any given year.

"Geologic repository" means a system for the disposal of radioactive wastes in excavated geologic media. A geologic repository includes (1) the geologic repository operations area, and (2) the geologic setting.

"Geologic repository operations area" means an HLW facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" or "site" is the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste.

"High-level radioactive waste" or "HLW" means (1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

"HWL facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat. 1244).[3]

"Host rock" means the geologic medium in which the waste is emplaced.

"Important to safety," with reference to structures, systems, and components, means those structures, systems, and components that provide reasonable assurance that radioactive waste can be received, handled, and stored without undue risk to the health and safety of the public.

"Indian Tribe" means an Indian tribe as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93-638).

"Isolation" means inhibiting the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

"Lithologic geologic medium" is a body of rock characterized by lithologic homogeneity.

"Overpack" means any buffer material, receptacle, wrapper, box or other structure, that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

"Public Document Room" means the place at 1717 H Street NW., Washington, D.C., at which records of the Commission will ordinarily be made available for public inspection and any other place, the location of which has been published in the Federal Register, at which public records of the Commission pertaining to a particular geologic repository are made available for public inspection.

"Radioactive waste" or "waste" means HLW and any other radioactive materials other than HLW that are received for emplacement in a geologic repository.

"Site" means the geologic setting.

"Site characterization" means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic respository, but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken.

"Stability" means that the nature and rates of natural processes such as erosion and faulting have been and are projected to be such that their effects will not jeopardize isolation of the radioactive waste.

"Subsurface facility" means the undergound portions of the geologic repository operations area including openings, backfill materials, shafts and boreholes as well as shaft and borehole seals.

"Transuranic wastes" or "TRU wastes" means radioactive waste containing alpha emitting transuranic elements, with radioactive half-lives greater than five years, in excess of 10 nanocuries per gram.

"Tribal organization" means a Tribal organization as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93-638).

"Underground facility" means the undergound structure, including openings and backfill materials, but excluding shafts, boreholes and their seals.

"Unrestricted area" means any area, access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials and any area used for residential quarters.

"Waste form" means the radioactive waste materials and any encapsulating or stabilizing materials, exclusive of containers.

"Waste package" means the airtight, watertight, sealed container which includes the waste form and any ancillary enclosures, including shielding, discrete backfill and overpacks.

3. Section 60.10 is revised to read as follows:

§ 60.10 Site characterization.

(a) Prior to submittal of an application for a license to be issued under this part the DOE shall conduct a program of site characterization with respect to the site to be described in such application.

(b) Unless the Commission determines with respect to the site described in the application that it is not necessary, site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced.

(c) As provided in § 51.40 of this chapter, DOE is also required to conduct a program of site characterization, including in situ testing at depth, with respect to alternative sites.

(d) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted to limit adverse effects on the long term performance of the geologic repository to the extent practical.

(2) As a minimum the location of exploratory boreholes and shafts shall be selected so as to limit the total number of subsurface penetrations above and around the underground facility.

(3) To the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for repository construction and operation or where large unexcavated pillars are planned.

(4) Subsurface exploratory drilling, excavation, and in situ testing before and during construction shall be planned and coordinated with repository design and construction.

4. Paragraphs (c)(1), (c)(3), and (c)(13) of § 60.21 are revised to read as follows:

§ 60.21 Content of application.

* * * * *

[3] These are DOE "facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such act [the Atomic Energy Act]" and "Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive wastes generated by [DOE], which are not used for, or are part of, research and development activities."

(e) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect facility design and performance. The description of the site shall identify the limits of the accessible environment with respect to the location of the geologic repository operations area.

(i) The description of the site shall also include the following information regarding subsurface conditions in the vicinity of the proposed underground facility—

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other permeable anomalies;

(C) The bulk geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The bulk hydrogeologic properties and conditions;

(E) The bulk geochemical properties; and

(F) The anticipated response of the bulk geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

(ii) The assessment shall contain—

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, and meteorology of the site;

(B) Analyses to determine the degree to which each of the favorable and adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation.

(C) An evaluation of the expected performance of the proposed geologic repository noting the rates and quantities of expected releases of radionuclides to the accessible environment as a function of time. In executing this evaluation DOE shall assume that those processes operating on the site are those which have been operating on it during the Quaternary Period and superpose the perturbations caused by the presence of emplaced radioactive waste on the natural processes.

(D) An analysis of the expected performance of the major design structures, systems, and components, both surface and subsurface, that bear significantly on the suitability of the geologic repository for disposal of radioactive waste assuming the anticipated processes and events and natural phenomena from which the design bases are derived. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

(E) An explanation of measures used to confirm the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be confirmed by using field tests, in situ tests, field-verified laboratory tests, monitoring data, or natural analog studies.

* * * * *

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety: This analysis shall consider—(i) the margins of safety under normal and conditions that may result from anticipated operational occurrences, including those or natural origin; (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena; and (iii) the effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to radionuclide containment and isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

* * * * *

(13) An identification and evaluation of the natural resources at the site, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the site to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscovered deposits, shall be conducted for the disturbed zone and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The estimate of net value shall take into account current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

* * * * *

5. Paragraph (a)(2) of § 60.31 is revised to read as follows:

§ 60.31 Construction authorization.

* * * * *

(a) * * *

(2) The site and design comply with the criteria contained in Supart E.

* * * * *

6. Paragraph (a)(2) of § 60.51 is revised to read as follows:

§ 60.51 License amendment to decommission.

(a) * * *

(2) a detailed description of the measures to be employed—such as land use controls, construction of monuments, and preservation of record—to regulate or prevent activities that could impair the long-term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for the use of future generations. As a minimum, such measures shall include—

(i) Identification of the geologic repository operations area by monuments that have been designated, fabricated, and emplaced to be as permanent as is practicable; and

(ii) Placement of records of the location of the geologic repository operations area and the nature and hazard of the waste in the archives of local and Federal government agencies, and archives elsewhere in the world that would be likely to be consulted by potentional human intruders.

* * * * *

7. New Subpart E, "Technical Criteria," Subpart F "Performance Confirmation," Subpart G, "Quality Assurance" and Subpart H, "Training and Certification of Personnel" are added to 10 CFR Part 60.

Subpart E—Technical Criteria

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60.101 Purpose and nature of findings.
60.102 Concepts.

Performance Objectives

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60.112 Required characteristics of the geologic setting.

Repository Operations Area

Sec.

60.121 Requirements for ownership and control of the geologic repository operations area.

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Design and Construction Requirements

60.130 General design requirements for the geologic repository operations area.
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60.135 Requirements for the waste package and its components.

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60.137 General requirements for performance confirmation.

Subpart F—Performance Confirmation

60.140 General requirements.
60.141 Confirmation of geotechnical and design parameters.
60.142 Design testing.
60.143 Monitoring and testing waste packages.

Subpart G—Quality Assurance

60.150 Scope.
60.151 Applicability.
60.152 Implementation.
60.153 Quality assurance for performance confirmation.

Subpart H—Training and Certification of Personnel

60.160 General requirements.
60.161 Training and certification program.
60.162 Physical requirements.

Subpart E—Technical Criteria

§ 60.101 Purpose and nature of findings.

(a)(1) Subpart B of this part prescribes the standards for issuance of a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area. In particular, § 60.41(c) requires a finding that the issuance of a license will not constitute an unreasonable risk to the health and safety of the public. The purpose of this subpart is to set out performance objectives and site and design criteria which, if satisfied, will support such a finding of no unreasonable risk.

(2) While these performance objectives and criteria are generally stated in unqualified terms, it is not they will be met can be presented. A reasonable assurance, on the basis of the record before the Commission, that the objectives and criteria will be met is the general standard that is required. For § 60.111, and other portions of this subpart that impose objectives and criteria for repository performance over long times into the future, there will inevitably be greater uncertainties. Proof of the future performance of engineered systems and geologic media over time periods of a thousand or many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period and hazards involved, that the outcome will be in conformance with those objectives and criteria.

(b) Subpart B of this part also lists findings that must be made in support of an authorization to construct a geologic repository operations area. In particular, § 60.31(a) requires a finding that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a repository of the design proposed without unreasonable risk to the health and safety of the public. As stated in that paragraph, in arriving at this determination, the Commission will consider whether the site and design comply with the criteria contained in this subpart. Once again, while the criteria may be written in unqualified terms, the demonstration of compliance may take uncertainties and gaps in knowledge into account, provided that the Commission can make the specified finding of reasonable assurance as specified in paragraph (a) of this section.

§ 60.102 Concepts.

(a) *The HLW facility.* NRC exercises licensing and related regulatory authority over those facilities described in section 203 (3) and (4) of the Energy Reorganization Act of 1974. Any of these facilities is designated an *HLW facility.*

(b) *The geologic repository operations area.*

(1) This part deals with the exercise of authority with respect to a particular class of HLW facility—namely a *geologic repository operations area.*

(2) A *geologic repository operations area* consists of those surface and subsurface areas that are part of a geologic repository where radioactive waste handling activities are conducted. The underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals, is designated the *underground facility.*

(3) The exercise of Commission authority requires that the geologic repository operations area be used for *storage* (which includes *disposal*) of *high-level radioactive wastes (HLW).*

(4) HLW includes irradiated reactor fuel as well as reprocessing wastes. However, if DOE proposes to use the geologic repository operations area for storage of *radioactive waste* other than HLW, the storage of this radioactive waste is subject to the requirements of this part. Thus, the storage of *transuranic-contaminated waste (TRU),* though not itself a form of HLW, must conform to the requirements of this part if it is stored in a geologic repository operations area.

(c) *Areas adjacent to the geologic repository operations area.* Although the activities subject to regulation under this part are those to be carried out at the geologic repository operations area, the licensing process also considers characteristics of adjacent areas. First, there is to be an area within which DOE is to exercise specified controls to prevent adverse human actions. Second, there is a larger area, designated the *geologic setting* or *site* which includes the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste from the accessible environment. The geologic repository operations area plus the geologic setting make up the *geologic repository.* Within the geologic setting, particular attention must be given to the characteristics of the host rock as well as any rock units surrounding the host rock.

(d) *Stages in the licensing process.* There are several stages in the licensing process. The *site characterization* stage, though begun before submission of a license application, may result in consequences requiring evaluation in the license review. The *construction stage* would follow, after issuance of a construction authorization. A *period of operations* follows the issuance of a license by the Commission. The period of operations includes the time during which *emplacement* of wastes occurs; and any subsequent period before permanent closure during which the emplaced wastes are *retrievable;* and *permanent closure,* which includes final backfilling of subsurface facilities, sealing of shafts, decontaminating and dismantling of surface facilities. Permanent closure represents the end of active human activities with the geologic repository operations area and engineered systems.

(e) *Containment.* Early during the repository life, when radiation and thermal levels are high and the consequences of events are especially difficult to predict rigorously, special emphasis is placed upon the ability to contain the wastes by waste packages within an engineered system. This is known as the *containment period.* The *engineered system* includes the waste packages as well as the underground facility. A *waste package* includes:

(1) The *waste form* which consists of the radioactive waste materials and any associated encapsulating or stabilizing materials.

(2) The *container* which is the first major sealed enclosure that holds the waste form.

(3) *Overpacks* which consist of any buffer material, receptable, wrapper, box or other structure, that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

(f) *Isolation.* Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. *Isolation* means the act of inhibiting the transport of radioactive material to the accessible environment in amounts and concentrations within limits. The *accessible environment* means those portions of the environment directly in contact with or readily available for use by human beings.

Performance Objectives

§ 60.111 Performance objectives.

(a) *Performance of the geologic repository operations area through permanent closure.*—(1) *Protection against radiation exposures and releases of radioactive material.* The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and any generally applicable environmental standards established by the Environmental Protection Agency.

(2) *Retrievability of waste.* The geologic repository operations area shall be designed so that the entire inventory of waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are complete. A reasonable schedule for retrieval is one that requires no longer than about the same overall period of time than was devoted to the construction of the geologic repository operations area and the emplacement of wastes.

(b) *Performance of the geologic repository after permanent closure.*—(1) *Overall system performance.* The geologic setting shall be selected and the subsurface facility designed so as to assure that releases of radioactive materials from the geologic repository following permanent closure conform to such generally applicable environmental radiation protection standards as may have been established by the Environmental Protection Agency.

(2) *Performance of the engineered system.*—(i) *Containment of wastes.*[6] The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. This requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW.

(ii) *Control of releases.*[6]

(A) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the total annual curie release as prescribed by this paragraph.

(B) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.

(3) *Performance of the geologic setting.*—(i) *Containment period.* During the containment period, the geologic setting shall mitigate the impacts of premature failure of the engineered system. The ability of the geologic setting to isolate wastes during the isolation period, in accordance with paragraph (b)(3)(ii) of this section, shall be deemed to satisfy this requirement.

(ii) *Isolation period.* Following the containment period, the geologic setting, in conjunction with the engineered system as long as that system is expected to function, and alone thereafter, shall be capable of isolating radioactive waste so that transport of radionuclides to the accessible environment shall be in amounts and concentrations that conform to such generally applicable environmental standards as may have been established by the Environmental Protection Agency. For the purpose of this paragraph, the evaluation of the site shall be based upon the assumption that those processes operating on the site are those which have been operating on it during the Quaternary Period, with perturbations caused by the presence of emplaced radioactive wastes superimposed thereon.

§ 60.112 Required characteristics of the geologic setting.

(a) The geologic setting shall have exhibited structural and tectonic stability since the start of the Quaternary Period.

(b) The geologic setting shall have exhibited hydrogeologic, geo-chemical, and geomorphic stability since the start of the Quaternary Period.

(c) The geologic repository shall be located so that pre waste emplacement groundwater travel times through the far field to the accessible environment are at least 1,000 years.

Ownership and Control of the Geolocghic Repository Operations Area

§ 60.121 Requirements for ownership and control of the geologic repository operations area.

(a) *Ownership of the geologic repository operations area.* The geologic repository operations area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use. These lands shall be held free and clear of all encumbrances, if

[6] The Commission specifically seeks comment on whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases. In particular, the Commission has considered whether the technical criteria should explicitly require containment to be for "as long as is reasonably achievable" and the release rate to be "as low as is reasonably achievable." Comments should address the merits of such a requirement, how to best frame it, and the practicality of its implementation.

significant, such as: (1) rights arising under the general mining laws; (2) easements for right-of-way; and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Establishment of controls.* Appropriate controls shall be established outside of the geologic repository operations area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the site or engineered system's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

Additional Requirements for the Geologic Setting

§ 60.122 Favorable conditions.

Each of the following conditions may contribute to the ability of the geologic setting to meet the performance objectives relating to isolation of the waste. In addition to meeting the mandatory requirements of § 60.112, a geologic setting shall exhibit an appropriate combination of these conditions so that, together with the engineered system, the favorable conditions presen[illegible]ficient to provide reason[illegible]ance that such performance ob[illegible] will be met.

(a) The nature [illegible] rates of tectonic processes that [illegible] occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(b) The nature and rates of structural processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(c) The nature and rates of hydrogeological processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(e) The nature and rates of geomorphic processes that have occurred since the start of the Quarternary period are such that, when projected they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(f) A host rock that provides the following groundwater characteristics—(1) low groundwater content; (2) inhibition of groundwater circulation in the host rock; (3) inhibition of groundwater flow between hydrogeologic units or along shafts, drifts, and boreholes; and (4) groundwater travel times, under pre-waste emplacement conditions, between the underground facility and the accessible environment that substantially exceed 1,000 years.

(g) Geochemical conditions that (1) promote precipitation or sorption of radionuclides; (2) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; and (3) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(h) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having increased capacity to inhibit radionuclide migration.

(i) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(j) Any local condition of the disturbed zone that contributes to isolation.

§ 60.123 Potentially adverse conditions.

The following are potentially adverse conditions. The presence of any such conditions may compromise site suitability and will require careful analysis and such measures as are necessary to compensate for them adequately pursuant to § 60.124.

(a) *Adverse conditions in the geologic setting.*

(1) Potential for failure of existing or planned man-made surface water impoundments that could cause flooding of the geologic repository operations area.

(2) Potential, based on existing geologic and hydrologic conditions, that planned construction of large-scale surface water impoundments may significantly affect the geologic repository through changes in the regional groundwater flow system.

(3) Potential for human activity to affect significantly the geologic repository through changes in the hydrogeology. This activity includes, but [illegible] withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage facilities, or underground military activity.

(4) Earthquakes which have occurred historically that if they were to be repeated could affect the geologic repository significantly.

(5) A fault in the geologic setting that has been active since the start of the Quaternary Period and which is within a distance of the disturbed zone that is less than the smallest dimension of the fault rupture surface.

(6) Potential for adverse impacts on the geologic repository resulting from the occupancy and modification of floodplains.

(7) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could affect the performance of the geologic repository through changes in the regional groundwater flow.

(8) Expected climatic changes that would have an adverse effect on the geologic, geochemical, or hydrologic characteristics.

(b) *Adverse conditions in the disturbed zone.* For the purpose of determining the presence of the following conditions within the distrubed zone, investigations should extend to the greater of either its calculated extent or a horizontal distance of 2 km from the limits of the underground facility, and from the surface to a depth of 500 meters below the limits of the repository excavation.

(1) Evidence of subsurface mining for resources.

(2) Evidence of drilling for any purpose.

(3) Resources that have either greater gross value, net value, or commercial potential than the average for other representative areas of [illegible] that are representative of and located in the geologic setting.

(4) Evidence of extreme erosion during the Quaternary Period.

(5) Evidence of dissolutioning of soluble rocks.

(6) The existence of a fault that has been active during the Quaternary Period.

(7) Potential for creating new pathways for radionuclide migration due to presence of a fault or fracture zone irrespective of the age of last movement.

(8) Structural deformation such as uplift, subsidence, folding, and fracturing during the Quaternary Period.

(9) More frequent occurrence of earthquakes or earthquakes of higher

magnitude than is typical of the area in which the geologic setting is located.

(10) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(11) Evidence of igneous activity since the start of the Quaternary Period.

(12) Potential for changes in hydrologic conditions that would significantly affect the migration of radionuclides to the accessible environment including but not limited to changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(13) Conditions in the host rock that are not reducing conditions.

(14) Groundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could affect the solubility and chemical reactivity of the engineered systems.

(15) Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered system.

(16) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(17) Geomechanical properties that do not permit deisign of stable underground openings during construction, waste emplacement, or retrieval operations.

§ 60.124 Assessment of potentially adverse conditions.

In order to show that a potentially adverse condition or combination of conditions cited in § 60.123 does not impair significantly the ability of the geologic repository to isolate the radioactive waste, the following must be demonstrated:

(a) The potentially adverse human activity or natural condition has been adequately characterized, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(b) The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural condition; and

(c)(1) The potentially adverse human activity or natural condition is shown by analysis in paragraph (b) of this section not to affect significantly the ability of the geologic setting to isolate waste, or

(2) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics cited in § 60.122, or

(3) The potentially adverse human activity or natural condition can be remedied.

Design and Construction Requirements

§ 60.130 General design requirements for the geologic repository operations area.

(a) Sections 60.130 through 60.134 specify minimum requirements for the design of, and construction specifications for, the geologic repository operations area. Requirements for design contained in §§ 60.131 through 60.133 must be considered in conjunction with the requirements for construction in § 60.134. Sections 60.130 through 60.134 are not intended to contain an exhaustive list of design and construction requirements. Omissions in §§ 60.130 through 60.134 do not relieve DOE from providing safety features in a specific facility needed to achieve the performance objectives contained in § 60.111. All design and construction criteria must be consistent with the results of site characterization activities.

(b) Systems, structures, and components of the geologic repository operations area shall satisfy the following:

(1) *Radiological protection.* The structures, systems, and components located within restricted areas shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in those restricted areas within the limits specified in Part 20 of this chapter. These structures, systems, and components shall be designed to include—

(i) Means to limit concentrations of radioactive material in air;

(ii) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(iii) Suitable shielding;

(iv) Means to monitor and control the dispersal of radioactive contamination;

(v) Means to control access to high radiation areas or airborne radioactivity areas; and

(vi) A radiation alarm system to warn of increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity [illegible] shall be designed with redundancy and in situ testing capability.

(2) *Protection against natural phenomena and environmental conditions.*

(i) The structures, systems, and components important to safety shall be designed to be compatible with anticipated site characteristics and to accommodate the effects of environmental conditions, so as to prevent interference with normal operation, maintainence and testing during the entire period of construction and operations.

(ii) The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the site will not result, in any relevant time period, in failure to achieve the performance objectives.

(3) *Protection against dynamic effects of equipment failure and similar events.* The structures, systems and components important to safety shall be designed to withstand dynamic effects that could result from equipment failure, such as missle impacts, and similar events and conditions that could lead to loss of their safety functions.

(4) *Protection against fires and explosions.*

(i) The structures, systems, and components important to safety shall be designed to perform their safety functions during and after fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

(5) *Emergency capability.*

(i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste, and permit prompt termination of operations and vacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(6) *Utility services.*

(i) Each utility service system shall be designed so that essential safety functions can be performed under both normal and emergency conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(iii) The emergency utility services shall be designed to permit testing of their functional operability and capacity. This will include the full operational sequence of each system when transferring between normal and emergency supply sources, as well as the operation of associated safety systems.

(iv) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and continued emergency power is provided to instruments, utility service systems, and operating systems, including alarm systems. This emergency power shall be sufficient to allow safe conditions to be maintained. All systems important to safety shall be designed to permit them to be maintained at all times in a functional mode.

(7) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(8) *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(9) *Instrumentation and control systems.* Instrumentation and control systems shall be designed to monitor and control the behavior of engineered systems important to safety over anticipated ranges for normal operation and for accident conditions. The systems shall be designed with sufficient redundancy to ensure that adequate margins of safety are maintained.

(10) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

§ 60.131 Additional design requirements for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the site, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility. The surface facilities shall be designed so as to permit inspection, repair, and decontamination of such wastes and their containers. Surface storage capacity is not required for all emplaced waste.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111.

(c) *Radiation control and monitoring.*—(1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal and emergency operations. The facilities shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111.

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decommissioning.

§ 60.132 Additional design requirements for the underground facility.

(a) General criteria for the underground facility.

(1) The underground facility shall be designed so as to perform its safety functions assuming interactions among the geologic setting, the underground facility, and the waste package.

(2) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of § 60.111.

(3) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall enhance containment and isolation of radionuclides to the extent practicable at the site.

(4) The underground facility shall be designed so that the effects of disruptive events such as intrusions of gas, or water, or explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments, where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Separation of excavation and waste emplacement (modular concept).* If concurrent excavation and emplacement of wastes are planned, then:

(1) The design shall provide for such separation of activities into discrete areas (modules) as may be necessary to assure that excavation does not impair waste emplacement or retrieval operations.

(2) Each module shall be designed to permit insulation from other modules if an accident occurs.

(d) *Design for retrieval of waste.* The underground facility shall be designed to—

(1) Permit retrieval of waste in accordance with the performance objectives (§ 60.111);

(2) Ensure sufficient structural stability of openings and control of groundwater to permit the safe conduct of waste retrieval operations; and

(3) Allow removal of any waste packages that may be damaged or require inspection without compromising the ability of the geologic repository to meet the performance objectives (§ 60.111).

(e) *Design of subsurface openings.*

(1) Subsurface openings shall be designed to maintain stability throughout the construction and operation periods. If structural support is required for stability, it shall be designed to be compatible with long-term deformation, hydrologic, geochemical, and thermomechanical characteristics of the rock and to allow subsequent placement of backfill.

(2) Structures required for temporary support of zones of weak or highly fractured rock sha be designed so as not to impair the placement of permanent structures or the capability to seal excavated areas used for the containment of wastes.

(3) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock over the long term. The size, shape, orientation, and spacing of openings and the design of engineered support systems shall take the following conditions into considerations—

(i) natural stress conditions;

(ii) deformation characteristics of the host rock under normal conditions and thermal loading;

(iii) The kinds of weaknesses or structural discontinuities found at various locations in the geologic repository;

(iv) Equipment requirements; and

(v) The ability to construct the underground facility as designed so that stability of the rock is enhanced.

(f) *Rock excavation.* The design of the underground facility shall incorporate excavation methods that will limit damage to and fracturing of rock.

(g) *Control of water and gas.*

(1) Water and gas control systems shall be designed to be of sufficient capability and capacity to reduce the potentially adverse effects of groundwater intrusion, service water intrusion, or gas inflow into the underground facility.

(2) Water and gas control systems shall be designed to control the quantity of water or gas flowing into or from the underground facility, monitor the composition of gases, and permit sampling of liquids.

(3) Systems shall be designed to provide control of water and gas in both waste emplacement areas and excavation areas.

(4) Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained.

(5) If the intersection of aquifers or water-bearing geologic structures is anticipated during construction, the design of the underground facility shall include plans for cutoff or control of water in advance of the excavation.

(6) If linings are required, the contact between the lining and the rock surrounding subsurface excavations shall be designed so as to avoid the creation of any preferential pathway for groundwater or radionuclide migration.

(h) *Subsurface ventilation.* The ventilation system shall be designed to—

(1) Control the transport of radioactive particulates and gases within and releases from the subsurface facility in accordance with the performance objectives (§ 60.111);

(2) Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure;

(3) Accommodate changes in operating conditions such as variations in temperature and humidity in the underground facility;

(4) Include redundant equipment and fail safe control systems as may be needed to assure continued function under normal and emergency conditions and

(5) Separate the ventilation of excavation and waste emplacement areas.

(i) *Engineered barriers.*

(1) Barriers shall be located where shafts could allow access for groundwater to enter or leave the underground facility.

(2) Barriers shall create a waste package environment which favorably controls chemical reactions affecting the performance of the waste package.

(3) Backfill placed in the underground facility shall be designed as a barrier.

(i) Backfill placed in the underground facility shall perform its functions assuming anticipated changes in the geologic setting.

(ii) Backfill placed in the underground facility shall serve the following functions:

(A) It shall provide a barrier to groundwater movement into and from the underground facility.

(B) It shall reduce creep deformation of the host rock that may adversely affect (*1*) waste package performance or (*2*) the local hydrological system.

(C) It shall reduce and control groundwater movement within the underground facility.

(D) It shall retard radionuclide migration.

(iii) Backfill placed in the underground facility shall be selected to allow for adequate placement and compaction in underground openings.

(j) *Waste handling and emplacement.*

(1) The systems used for handling, transporting, and emplacing radioactive wastes shall be designed to have positive, fail-safe designs to protect workers and to prevent damage to waste packages.

(2) The handling systems for emplacement and retrieval operations shall be designed to minimize the potential for operator error.

(k) *Design for thermal loads.*

(1) The underground facility shall be designed so that the predicted thermal and thermomechanical response of the rock will not degrade significantly the performance of the repository or the ability of the natural or engineered barriers to retard radionuclide migration.

(2) The design of waste loading and waste spacings shall take into consideration—

(i) Effects of the design of the underground facility on the thermal and thermomechanical response of the host rock and the groundwater system;

(ii) Features of the host rock and geologic setting that affect the thermomechanical response of the underground facility and barriers, including but not limited to, behavior and deformational characteristics of the host rock, the presence of insulating layers, aquifers, faults, orientation of bedding planes, and the presence of discontinuities in the host rock; and

(iii) The extent to which fracturing of the host rock is influenced by cycles of temperature increase and decrease.

§ 60.133 Design of shafts and seals for shafts and boreholes.

(a) *Shaft design.* Shafts shall be designed so as not to create a preferential pathway for migration of groundwater and so as not to increase the potential for migration through existing pathways.

and borehole seals shall be designed so that:

(1) Shafts and boreholes will be sealed as soon as possible after they have served their operational purpose.

(2) At the time of permanent closure sealed shafts and boreholes will inhibit transport of radionclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. In the case of soluble rocks, the borehole and shaft seals shall also be designed to prevent groundwater circulation that would result in dissolution.

(3) Contact between shaft and borehole seals and the adjacent rock does not become a preferential pathway for water.

(4) Shaft and borehole seals can accommodate potential variations of stress, temperature, and moisture.

(5) The materials used to construct the seals are appropriate in view of the geochemistry of the rock and groundwater system, anticipated deformations of the rock, and other in situ conditions.

(c) *Shaft conveyances used in radioactive waste handling.*

(1) Shaft conveyances used to transport radioactive materials shall be designed to satisfy the requirements as set forth in § 60.130 for systems, structures, and components important to safety.

(2) Hoists important to safety shall be designed to preclude cage free fall.

(3) Hoists important to safety shall be designed with a reliable cage location system.

(4) Hoist loading and unloading systems shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(5) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place, grappled, and ready for transfer.

§ 60.134 Construction specifications for surface and subsurface facilities.

(a) *General requirement.* Specifications for construction shall conform to the objectives and technical requirements of §§ 60.130 through 60.133.

(b) *Construction management program.* The construction specifications shall facilitate the conduct of a construction management program that will ensure that construction activities do not adversely affect the suitability of the site to isolate the waste or jeopardize the isolation capabilities of the underground facility, boreholes, shaft, and seals, and that the design is followed.

(c) *Construction records.* The construction specifications shall include requirements for the development of a complete documented history of repository construction. This documented history shall include at least the following—

(1) Surveys of underground excavations and shafts located via readily identifiable surface features or monuments;

(2) Materials encountered;

(3) Geologic maps and geologic cross sections;

(4) Locations and amount of seepage;

(5) Details of equipment, methods, progress, and sequence of work;

(6) Construction problems;

(7) Anomalous conditions encountered;

(8) Instrument locations, readings, and analysis;

(9) Location and description of structural support systems;

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

(d) *Rock excavation.* The methods used for excavation shall be selected to reduce to the extent practicable the potential to create a preferential pathway for groundwater or radioactive waste migration or increase migration through existing pathways.

(e) *Control of explosives.* If explosives are used, the provisions of 30 CFR 57.6 (Explosives) issued by the Mine Safety and Health Administration, Department of Labor, shall be met, as minimum safety requirements for storage, use and transport at the geologic repository operations area.

(f) *Water control.* The construction specifications shall provide that water encountered in excavations shall be removed to the surface and controlled in accordance with design requirements for radiation control and monitoring (§ 60.131(c)).

(g) *Waste handling and emplacement.* The construction specifications shall provide for demonstration of the effectiveness of handling equipment and systems for emplacement and retrieval operations, under operating conditions.

Waste Package Requirements

§ 60.135 Requirements for the waste package and its components.

(a) *General requirements of design.* The design of the waste package shall include the following elements:

(1) *Effect of the site on the waste package.* The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(2) *Effect of the waste package on the underground facility and the natural barriers of the geologic setting.* The waste package shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the performance of the underground facility or the geologic setting. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) *Waste form requirements.* Radioactive waste that is emplaced in the underground facility shall meet the following requirements:

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall have been consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) *Combustibles.* All combustible radioactive wastes must have been reduced to a noncombustible form unless it can be demonstrated that a fire involving a single package will neither compromise the integrity of other packages, nor adversely affect any safety-related structures, systems, or components.

(c) *Waste package requirements.* The waste package design shall meet the following requirements:

(1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials that could interfere with operations in the underground facility or compromise the ability of the geologic repository to satisfy the performance objectives.

(2) *Free liquids.* The waste package shall not contain free liquids in an amount that could impair the structural integrity of waste package components (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of package perforation.

(3) *Handling.* Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) *Unique identification.* A label or other means of identification shall be provided for each package. The identification shall not impair the integrity of the package and shall be applied in such a way that the information shall be legible at least to the end of the retrievable storage period. Each package identification shall be consistent with the package's permanent written records.

Performance Confirmation Requirements

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

Subpart F—Performance Confirmation

§ 60.140 General requirements.

(a) The performance confirmation program shall ascertain whether—

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program will include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The confirmation program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the repository for monitoring the condition of the waste packages. Packages chosen for the program shall be representative of those to be emplaced in the repository.

(b) Consistent with safe operation of the repository, the environment of the waste packages selected for the waste package monitoring program shall be representative of the emplaced wastes.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

Subpart G—Quality Assurance

§ 60.150 Scope.

(a) As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the repository and its subsystems or components will perform satisfactorily in service.

(b) Quality assurance is a multidisciplinary system of management controls which address safety, reliability, maintainability, performance, and other technical disciplines.

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety and to activities which would prevent or mitigate events that could cause an undue risk to the health and safety of the public. These activities include: exploring, site selecting, designing, fabricating, purchasing, handling, shipping, storing, cleaning, erecting, installing, emplacing, inspecting, testing, operating, maintaining, monitoring, repairing, modifying, and decommissioning.

§ 60.152 Implementation.

DOE shall implement a quality assurance program based on the criteria of Appendix B of 10 CFR Part 50 as applicable, and appropriately supplemented by additional criteria as required by § 60.151.

§ 60.153 Quality assurance for performance confirmation.

The quality assurance program shall include the program of tests, experiments and analyses essential to achieving adequate confidence that the emplaced wastes will remain isolated from the accessible environment.

Subpart H—Training and Certification of Personnel

§ 60.160 General requirements.

Operations that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety must also be certified in such operations.

§ 60.161 Training and certification program.

The DOE shall establish a program for training, proficiency testing, certification and requalification of operating and supervisory personnel.

§ 60.162 Physical requirements.

The physical condition and the general health of personnel certified for operations that are important to safety shall not be such as might cause operational errors that could endanger the public health and safety. Any condition which might cause impaired judgement or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, so long as appropriate provisions are made to accomodate such defect.

Dated at Washington, D.C. this 2nd day of July, 1981.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 81-[illegible] Filed [illegible]; 8:45 am]

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APPENDIX D

ENVIRONMENTAL PROTECTION AGENCY

40 CFR 191

ENVIRONMENTAL STANDARDS AND
FEDERAL RADIATION PROTECTION GUIDANCE FOR
MANAGEMENT AND DISPOSAL OF
SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

AGENCY: U.S. Environmental Protection Agency

ACTION: Proposed Rule

SUMMARY: The Environmental Protection Agency requests comments on proposed radiation protection standards and Federal radiation protection guidance for the management and disposal of spent nuclear reactor fuel and high-level and transuranic wastes. The proposed guides would establish seven general criteria to be followed when these wastes are disposed of. They address problems inherent in the design and construction of systems that must isolate hazardous materials for very long periods of time without human intervention. The proposed standards would limit the amount of radioactivity that may enter the biosphere. The standards require a reasonable expectation that these limits will be satisfied for ten thousand years after disposal. These requirements would apply to disposal by any method, except disposal directly into the oceans or ocean sediments. The proposed standards also would limit the radiation exposure of members of the public from management of spent fuel and of waste prior to disposal.

After we consider the comments received on this proposal, we will develop final versions of the standards and guides. We will then recommend that the President approve the guides as Federal Radiation Protection Guidance for all agencies. The final standards will be promulgated as a new Part 191 to Title 40 of the Code of Federal Regulations (40 CFR 191). The standards and guides will be implemented by the Nuclear Regulatory Commission and the Department of Energy under their respective statutory responsibilities.

DATE: Comments should be received on or before (180 days after publication).

Public hearings to receive comments on the proposed standards and guides will be held in several cities.

ADDRESS: Comments should be sent to the Director, Criteria and Standards Division (ANR-460), Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C. 20460. Copies of all documents will be available in Docket No. _-__-_ , which is located in the West Tower Lobby, Gallery 1, Central Docket Section, Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. Single copies of the Draft Environmental Impact Statement for this action may be obtained by writing to the Director.

FOR FURTHER INFORMATION CONTACT: Daniel Egan, telephone number (703) 557-8610, or Dr. Abraham Goldin, telephone number (703) 557-7380.

SUPPLEMENTARY INFORMATION: Proper management and disposal of the wastes produced by the irradiation of fuel elements in nuclear reactors are important because of the inherent hazards of the large amounts of radioactivity they contain. Large quantities of these wastes already exist and more are being produced in national defense programs, commercial nuclear power plants, and research reactors. They are being held in storage facilities until disposal methods are developed.

These wastes contain many different radionuclides. Some of these nuclides emit alpha particles; others emit beta particles. Some radionuclides emit gamma rays in addition to alpha or beta particles. The radionuclides decay with half-lives ranging from less than one year to millions of years. We have concentrated our attention on radionuclides with half-lives greater than 20 years because they must be isolated from people for very long times. Thus, we exclude radionuclides such as tritium, krypton-85, and plutonium-241, which are present in large quantities in freshly discharged fuel, but they decay so rapidly that they do not require long-term isolation. Radionuclides with half-lives of 20 years or less will decay to less than 0.1% of their original activity in 200 years.

Reprocessing reactor fuel used for national defense activities has produced about 500 million curies of radionuclides with half-lives greater than 20 years. Most of the activity is due to strontium-90 and cesium-137. These wastes are stored in various liquid and solid forms on three Federal reservations in Idaho, Washington, and South Carolina. Relatively small additions are being made from ongoing defense programs.

Spent fuel from commercial nuclear power reactors contains about 800 million curies of radionuclides with half-lives greater than 20 years. About 10 million curies of this radioactivity are due to radionuclides, such as plutonium, which emit alpha particles. Most of this spent fuel is stored at reactor sites. Over the next few years, this inventory is expected to grow at a rate of about 200 million curies per year from reactors currently licensed to operate. At some reactor sites, spent fuel storage capacity is almost used up. Plans to store additional spent fuel at locations away from reactor sites are under consideration by the Federal Government.

Nuclear reactors use some isotopes of uranium, plutonium, or thorium to produce energy from nuclear fission. These elements are commonly referred to as "heavy metals." The amount of wastes produced is roughly proportional to the amount of these elements placed into a reactor. We use the unit "wastes generated per metric ton of heavy metal (MTHM)" to measure the amount of waste placed in disposal systems. The amount of ore needed to produce one MTHM depends on the reactor type, degree of reprocessing, and quality of ore. For the light water reactors currently used in the United States, about 6,000 metric tons of uranium ore are used to produce one MTHM of reactor fuel. We have used this relationship to associate amounts of waste from reactor fuel with uranium ore.

The Agency's purpose in proposing these standards and guides is simply to protect the public health and the environment from the hazards these wastes present. We neither favor nor oppose nuclear power. Similarly, we do not advocate any particular method for disposing of these materials. We do require that any disposal method offer at least as much protection as the one we have assessed as part of the basis for these standards and guides.

DESCRIPTION OF THE PROPOSED ACTION

Under authorities established by the Atomic Energy Act and Reorganization Plan No. 3 of 1970, we are proposing generally applicable environmental standards and Federal radiation protection guides for disposing of these wastes. The Draft Environmental Impact Statement (EIS) published with this proposal includes detailed discussions of the reasons for our selections of proposed standards and guides, and provides extensive summaries of the technical analyses used. This preamble describes the proposed action and highlights features that we believe are of major interest.

The proposed standards and guides apply to spent reactor fuel, highly radioactive wastes derived from reprocessing spent fuel ("high-level wastes"), and to certain wastes containing long-lived radionuclides of elements heavier than uranium ("transuranic wastes"). Transuranic wastes are covered if they contain 100 nanocuries or more of alpha-emitting transuranic isotopes, with half-lives greater than one year, per gram of waste. People could receive, under some possible (but not likely) circumstances, more than 500 millirems per year from wastes containing more than 100 nanocuries of transuranic elements per gram if these wastes were not well isolated. 500 millirems per year is the Federal limit for individuals in the general population. Because these circumstances could last for very long times, we are proposing the same controls for these wastes as required for high-level wastes. Protection requirements for transuranic wastes containing less than 100 nanocuries per gram will be considered in future standards.

In developing the proposed standards, we estimated the risks from disposal systems that use methods of controlling releases which either are available now or are likely to be available in the near future. We also estimated the doses to individuals and populations from waste management. From these evaluations, we conclude that:

1. Any harm to people, including future generations, from the management and disposal of spent fuel, high-level, and transuranic wastes can be kept very small. The assessments which support this conclusion are outlined below and are discussed extensively in the Draft EIS.

2. These standards and guides adequately protect the public from harm. Under them, the risks to future generations from the wastes will be no greater than the risks from equivalent amounts of unmined uranium ore. These risks will also be less than the other risks currently associated with generating electricity from nuclear energy, and they will be very much less than the risks from natural background radiation.

In determining the release limits given in the standards, we had to project the performance of disposal systems which have not yet been demonstrated. There are significant uncertainties inherent in such projections. To avoid underestimating the risks associated with such systems, we assumed levels of performance that we are confident will be met by well-designed systems. Our estimates are, therefore, upper bounds of the risks. When actual control methods are selected and demonstrated at specific sites, estimated releases are likely to be well below the amounts allowed by the proposed standards. Accordingly, the proposed guides instruct the implementing agencies to reduce releases below these upper bounds to the extent re onably achievable, taking into account technical, social, and econ . considerations.

The standards apply to both management and disposal. Subpart A applies to management and includes storage, preparation of the wastes for disposal, and placing them in a disposal site. Off-site transportation is not covered. Subpart B applies to releases after the wastes are isolated enough so that it would be much harder to get them out of the disposal system than it was to put them in. With a geologic repository, for example, Subpart B would take effect when the mine was backfilled and sealed. The proposed Federal guides, included as Appendix A to the standards, apply only to disposal.

DECISION NOT TO PUBLISH GENERAL WASTE DISPOSAL CRITERIA

On November 15, 1978, we proposed general Federal Radiation Protection Guidance for the disposal of all types of radioactive wastes (43 FR 53262). After further thought, we believe that the characteristics of different kinds of radioactive wastes are too dissimilar for general criteria to be appropriate. Therefore, we do not plan to issue them. We believe the best course is to write a series of standards and guides for disposing of specific types of radioactive waste. The insights we gained from working on the general criteria have been useful in developing these standards and guides.

REGULATORY ANALYSIS

Executive Order 12044, "Improving Government Regulations," requires Federal agencies to prepare a regulatory analysis for significant regulations. This analysis should contain: (1) a succinct statement of the problem, (2) a description of the major alternative ways of dealing with the problem, (3) an analysis of the economic consequences of each of these alternatives, and (4) a detailed explanation of the reasons for choosing one alternative over the others. EPA's plan (40 FR 30988) to implement Executive Order 12044 contains more detailed guidelines for the economic portions of a regulatory analysis.

Most of the topics required for a regulatory analysis are considered in this Federal Register notice and in the Draft EIS supporting this action. Both documents discuss the problems associated with these wastes and indicate why we are developing environmental standards and radiation protection guidance. The Draft EIS describes the possible alternative regulatory approaches that we considered, and it also explains why we chose this proposed action. We did not have sufficient information to determine the economic impacts of choosing either a more restrictive or a less restrictive numerical standard, because the data required to make such evaluations are not available now and may not be available for a long time. Our analyses are based only on information about the costs and effectiveness for a model of a mined deep geologic disposal repository. Both the cost and effectiveness of geologic disposal depend on the characteristics of the particular site. Information on cost and effectiveness for other methods is even more uncertain than for the mined geologic repository. As a result of these limitations, we have not been able to estimate the costs of different levels of protection. Therefore, economic considerations have played a very minor role in our comparison of alternatives.

We believe our proposed standards and guides provide adequate protection of public health and the environment. We think that they can be met by careful use of existing technologies, and would not cause unreasonable economic consequences.

Most of the information required for a regulatory analysis is also required for an environmental impact statement. Therefore, because of the lack of the required information described above, we did not prepare a separate regulatory analysis document.

The remainder of this notice describes our proposed action in more detail, summarizes its potential health and economic effects, and discusses the implementation of these requirements. In several places, we identify topics on which we would especially like comments.

(40 CFR 191 Subpart A)

WASTE MANAGEMENT

Certain operations required before disposing of high-level or transuranic radioactive wastes are not regulated under our Uranium Fuel Cycle Standards (40 CFR 190). These operations principally involve storage of the materials, solidification or other preparation for disposal, and placing the wastes in disposal sites. Subpart A applies to spent fuel management, regardless of whether the fuel is considered to be waste, except for management already regulated by 40 CFR 190.

We estimated the largest expected radiation exposures to members of the public from waste management and storage operations associated with geologic disposal and found them to be somewhat smaller than the requirements set in 40 CFR 190. We propose to extend the limitations contained in Part 190 to the operations addressed by this new Part 191 for two reasons:

1. Other strategies for disposal could involve operations, such as chemical separation of transuranic elements, which are similar to those of spent fuel reprocessing. Reprocessing operations were a significant consideration in selecting the limits of 40 CFR 190. Setting the standards in Part 191 at the levels indicated by assessments based only on geologic disposal activities could preclude other disposal strategies which might be better.

2. Some of the operations addressed by Part 191 may take place near operations regulated by Part 190. Establishing different limitations for different operations at the same site would create difficult implementation problems with little, if any, additional public health protection. The provisions of Part 191 require the combined impacts from multiple operations to meet a single set of dose limitations which will be the same in both Parts 190 and 191.

Section 191.03 therefore requires that the combined annual dose equivalent to any member of the public due to operations covered by Part 190, and to direct radiation and planned discharges of radioactive materials covered by this Subpart, shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ. It also requires that waste management operations be conducted so as to reduce exposures for members of the public below this level to the extent reasonably achievable, taking into account technical, social, and economic considerations.

(40 CFR 191 Subpart B)

DISPOSAL

Standards and guides for the disposal of high-level and transuranic radioactive wastes require far different considerations than those for management. These include:

1. The intent of disposal is to isolate the wastes from the environment for a longer time than that over which active institutional controls, such as monitoring the disposal site to detect releases of radioactivity, can be relied upon for protection.

2. Disposal systems must be designed so that very little radioactivity will return to the environment if the system performs as intended. Thus, the principal concern is the possibility of unintentional releases, either due to unintended events or inadequacies in the disposal system.

These considerations have several ramifications for standards development. First, the standards can only be implemented in the design phase--by setting design principles or by analytically projecting disposal system performance. The more familiar concepts of implementation involving monitoring of emissions or ambient levels of pollutants are not applicable.

Second, the standards must address unintentional releases such as those resulting from human intrusion or geologic faulting. Their provisions must be applicable to a variety of disposal strategies because the

Agency does not have the authority to specify details of disposal method designs. Regulations to be developed by the Nuclear Regulatory Commission (NRC) or DOE, as appropriate, will control specific designs.

Third, the standards must allow for unusually large uncertainties. These include both uncertainties in our current knowledge about disposal techniques and inherent uncertainties about the distant future.

We addressed these issues by developing both general criteria and projected performance requirements for disposal systems. The general criteria will be Federal guides and the projected performance requirements will be generally applicable environmental standards. These two parts of our proposed action are complementary: the general criteria provide qualitative requirements to reduce the chance of future environmental damage; the projected performance requirements set numerical limits on potential releases.

(APPENDIX A)

GENERAL CRITERIA

The proposed radiation protection guides given in Appendix A to the proposed 40 CFR 191 include these criteria:

1. The wastes should be disposed of promptly once adequate methods are available in order to reduce the chance of accidents during long-term storage. We have not established a time limit for this disposal, because the appropriate length of storage may depend on details on the disposal system design. For example, it may be desirable to store high-level wastes for ten years or more to allow for decay of most of the short-lived radionuclides. The primary intent of this criterion is to prevent wastes from being stored indefinitely in order to avoid ultimate disposal.

2. Because they must be effective for so long, disposal systems should offer as much protection as is reasonably achievable.

3. Disposal systems should reduce the consequences of possible mistakes in selection, design, or construction by using several different types of barriers, both engineered and natural, and by taking full advantage of the protection each has to offer. With this redundancy, the unexpected failure of one or more barriers will be compensated for by other barriers. We could also have required that disposal systems meet the numerical performance requirements even if some of their barriers fail. Although additional protection would be provided by such a requirement, we do not believe that this is the best way to increase protection of the public. It would create difficult implementation problems, such as defining "barrier," and it could result in large additional costs and long delays. We believe that making the overall disposal system meet numerical performance requirements by taking advantage of substantial protection from each of its components will provide adequate protection most economically. However, we particularly seek comment on this issue.

4. Protection from the wastes should not depend on the ability of people to control them for more than 100 years after disposal, although measures which require human attention are useful supplements to passive controls.

5. The dangers and locations of disposal systems should be recorded in the most permanent ways practicable in order to reduce the chances of unintended disruption of disposal systems by future generations.

6. Disposal systems should not be located where there has been mining for resources, or where there is a reasonable potential for future exploration for scarce or easily accessible resources. Furthermore, disposal systems should not be located where there is a significant concentration of any material which is not widely available from other sources. This criterion would discourage the use of geologic formations which are often associated with resources. For example, the frequent mining of salt domes either for their relatively pure salt or for use as storage caverns would argue against locating a repository in this type of structure. However, this same concern would generally not apply to bedded salt deposits because they are much more common. We particularly seek comment on this criterion because it could rule out sites which might otherwise be advantageous in meeting all of our other requirements.

7. Recovery of most of the wastes should be possible long after disposal if unforeseen events require this in the future, unless the wastes are removed from the Earth. The various isolation requirements of these standards would make recovery after disposal very difficult and expensive and probably dangerous. Nevertheless, because some of our scientific understanding may prove to be wrong in a way that would produce much greater risks than we expect, future generations must be able to recover the wastes if they deem it essential. An important implication of this requirement is that the physical location of the bulk of the wastes must be reasonably predictable after disposal. Current plans for mined geologic disposal would meet this requirement. However, some possible disposal methods, such as deep well injection of liquid wastes or rock melting concepts, may not. Since this requir ment could eliminate some otherwise

feasible and perhaps advantageous disposal methods, we particularly seek public comment about it.

Executive Order 12088 makes the head of each Executive agency responsible for compliance with these guides, once the President has approved them as Federal Radiation Guidance. In addition, the Order directs the Administrator of the Environmental Protection Agency to monitor compliance by Executive agencies and to review and approve required compliance plans. Conflicts on implementation may be resolved by the Director of the Office of Management and Budget. Exemptions may be granted by the President.

(SECTION 191.13)

PROJECTED PERFORMANCE REQUIREMENTS

The projected performance requirements assume that we can predict some aspects of the future well enough to use the predictions for selecting and implementing disposal methods. Assessment of any disposal plan will require the combination of assumptions about the future with engineering and design information about the disposal method and geologic data for the site. Such assessments can be used to decide whether a particular disposal method provides adequate protection and to compare various methods to determine the degree of protection that is reasonably achievable.

To develop these standards, we assessed the environmental impacts of high-level waste disposal in mined geologic repositories. Geologic repositories were chosen because much more information is available on this method than on others. The projected performance requirements, however, are meant to apply to any method of disposal except disposal directly into the oceans or ocean sediments. Thus, any other disposal method would have to provide at least as much protection as that projected for geologic disposal.

The standards do not apply to disposal in oceans or ocean sediments because such disposal of high-level waste is now prohibited by the Marine Protection, Research, and Sanctuaries Act of 1972 and the London Dumping Convention of 1972. However, disposal in deep ocean sediments is currently being studied and may prove to be a technically feasible option. Thus, we specifically request public comment on extending these standards to include possible ocean disposal methods so that, if the law and treaty were changed, these standards could apply to disposal of high-level waste in the oceans or ocean sediments.

In our assessments of geologic disposal, we identified expected and accidental releases of radioactivity from a generic model of a repository. The model repository contains 100,000 metric tons of heavy metal (MTHM) as spent reactor fuel, about as much as would be generated during the operating lifetimes of 100 reactors of current design. The initial amounts of some of the principal radionuclides in this model repository would be: eight billion curies of cesium-137; six billion curies of strontium-90; 200 million curies of americium-241; 30 million curies of plutonium-239; and one million curies of technetium-99.

We examined the capabilities of waste canisters, waste chemical forms, repository design, and geologic media to prevent or delay the release of radionuclides. We selected reasonably achievable characteristics for each portion of the disposal system. For accidental releases, we estimated the probabilities of events leading to releases. Intentional disruption of the disposal system was not considered.

Radionuclides were considered to be released from the disposal system if they reach the "accessible environment," which includes: surface waters, land surfaces, the atmosphere, and underground formations which might provide ground water for human consumption. Including these formations in the definition of "accessible environment" protects aquifers which might become significant sources of water in the future, regardless of whether they are now being used as water supplies.

We propose to use the designations to be established under Agency regulations for underground injection control (UIC) programs (40 CFR 146) to identify ground water supplies which should be part of the "accessible environment." Under these rules, most geologic formations which can provide useable quantities of water with a total dissolved solids (TDS) content less than 10 grams per liter are protected. Specific exceptions can be made for formations which are impractical sources of water, for example, because of depth or low productivity.

We plan to make one exception to the UIC procedure. The proposed disposal standards do not limit releases to geologic formations which are within one mile of a disposal system, because the formation itself can be an important barrier in a disposal system. A one-mile distance is long enough to allow significant retention of radionuclides by geologic barriers, but short enough so that only a very small part of available ground water could be significantly contaminated.

Our regulations and the assessments on which we base them cover releases of radionuclides to the accessible environment for a period of 10,000 years after disposal. We believe that a disposal system capable of meeting these requirements for 10,000 years will continue to protect people and the environment beyond 10,000 years. We selected 10,000 years as the assessment period for three reasons:

1. It is long enough for releases through groundwater to reach the accessible environment. If we had selected a shorter time, such as 1,000 years, our estimates of radionuclides reaching the accessible environment would be deceptively low, because groundwater could take 1,000 years to travel a mile at a well-selected site, and most radionuclides would take much longer. Choosing 10,000 years for assessment encourages selection of sites where the geochemical properties of the rock formations can significantly reduce releases of radioactivity through groundwater.

2. Major geologic changes, such as development of a faulting system or a volcanic region, take much longer than 10,000 years. Thus the likelihood and characteristics of geologic events which might disrupt the disposal system are reasonably predictable over this period.

3. Radioactive decay will reduce the radionuclide inventory of the wastes to about 0.1% of its original value in 10,000 years. Any hazards from the radioactivity in the wastes will have decreased to about those from the equivalent amount of unmined ore.

We estimated the amounts of radioactivity that might reach the accessible environment over this time period under various circumstances. Then, the premature deaths from cancer caused by these releases were estimated using very general models of environmental transport and a linear, nonthreshold dose-effect relationship between exposure and cancers caused. This relationship assumes that the number of premature cancer deaths induced in a population is proportional to the total dose received by the population, even at very low individual doses, and does not depend on the population size.

Releases from geologic repositories fall into three general categories. Relatively small releases would be caused by expected processes and by fairly likely but unintended events, such as human intrusions. These processes and events lead to what we call "reasonably foreseeable" releases. Moderate releases would result from much less likely events, such as fault movements or other disruptive geologic events and these we call "very unlikely releases." Very large releases would result only from the intrusion of volcanos or impacts by huge meteorites. If sites are selected away from regions of volcanic activity, these large releases will be extremely unlikely.

We used our estimates of releases and their likelihood to select limits on total releases of radioactivity over 10,000 years. Limits were set for two categories of releases in terms of their probabilities: "reasonably foreseeable," and "very unlikely." Reasonably foreseeable releases are those which have more than one chance in 100 of occurring within 10,000 years. Very unlikely releases are those whose chance of occurring within 10,000 years is less than one in 100 and more than one in 10,000. No limits were set for releases which have less than one chance in 10,000 of occurring within 10,000 years.

Our assessments of repository performance gave estimates of the possible premature cancer deaths expected from releases after disposal. These estimates can vary considerably depending upon the assumptions used and the geologic media considered. For well-designed 100,000 MTHM model repositories in salt and granite, we estimate several hundred premature deaths over 10,000 years. Because our analyses are too uncertain to determine reliably more than the order of magnitude of the risks, we adjusted our estimates to 1,000 premature deaths over 10,000 years for a 100,000 MTHM repository. We then used these adjusted estimates as the basis for calculating the release limits specified in Appendix B of the standards.

According to our model, more of the projected harm from releases results from possible human instrusions than from geologic processes. However, predicting human actions is much more uncertain than predicting natural events. In particular, we could only guess at the frequency at which some actions (such as drilling for resources) would be taken. We considered setting separate performance requirements that would limit the radioactivity that could be released by any one likely human intrusion, in order to avoid having to estimate such frequencies. However, we did not do this because: (1) setting separate requirements for natural and human events would not place an upper limit on risk; and (2) setting separate requirements for individual intrusions in addition to the total combined requirements would not appreciably increase confidence that the overall limits would be met unless we made the individual limits unreasonably low. We specifically request comments on this issue.

The release limits are given in Table 1 in terms of curies per 1,000 MTHM. The release limit for each radionuclide is the number of curies of that radionuclide that we estimate could cause 1,000 premature deaths over 10,000 years if it were the only radionuclide released from a 100,000 MTHM repository. For releases involving more than one radionuclide, the allowed release for each radionuclide is reduced to the fraction of its limit that insures that the overall limit on harm is not exceeded. For transuranic wastes, the release limits are in units of an amount of wastes containing three million curies of alpha-emitting transuranic radionuclides. These units were chosen so that the standards would require alpha-emitting radioactivity from either high-level or transuranic wastes to be isolated with about the same degree of effectiveness. This procedure for using the release limits is described in Appendix B to the proposed standards. Compliance with these performance requirements will be achieved if the projected releases from a disposal system do not exceed these release limits.

EFFECTS ON HEALTH

A disposal system that could hold wastes from 100,000 MTHM could contain all existing wastes and the future wastes from all currently operating reactors. We estimate that this quantity of wastes, when disposed of in accordance with the proposed standards, would cause no more than 1,000 premature deaths from cancer in the first 10,000 years after disposal: an average of one every 10 years.

Our estimate of 1,000 deaths over 10,000 years is not intended to be a precise projection of the actual risk from waste disposal. Food chains, ways of life, and the size and geographical distributions of populations will undoubtedly change over any 10,000 year period. Unlike geological processes, factors such as these cannot be accurately predicted over long periods of time. Thus, in making our health effects projections we found it necessary to depend upon the use of very general models of environmental pathways, and to assume current population distributions and death rates. As a consequence, these projections are intended to be used primarily as a tool for comparing the performance of one waste disposal system to another and for comparison of the risks of waste disposal with those of undisturbed ore bodies. The results of our analysis should not be considered a reliable projection of the "real" or absolute number of health effects resulting from compliance with our standards.

Most of the excess cancer deaths caused by the waste would occur more than 1,000 years after disposal. This discontinuity between when the wastes are generated and when the projected health effects manifest themselves has resulted in a particularly difficult problem in determining what level of residual risk should be reasonably permitted by these standards. The difficulty arises from the fact that most of the benefits derived in the process of waste production fall upon the current generation while most of the risks fall upon future generations. Thus, a problem of intergenerational equity with respect to the distribution of risks and benefits becomes apparent. This problem is sometimes referred to as the intergenerational risk issue, and it is not unique to the disposal of high-level radioactive wastes. If we were to insure that our standards fully satisfy a criterion of intergenerational equity with respect to the distribution of risks and benefits, it appears we should require that no risk be passed on to future generations. This is a condition which we conclude cannot be met by disposal technologies foreseeable within this century.

In the face of this dilemma, we are left with two major options: (1) delay setting standards in the hope that future technologies would provide better control, or (2) proceed to set standards on the basis of the best technology that can reasonably be achieved given current scientific, technical, and fiscal capabilities. We have chosen the latter approach. In so doing we have made the judgment that current knowledge is sufficient to allow for the development of repositories which will reduce risks to a reasonable level. We believe these risks are reasonable because they are very small and the only alternative available is to delay disposal to some indefinite time in the future.

There is one additional factor which has contributed to our decision on the reasonableness of the risks permitted under our proposed standards. This is an analysis we have prepared of the risks associated with undisturbed uranium ore bodies.

Uranium Ore: Most uranium ore in the United States occurs in permeable geologic strata containing flowing ground water. Radionuclides in the ore, particularly uranium and radium, continuously enter this ground water. We estimated the harm from these undisturbed ore bodies using the same environmental models that we used for releases from the waste repository. The effects associated with the amount of ore needed to produce the high-level wastes that would fill the model geologic repository can vary considerably. Part of this variation corresponds to actual differences from one ore body to another; part can be attributed to uncertainties in the assessment. The estimates ranged from 300 to 1,000,000 excess cancer deaths over 10,000 years. Thus, leaving the ore unmined presents at least as great a risk to future generations as disposal of the wastes covered by these standards.

It remains unclear to us whether this analysis provides an adequate means of resolving the question of intergenerational risk. It has, however, helped to influence our decision of what is an acceptable level of residual risk given our current scientific, technological, and fiscal capabilities. We particularly invite comment upon the questions of intergenerational risk and the acceptability of risk. Additionally, for purposes of comparisons of risks permitted under the standards to radiation risks we are currently exposed to, we have included a brief discussion of the risks from natural background and from the uranium fuel cycle.

Variations in Natural Background: Radionuclides occur naturally in the earth in very large amounts, and are produced in the atmosphere by cosmic radiation. Everyone is exposed to natural background radiation from these natural radionuclides and from direct exposure to cosmic radiation. These natural background radiation levels have remained relatively constant for a very long time. According to the same linear nonthreshold dose effect relationship used in the other analyses, an increase of one millirem per year (about one percent) in natural background in the United States would result in about 40 additional deaths per year, or 400,000 over a 10,000 year period. Natural background rates vary within the United States by tens of millirems per year, and future generations will experience this same variation.

Nuclear Power Generation: The model geologic repository considered in developing these standards contains the wastes produced in generating about 3,000 gigawatt-years of electricity. This is the output of about 100 large nuclear power plants operating for 40 years each. We estimate that the normal operations of these reactors and their supporting facilities, such as uranium mills and fuel fabrication plants (but excluding uranium mines), will cause about 3,000 excess deaths in the first 100 years after the power is produced. (These estimates do not include deaths from any accidental radioactive releases at these facilities.) Therefore, risks to future generations from disposal of high-level wastes are significantly less than the risks to the generations receiving the immediate benefits from the electric power generated.

ECONOMIC ANALYSIS

The proposed standards for disposal of high-level radioactive wastes will be applied to a developing technology, where the available information base is still incomplete. Therefore, it is difficult to determine the added costs of compliance with the standards. Instead, we have designated a reference program, which is based on disposal cost estimates previously published by DOE. We then increased these DOE estimates to allow for additional expenditures which might be needed to implement a high-level waste disposal program in full compliance with our proposed standards and guides. The difference between the cost of the reference program and the cost of a program in compliance with these proposed standards does not necessarily represent the cost of implementing these standards. In fact, it seems likely that prudent considerations and current public opinion will require that any waste disposal method will cost more than the earlier DOE estimates. Thus, the incremental difference represents our estimate of the maximum potential economic impact of the proposed standards. Commercial and military high-level wastes are considered separately in this section.

Commercial Waste

We assumed a reference waste management and disposal program based upon studies performed by DOE to support the President's spent fuel policy. This reference program involves the geologic disposal of spent fuel in salt formations using carbon steel canisters. We based our estimates of the economic impacts of this reference program on potential charges to utilities for waste management services to be provided by the Government. From the DOE analyses, we estimate that the cost to utilities in 1990 would range from 0.6 to 1.4 (1978) mills per kwh. The total annual cost for 1990 would be 500 million to 1.2 billion (1978) dollars. This charge covers all waste management costs, except for reactor site storage of spent fuel. The year 1990 was selected because the DOE estimates were based on the waste management program being established by then.

We assessed the costs, above those for the reference program, that might be caused by our proposal. First, we estimated the cost for each component involved in the management and disposal of spent fuel. The costs of the management and disposal of spent fuel include: storage of spent fuel for ten years after discharge from the reactor, which covers both reactor-site and away-from-reactor storage; transportation of the spent fuel from the storage site to a facility designed for encapsulation of the waste; the encapsulation of the waste, which includes the necessary handling and processing before disposal; disposal in a geologic repository; Government research and development; Government overhead; and decommissioning of waste management facilities and post-operational activities.

Three of these components may be affected by this action. Encapsulation costs may be larger if compliance requires more durable canisters (e.g., stainless steel or titanium canisters). Disposal costs, which include constructing, operating, and backfilling a geologic repository, will be affected if compliance requires the use of geologic media which are more expensive to mine than salt formations (e.g., granite). Research and development costs may increase because of additional site evaluation and additional research for improved control technologies (e.g., more stable waste forms). Based on these three possible effects, we estimate that the proposed action could result in commercial waste management costs up to 50 percent larger than those for the reference program. The total waste management costs would increase the cost of nuclear generation of electricity by about 10 percent. We estimate the total annual cost of the waste management program in compliance with the standards in 1990 as no more than 1.8 billion (1978) dollars. These waste management and disposal costs would be less than 3 percent of total electric utility revenues in 1979, and should be a smaller portion of future revenues. Thus, they should cause no more than a 3 percent average increase in future electricity rates.

Military Waste

We considered a DOE reference program based on disposal in on-site geologic repositories. We estimated that the total cost of this reference program would be about 3.7 billion (1978) dollars to dispose of all existing military wastes and additional military wastes generated through 1990. The present value of this reference program cost, at a discount rate of 10 percent, is 1.8 billion (1978) dollars.

Our proposed requirements could increase this cost in five areas: waste processing, encapsulation, transportation, disposal, and research and development. In the reference program, long-lived technetium-99 would be left in processed salt cake and stored in existing on-site tanks. Under our standards, additional processing would be required to separate technetium-99 for disposal. Encapsulation costs would be increased if a canister providing greater protection is needed. Transportation would cost much more if the high-level wastes must be disposed of off-site. If the selected off-site geologic media are more difficult to mine than the on-site media, disposal costs may be increased. Research and development costs would be increased because more extensive site evaluation and research on better control technologies may be needed.

We calculated the extra costs for each of these areas, considering both projected costs and potential delays. We estimated that the extra costs could be as large as 1.7 billion (1978) dollars, for a total defense waste program cost of 5.4 billion (1978) dollars. This would be an increase of almost 50 percent over the cost of the reference program. Our estimate of the present value of the additional cost is 320 million (1978) dollars, for a total discounted cost for the defense waste program of 2.1 billion (1978) dollars. This would be an increase of less than 20 percent over the discounted cost of the reference program.

IMPLEMENTATION

Standards for operations (Subpart A) will be implemented by the NRC for commercial nuclear power activities and by the DOE for national defense facilities. Implementation procedures for Subpart A will be very similar to those for the Uranium Fuel Cycle Standards (40 CFR 190).

DOE will select, design, and construct all disposal facilities for high-level and transuranic wastes. Our requirements for disposal (Subpart B and Appendix A) will be implemented by NRC for all high-level wastes, whether the wastes come from commercial or military activities. NRC will do this by developing the necessary regulations (primarily 10 CFR 60) and by issuing appropriate licenses to DOE. Under current law, disposal of transuranic wastes from military activities is not regulated by NRC; therefore, DOE will apply our requirements to the disposal of these transuranic wastes.

The standards for disposal must be implemented through design specifications. The implementing agency will have to evaluate long-term performance projections of the designed system. As a result, a vital part of implementation will be the use of adequate models, including the probabilities of unplanned events, to relate appropriate site and engineering data to projected performance.

The NRC has made substantial progress in developing such analytical models to predict long-term performance of actual geologic repositories. These models include estimates of the effects of uncertainties in the data. Thus, they give information about needs for obtaining better data to determine if repositories meet the projected performance requirements of these standards.

At our request, the National Academy of Sciences (NAS) studied the difficulties in verifying compliance with the long-term environmental protection requirements for geologic disposal. They have developed an approach that specifies the types of information needed and outlines appropriate methods for obtaining this data at prospective sites.

Based on the NAS study, NRC's models, and our own analytical efforts, we have concluded that these disposal standards can be implemented. We believe that it would be best if implementing agencies use generic rule-making proceedings. Such proceedings would consider comprehensive risk assessments which calculate potential releases of radionuclides from various events or processes. The assessments would identify the important engineering design and site selectic. parameters and would indicate how potential releases depend on these parameters. The generic proceedings would then be able to establish limits for the important design and site parameters which, if met, would provide a reasonable expectation of compliance with these standards. Only these limits would need to be satisfied in subsequent licensing actions. We believe generic proceedings are the best way to proceed because the methods needed to address uncertainties could be developed more easily through generic rulemaking than in specific licensing actions.

DATED:

Administrator

A new Part 191 is proposed to be added to Title 40, Code of Federal Regulations, as follows:

SUBCHAPTER F - RADIATION PROTECTION PROGRAMS

PART 191 - ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR MANAGEMENT AND DISPOSAL OF SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

Subpart A - Environmental Standards for Management and Storage

191.01 Applicability
191.02 Definitions
191.03 Standards for Normal Operations
191.04 Variances for Unusual Operations
191.05 Effective Date

Subpart B - Environmental Standards for Disposal

191.11 Applicability
191.12 Definitions
191.13 Projected Performance Requirements
191.14 Effective Date

Appendices

Appendix A General Criteria for Disposal of High-Level and Transuranic Radioactive Wastes

Appendix B Release Limits for Projected Performance Requirements

AUTHORITY: The Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970.

SUBPART A - ENVIRONMENTAL STANDARDS FOR MANAGEMENT AND STORAGE

191.01 Applicability

This Subpart applies to radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes, to the extent that these operations are not subject to the provisions of Part 190 of Title 40.

191.02 Definitions

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of Part 190.

(a) "Spent nuclear fuel" means any nuclear fuel removed from a nuclear reactor after it has been irradiated.

(b) "High-level radioactive wastes" means: (i) wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, in a facility for reprocessing spent nuclear fuels; (ii) the concentrated wastes from subsequent extraction cycles, or equivalent; (iii) solids derived from such wastes; or (iv) spent nuclear fuel if disposed of without reprocessing.

(c) "Transuranic wastes," as used in this Part, means wastes containing more than 100 nanocuries of alpha emitting transuranic isotopes, with half-lives greater than one year, per gram of waste.

(d) "Storage" means placement of radioactive wastes with planned capability to readily retrieve such materials.

(e) "Management and storage" means any activity, operation, or process, except for transportation, conducted to prepare spent nuclear fuel, high-level or transuranic radioactive wastes for storage or disposal, the storage of any of these materials, or activities associated with the disposal of these materials.

(f) "General environment" means the total terrestial, atmospheric, and aquatic environments outside sites within which any operation associated with the management and storage of spent nuclear fuel, high-level or transuranic radioactive wastes is conducted.

(g) "Member of the public" means any individual who is not engaged in operations involving the management, storage, and disposal of materials covered by these standards and guides. A worker so engaged is a member of the public except when on duty at a site.

191.03 Standards for Normal Operations

Operations covered by this Subpart should be conducted so as to reduce exposures to members of the public to the extent reasonably achievable, taking into account technical, social, and economic considerations. As an upper limit, except for variances in accordance with 191.04, these operations shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public due to: (i) operations covered by Part 190, (ii) planned discharges of radioactive material to the general environment from operations covered by this Subpart, and (iii) direct radiation from these operations; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, or 25 millirems to any other organ.

191.04 Variances for Unusual Operations

The standards specified in 191.03 may be exceeded if:

(a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is in the public interest, and

(b) Information is promptly made a matter of public record delineating the nature of the unusual operating conditions, the degree to which this operation is expected to result in levels in excess of the standards, the basis of the variance, and the schedule for achieving conformance with the standards.

191.03 Standards for Normal Operations

Operations covered by this Subpart should be conducted so as to reduce exposures to members of the public to the extent reasonably achievable, taking into account technical, social, and economic considerations. As an upper limit, except for variances in accordance with 191.04, these operations shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public due to: (i) operations covered by Part 190, (ii) planned discharges of radioactive material to the general environment from operations covered by this Subpart, and (iii) direct radiation from these operations; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, or 25 millirems to any other organ.

191.04 Variances for Unusual Operations

The standards specified in 191.03 may be exceeded if:

(a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is in the public interest, and

(b) Information is promptly made a matter of public record delineating the nature of the unusual operating conditions, the degree to which this operation is expected to result in levels in excess of the standards, the basis of the variance, and the schedule for achieving conformance with the standards.

191.05 Effective Date

The standards in this Subpart shall be effective 12 months from the promulgation date of this rule.

SUBPART B - ENVIRONMENTAL STANDARDS FOR DISPOSAL

191.11 Applicability

This Subpart applies to radioactive materials released into the accessible environment as a result of the disposal of high-level or transuranic radioactive wastes, including the disposal of spent nuclear fuel. This Subpart does not apply to disposal directly into the oceans or ocean sediments.

191.12 Definitions

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of this Part.

(a) "Disposal" means isolation of radioactive wastes with no intent to recover them.

(b) "Underground sources of drinking water" means aquifers which have been designated as such under Part 146 of Title 40.

(c) "Accessible environment" means the Earth's atmosphere, land surface, surface waters, and those underground sources of drinking water that are more than one mile in any direction from the original location of the radioactive wastes in a disposal system.

(d) "Barriers" means any materials or structures that prevent or substantially delay movement of the radioactive wastes toward the accessible environment.

(e) "Disposal system" means any combination of engineered and natural barriers that contains radioactive wastes after disposal.

(f) "Reasonably foreseeable releases" means releases of radioactive wastes to the accessible environment that are estimated to have more than one chance in 100 of occurring within 10,000 years.

(g) "Very unlikely releases" means releases of radioactive wastes to the accessible environment that are estimated to have between one chance in 100 and one chance in 10,000 of occurring within 10,000 years.

(h) "Performance assessment" means an analysis which identifies those events and processes which might affect the disposal system, examines their effects upon its barriers, and estimates the probabilities and consequences of the events. The analysis need not evaluate risks from all identified events. However, it should provide a reasonable expectation that the risks from events not evaluated are small in comparison to the risks which are estimated in the analysis. The analysis should address the uncertainties in the estimates. To provide reasonable confidence in its results, the analysis shall be subjected to peer review by technically competent individuals independent of the organization preparing the assessment.

(i) "Heavy metal" means all uranium, plutonium, or thorium placed into a nuclear reactor.

191.13 <u>Projected Performance Requirements</u>

(a) Disposal systems shall be designed to comply with the projected performance requirements of this section. These requirements are upper limits. In accordance with Appendix A, the implementing agency should establish design objectives which will reduce releases as far below these limits as reasonably achievable.

(b) Disposal systems for high-level or transuranic wastes shall be designed to provide a reasonable expectation, based upon quantitative performance assessments, that for 10,000 years after disposal:

(1) Reasonably foreseeable releases of waste to the accessible environment are projected to be less than the quantities calculated according to Appendix B.

(2) Very unlikely releases of waste to the accessible environment are projected to be less than ten times the quantities calculated according to Appendix B.

191.14 <u>Effective Date</u>

The standards in this Subpart shall be effective immediately upon promulgation of this rule.

APPENDIX A - GENERAL GUIDANCE FOR DISPOSAL OF HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

The general guidance recommended in this appendix, when approved by the President, would provide radiation protection guidance to all Federal agencies in accordance with Executive Order 10831 and 42 U.S.C. 2021(h). Disposal systems for high-level or transuranic wastes should comply with each of the following recommendations:

Recommendation 1: Wastes should be disposed of promptly once disposal systems which comply with these standards are developed.

Recommendation 2: Disposal systems should be designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations.

Recommendation 3: Disposal systems should use several different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers should be included. Each such barrier should separately be designed to provide substantial isolation, regardless of how well the other barriers perform.

Recommendation 4: Active institutional controls should not be relied upon to isolate the wastes for more than 100 years after disposal.

Recommendation 5: Disposal systems should be identified by the most permanent markers and records practicable to indicate the dangers of the wastes and their location.

Recommendation 6: Disposal systems should not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthermore, disposal systems should not be located where there is a significant concentration of any material which is not widely available from other sources.

Recommendation 7: Disposal systems should be designed so that most of the wastes may be recovered if this is found necessary in the future, unless the wastes are removed from the Earth.

DEFINITIONS:

(1) "Active institutional controls" means maintaining an institutional capability to: (i) restrict or deny access, (ii) monitor, terminate, or clean up releases to the accessible environment, or (iii) preserve knowledge about the location, design, or inventory of a disposal site.

(2) All other terms shall have the same meaning as in 40 CFR 191.

APPENDIX B - RELEASE LIMITS FOR
PROJECTED PERFORMANCE REQUIREMENTS

NOTE 1: The Release Limits in Table 1 apply either to the amount of high-level wastes generated from 1,000 metric tons of heavy metal (MTHM), or to an amount of transuranic (TRU) wastes containing three million curies of alpha-emitting transuranic radionuclides. To develop Release Limits for a particular disposal system, the quantities in Table 1 shall be adjusted for the amount of wastes included in the disposal system. For example:

(a) If a particular disposal system contained the high-level wastes from 50,000 MTHM, the Release Limits for that system would be the quantities in Table 1 multiplied by 50 (50,000 MTHM divided by 1,000 MTHM).

(b) If a particular disposal system contained 15 million curies of transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by five (15 million curies divided by three million curies).

(c) If a particular disposal system contained both the high-level wastes from 50,000 MTHM and 15 million curies of transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by 55:

$$\frac{50{,}000 \text{ MTHM}}{1{,}000 \text{ MTHM}} + \frac{15{,}000{,}000 \text{ curies TRU}}{3{,}000{,}000 \text{ curies TRU}} = 55$$

NOTE 2: In cases where a mixture of radionuclides is projected to be released, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 1 and Note 1. The sum of such ratios for all the radionuclides in the mixture may not exceed one.

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, and RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} \leq 1$$

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WH

TECHNICAL ASSISTANCE FOR REGULATORY DEVELOPMENT: REVIEW AND EVALUATION OF THE EPA STANDARD 40CFR191 FOR DISPOSAL OF HIGH-LEVEL WASTE

VOLUME 1

EXECUTIVE SUMMARY

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Volume 1	Executive Summary N. R. Ortiz, K. Wahi
Volume 2	A Simplified Analysis of a Hypothetical High-Level Waste Repository in a Basalt Formation R. E. Pepping, M. S. Chu, M. D. Siegel
Volume 3	A Simplified Analysis of a Hypothetical High-Level Waste Repository in a Tuff Formation M. D. Siegel, M. S. Chu
Volume 4	A Simplified Analysis of a Hypothetical High-Level Waste Repository in a Bedded Salt Formation R. E. Pepping, M. S. Chu, M. D. Siegel
Volume 5	Health Effects Associated with Unit Radionuclide Releases to the Environment J. C. Helton
Volume 6	Calculation of Health Effects Per Curie Release for Comparison with the EPA Standard G. E. Runkle

ABSTRACT

The Environmental Protection Agency (EPA) has prepared a draft Standard (40CFR191, Draft 19)[1] which, when finalized, will provide the overall system requirements for the geologic disposal of radioactive waste. This document (Vol. 1) provides an "Executive Summary" of the work performed at Sandia National Laboratories, Albuquerque, NM. (SNLA) under contract to the US Nuclear Regulatory Commission (NRC) to analyze certain aspects of the draft Standard. The issues of radionuclide release limits, interpretation, uncertainty, achievability, and assessment of compliance with respect to the requirements of the draft Standard are addressed based on the detailed analyses presented in five companion volumes to this report.

Introduction

The Environmental Protection Agency (EPA) has prepared a draft Standard (40CFR191, Draft 19)[1] which, when finalized will provide the overall system requirements for the geologic disposal of radioactive waste. Volume 1 of this series of reports provides an "Executive Summary" of the work performed at Sandia National Laboratories, Albuquerque, NM (SNLA) under contract to the US Nuclear Regulatory Commission to analyze certain aspects of the draft Standard. There are five companion volumes to this report that describe, in detail, the analyses carried out. Analyses of hypothetical repositories in three candidate media (Vols. 2, 3, 4) were performed to address the issues of interpretation, achievability, uncertainty, and compliance with respect to the requirements of the draft Standard. An analysis investigating the health effects associated with unit radionuclide releases (Vol. 5) was performed to ascertain the release limits of the draft Standard and their relationship to the assumed health effects. Calculations of health effects per curie of release, similar to those in Volume 5, were carried out for the purpose of showing the effects of uncertainty (Vol. 6) in defining the release limits.

Radionuclide Release Limits

The objective of the draft Standard is to set forth requirements that will ensure public health and safety by minimizing the risks associated with the permanent disposal of nuclear wastes. In an attempt to establish release limits for various radionuclides, the EPA selected a limit on long-term risks of 1,000 health effects (i.e., latent cancer fatalities) over 10,000 years for a 100,000 metric ton of heavy metal (MTHM) repository (for reasonably foreseeable releases). This is equivalent to ten health effects per 1,000 MTHM. The EPA determined the release limit for a given radionuclide by calculating the number of curies that, if released to the accessible environment, will not cause more than ten health effects per 1,000 MTHM over 10,000 years. Using the same health effects constraint, SNLA calculated independently the number of curies for each radionuclide as described in Volume 5 of this report. The results are compared with the EPA release limits in Table 1. The two sets of release limits are seen to be very similar, with the exception of ^{99}Tc.

The release limits shown in Table 1 are derived, both by EPA and SNLA, by using single point values for the input parameters or variables that are known to have uncertainties. The effect of these uncertainties was scoped in the present study by performing calculations in which ranges and distributions were assigned to the distribution coefficients (R_d), river discharge, regional erosion rates, and exchange factor between the

TABLE 1
A Comparison of Cumulative Release Limits
to the Accessible Environment
for 10,000 Years After Disposal

Radionuclide	Half-Life (years)[a]	Proposed Release Limit[b] (curies per 1000 MTHM)	Release Limit From Table 1-1[c] (curies per 1000 MTHM)
Am241	458	10	14
Am243	7370	4	4
C14	5730	200	218
Cs135	3.E6	2000	2625
Cs137	30.2	500	505
Np237	2.14E6	20	17
Pu238	86	400	437
Pu239	2.44E4	100	145
Pu240	6580	100	153
Pu242	3.79E5	100	148
Ra226	1600	3	NE
Sr90	28.1	80	83
Tc99	2.12E5	2000	35,088
Sn126	1.E5	80	83
Any other alpha-emitting radionuclide		10	
Any other radionuclide which does not emit alpha particles		500	

a From Ref. 2
b From Ref. 1
c From Volume 5
NE no estimate

surface water and soil compartments. A sample comparison with the EPA calculation is presented in Figure 1, which shows the health effects associated with one curie of a given radionuclide when the ingestion pathways are considered.

The results of this analysis suggest that the release limits for ^{241}Am, ^{243}Am and ^{237}Np may be overly conservative and may warrant a re-examination by the EPA. Also, the EPA release limit for ^{135}Cs would appear not to be restrictive enough and may also warrant some reconsideration.

Although the results in Volume 6 generally suggest that the EPA made assumptions conservative enough to cover the uncertainties expected in the input variables considered by SNLA, they do not establish that the EPA release limits proposed in the Standard are overly conservative. However, SNLA did not address all the uncertainties in the input parameters. A more complete comparison and discussion is included in Volume 6.

Interpretation of the Requirements

The draft Standard requires high-level waste repositories to be designed to provide a reasonable expectation that for 10,000 years after disposal: (1) reasonably foreseeable releases of waste to the accessible environment are projected to be less than the quantities in Table 1, and (2) very unlikely releases of waste to the accessible environment are projected to be less than ten times the quantities in Table 1. The draft Standard defines: (1) "reasonably foreseeable releases" as releases of radioactive wastes to the accessible environment that are estimated to have more than one chance in 100 of occurring within 10,000 years, and (2) "very unlikely releases" as releases of radioactive wastes to the accessible environment that are estimated to have between one chance in 100 and one chance in 10,000 of occurring within 10,000 years.

The draft Standard uses, but does not define, the word "release." The interpretation of this word affects the manner in which compliance is assessed. Two possible interpretations are:

Interpretation 1: The word "release" defines a unique scenario* leading to radionuclide release. The draft Standard is applied independently to the probability of release for each scenario.

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* Scenarios are events, features, and processes, both natural and human induced, that could conceivably alter the natural state of the disposal site and result in human exposure to radionuclides released from the underground facility.

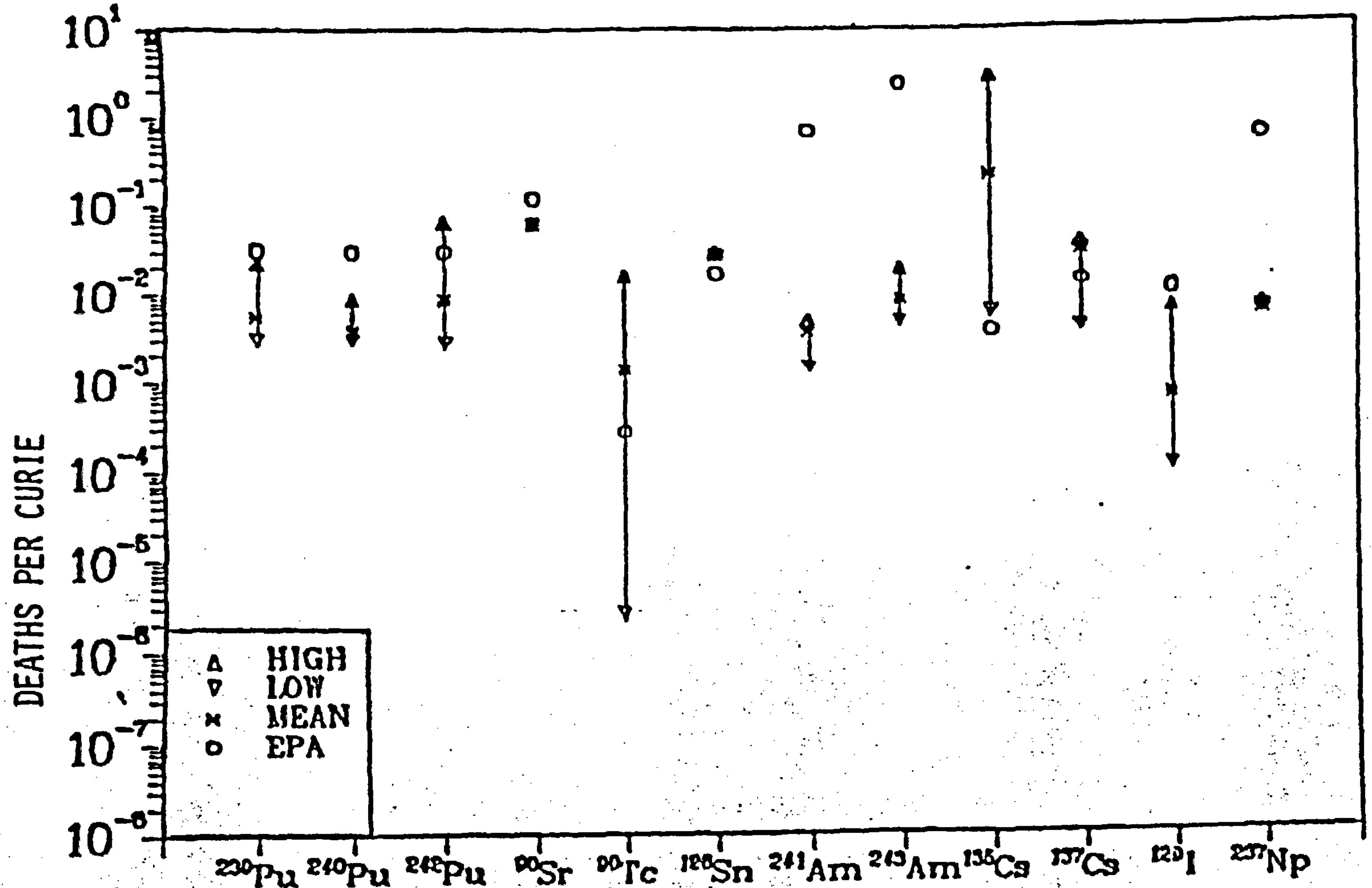

Figure 1: Health effects associated with one curie release for the ingestion pathways.

Interpretation 2: A "release" involves all scenarios that may result in discharges to the environment during the regulatory period. The magnitude of the discharge is given by its corresponding EPA Release Ratio.* Estimation of the probability of exceeding a given value of the EPA Release Ratio includes contributions from all scenarios.

Analyses were performed based on the above interpretations. In the analyses of the hypothetical basalt repository (Vol. 2), compliance assessment was investigated in terms of Interpretation 1 and 2. In the analysis of the hypothetical tuff repository (Vol. 3), compliance assessments were made using a modified version of Interpretation 1 such that the scenario probability (and not release probability) determined the allowable release limit. In the analysis of a hypothetical bedded salt repository (Vol. 4), the results of the direct-hit scenarios are presented individually in conformance with Interpretation 1; the results of the four ground-water transport scenarios are combined as suggested by Interpretation 2. The results discussed in Volume 2 indicate that the number of predicted violations to the draft Standard will vary depending on the selected interpretation. As discussed in Volume 2, we feel that Interpretation 2 is more in the spirit of the risk-based requirements of the draft Standard, since it considers all sources producing a release greater or equal to the specified release limits. EPA should clarify the intended interpretation.

Achievability of the Requirements

Simplified analyses of hypothetical repositories in basalt, tuff, and bedded salt formations have been performed with the intent of predicting integrated releases to the accessible environment and comparing them to the release limits of the draft Standard. Each of the interpretations stated above has been used in expressing the results of these analyses in terms of the release limits of the draft Standard. An appropriate set of scenarios has been chosen for analysis in each of the three media; i.e., the scenarios chosen for a given medium are, in general, different from the ones chosen for the other two media. Table 2 summarizes the postulated scenarios for hypothetical repositories in basalt, tuff, and bedded salt. A

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* Obtained by summing over all radionuclides the ratio of the integrated discharge to the release limit. For a given radionuclide, the release limit is the value given in Table 1 or ten times that, depending on the probability of release.

TABLE 2

Scenarios Analyzed for Hypothetical Repositories in Basalt, Tuff, and Bedded Salt

Host Medium	Scenario Number and Description					
Basalt	<u>Scenario 1</u> Routine release with no disruption	<u>Scenario 2</u> Fractures in dense basalt	<u>Scenario 3A</u> Borehole connection to upper aquifer; mixing cell source model	<u>Scenario 3B</u> Borehole connection to upper aquifer; leach limited: 10^{-4}-10^{-7} per year	<u>Scenario 3C</u> Borehole connection to upper aquifer; leach limited: 10^{-3}-10^{-7} per year	
Tuff	<u>Scenarios 1 & 1B</u> 1. No retardation in any fractured layers 1B. Rock matrix diffusion in fractured layers	<u>Scenarios 2 & 2B</u> Both use rock matrix diffusion and the vertical gradient is unaffected by thermal pulse in each. 2B uses the mixing cell source model	<u>Scenario 3</u> Retardation in some fractured layers due to zeolites	<u>Scenario 4</u> Retardation in porous vitric or devitrified tuff in some fractured layers	<u>Scenarios 5 & 5B</u> Both experience 300 ft. rise in water table 5. Retardation as in Scenario 1 5B. Retardation as in Scenario 1B	<u>Scenario 6</u> Retardation as in Scenario 1; accessible environment 8 miles from repository
Bedded[a] Salt	<u>Scenario 1</u> U-tube formed by a failed shaft seal and one or more boreholes; water originates from and returns to primary aquifer	<u>Scenario 2</u> U-tube formed by two or more boreholes; water originates from and returns to primary aquifer	<u>Scenario 3</u> U-tube formed by a failed shaft seal and one or more boreholes; water originates from and returns to secondary aquifer	<u>Scenario 4</u> U-tube formed by two or more boreholes; water originates from and returns to secondary aquifer	<u>Scenario 5</u> Canister direct hit; rapid and direct movement of radionuclides to surface	<u>Scenario 6</u> Brine pocket penetration

leach-limited source model is implied unless stated otherwise in Table 2. The discharge location (accessible environment) is at a distance of one mile in all cases, except for Scenario 6 in tuff where this distance is eight miles.

The above analyses were performed using the SNLA Risk Assessment Methodology [3,4,5]. The methodology also incorporates uncertainty and sensitivity techniques to calculate consequences (integrated discharges) and the associated release probabilities. Ranges and distributions are assigned to those input variables, from the set of variables needed to define ground-water and radionuclide transport, that are known to have significant uncertainties. A Latin Hypercube Sampling (LHS) technique [5] is then used to sample input values to be used in the calculation of ground-water and radionuclide transport.

A quantitative description of the degradation of the waste form and its release at the boundary of the engineered barrier is provided by a "source model." Three different source models were utilized in the present work:

Source #1 — This is a leach-limited source model. A different leach-rate range is chosen for each medium. A range of 10^{-3} to 10^{-7}/yr is used for tuff, and a maximum range of 10^{-4} to 10^{-7}/yr is used for basalt and bedded salt. The complete inventory of waste is assumed to be available for leaching.

Source #2 — This leach-limited source has the same range as Source #1 in terms of release rate, but the amount of waste available for transport is reduced. Each borehole allows only the penetrated waste in the particular backfilled storage room to be available for transport.

Source #3 — This source resembles Source #2 but allows the backfilled rooms to be modeled as a mixing cell where wasteforms are leached uniformly. Solubility limits are allowed to apply to radionuclide concentrations in the mixing cell.

Only the repository in bedded salt was analyzed with all three source models.

Although the draft Standard has defined a regulatory period of 10,000 years, the present analysis was carried out to a total of 50,000 years, and the results are presented in increments of 10,000 years. This was done in order to assess the adequacy of the 10,000-yr period of regulation.

An examination of the results from the basalt analyses indicates that Scenario 1 does not violate the EPA release limits when using Interpretation 1, during the first 50,000 years. Slight violations do occur for Scenario 2 in each of the five 10,000-yr increments. The Scenario 3 results show a strong dependence on the type of source model used. In Scenario 3A, no violations occurred during the first, second, and fifth 10,000-yr period. In Scenarios 3B and 3C, large to very large violations occurred in each of the five 10,000-yr periods considered.

In the tuff analysis, it was assumed that all the scenarios considered were reasonably foreseeable. During the first 10,000-yr period, Scenarios 1, 1B, 3, 4 and 5 show very slight to slight violation of the draft Standard limits; Scenarios 5B and 6 show no violation and Scenarios 2 and 2B show large violations. In general, the number of vectors* or the extent of violation, or both, tend(s) to increase in each of the subsequent 10,000-yr periods analyzed. This increase, however, is gradual and typically within an order of magnitude.

As with the basalt results, the bedded salt results were evaluated using Interpretations 1 and/or 2. The ground-water transport scenarios (Scenarios 1-4) were repeated using three different source models, and the results are evaluated using Interpretation 2. Substantial variations in the results occur when different source models are used. Gross violations occur when Source #1 is used. No violation occurs during the first 10,000 years for Source #2; violations during the subsequent 10,000-yr period are extremely minor. No violations occur during any of the five 10,000-yr periods when Source #3 is used. Interpretation 1 was used in presenting the results of Scenarios 5 and 6. The direct hit scenario, Scenario 5, indicates a slight violation during the first 10,000-yr period. The brine-pocket penetration scenario, Scenario 6, indicates a relatively large violation of the EPA limit.

The results for all three media for the first 10,000 years are summarized in Table 3. Sample plots of probability of exceeding release ratio on the abcissa are shown in Figure 2 for basalt, Figure 3 for tuff, and Figures 4 and 5 for bedded salt. A direct comparison among the three different media is not recommended due mainly to the fact that the scenarios analyzed are different.

Conclusions and Recommendations

Based on the results of the analyses performed by SNLA, the following conclusions and recommendations are presented.

* A vector, in the present context, represents a complete set of input values selected by the sampling program to carry out a transport calculation. Different vectors represent different combinations of input parameter values.

TABLE 3

Summary of Results of Simplified Analysis for Hypothetical Repositories in Basalt, Tuff, and Bedded Salt (10,000-yr period)

Host Medium	Scenario Number and Description				
	Interpretation #1				
BASALT	Scenario 1	Scenario 2	Scenario 3A	Scenario 3B	Scenario 3C
percent violations	No violations	3%	No violations	~20%	~10%
maximum release ratio		1.3		~1,000.	~100.
contrib. radio-nuclides		C14		Several	Several

	Interpretation #2
BASALT	
percent violations	No violations (Using Scenarios 1, 2 & 3A)

	Modified Interpretation #1								
TUFF	Scenarios 1 and 1B		Scenarios 2 and 2B		Scenario 3	Scenario 4	Scenarios 5 and 5B		Scenario 6
percent violations	1%	1%	10%	8%	1%	1%	3%	none	none
maximum release ratio	2.4	1.7	207	22	.9	1.9	7.9		
contrib. radio-nuclides	Tc99	Tc99	U234 Np237 U238 U236	U234 U236 Np237	Tc99	Tc99	C14		

	Interpretation #1				
BEDDED SALT	Source #	Scenario 1	Scenario 2	Scenario 3	Scenario 4
percent violations	1	61%	59%	27%	28%
	2	no violation	1%	<1%	no violation
	3	no violation	no violation	no violation	no violation
maximum release ratio	1	44	43	25	25
	2	-	1.6	1.2	-
contrib. radio-nuclides	1	U234 Am243 U236 U238	U234 Am243 U236 U238	U234 U236 U238	U234 U236 U238
	2	-	Am243* U234*	U234*	-

	Interpretation #1		**Interpretation #2**
BEDDED SALT	Scenario 5	Scenario 6	Scenarios 1, 2, 3 & 4
percent violations	Very slight violation	Some violations	Source 1: large violations Source 2: no violations Source 3: no violations

*The individual radionuclide gives release ratio ≤ 1.

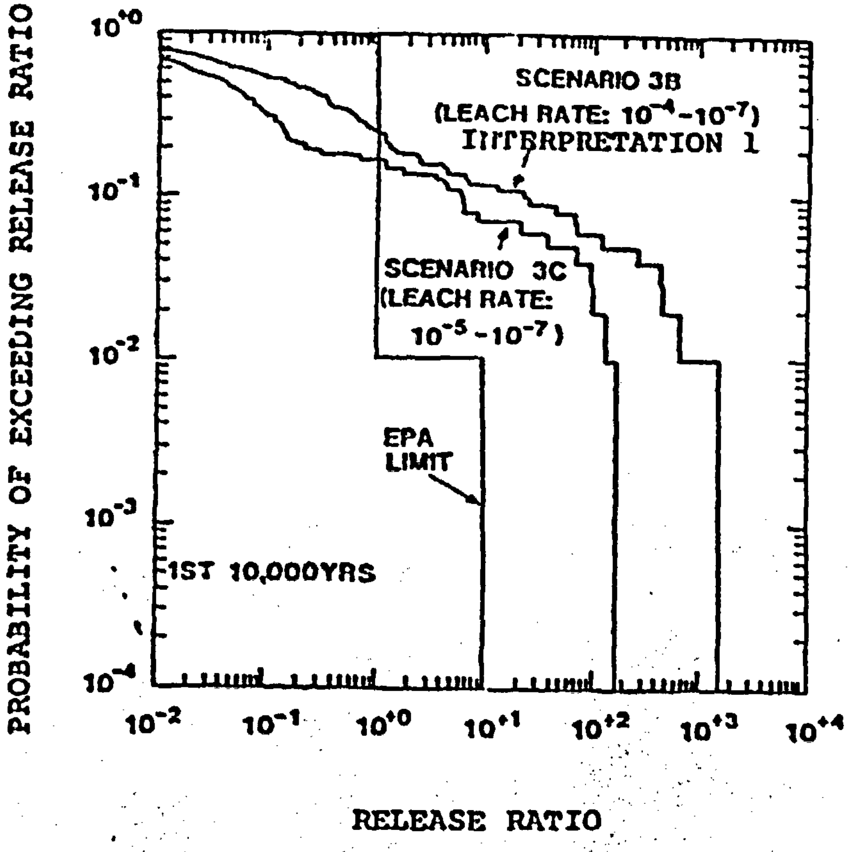

Figure 2(a). Probability of Exceeding Release Ratio, Scenarios 3B and 3C, Basalt Repository.

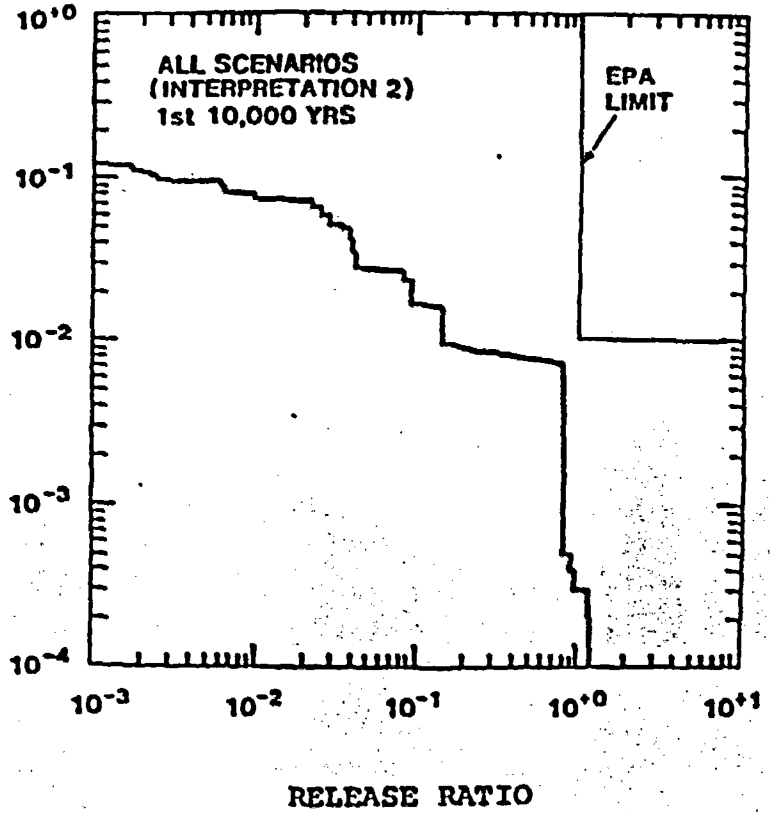

Figure 2(b). Probability of Exceeding Release Ratio, Scenarios 1, 2, 3A, Basalt Repository.

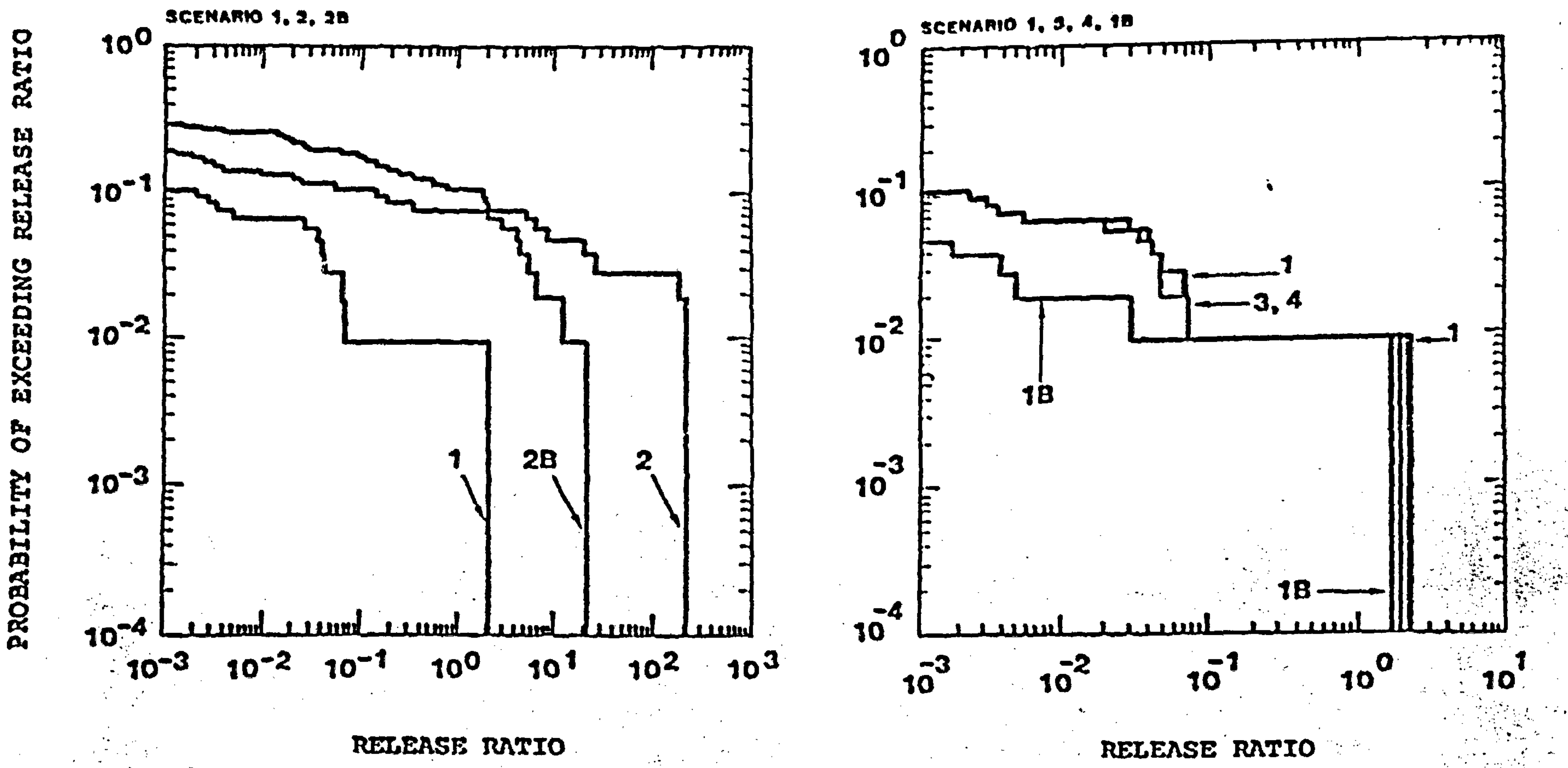

Figure 3. Probability of Exceeding Release Ratio During First 10,000 Years, Tuff Repository.

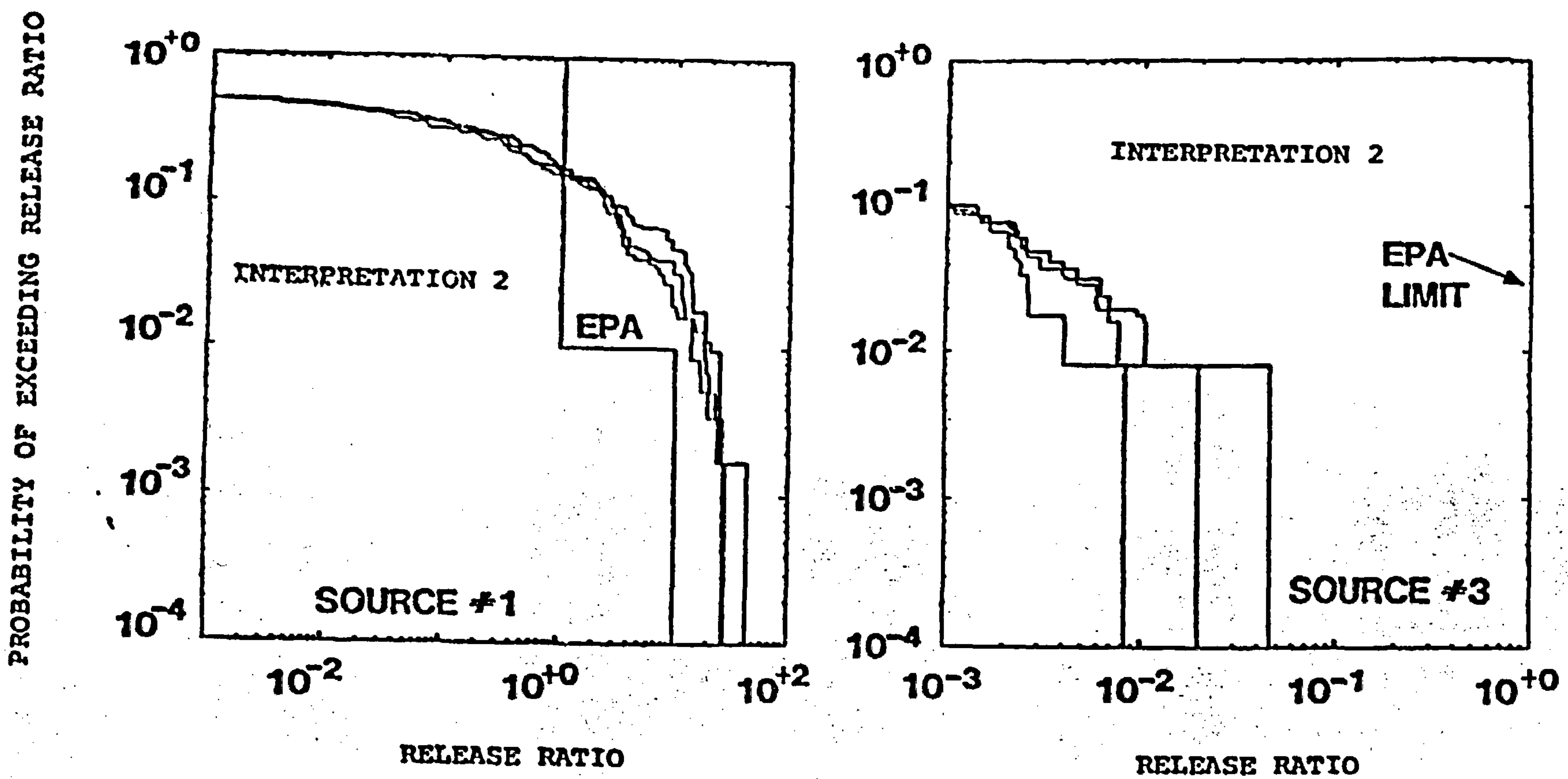

Figure 4. Probability of Exceeding Release Ratio During First 10,000 Years, Groundwater Transport Scenarios, Source #1 and Source #3, Bedded Salt Repository.

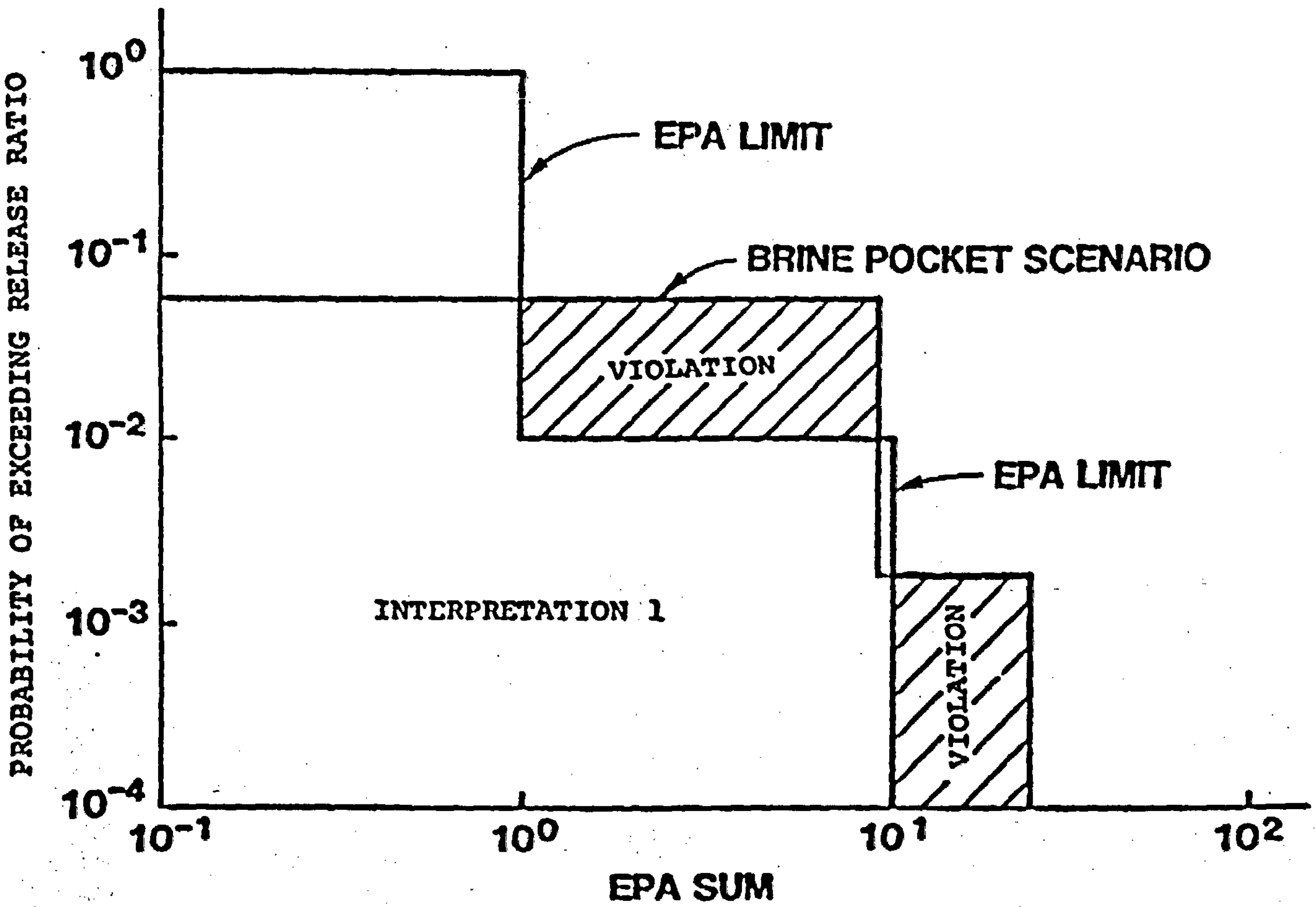

Figure 5. Probability of Exceeding Release Ratio, Scenario 6, First 10,000 Years, Bedded Salt Repository.

- The radionuclide release limits in the draft Standard are in agreement with the values calculated by SNLA with the exception of ^{99}Tc. The draft Standard allows a lower release limit for ^{99}Tc.

- In general, the health effects (per curie) calculated by EPA for the ingestion pathways are higher than the ranges calculated by SNLA. The exceptions are ^{126}Sn and ^{135}Cs. The results of this analysis for ^{241}Am, ^{243}Am and ^{237}Np indicate that the release limits for these radionuclides may be overly conservative and may warrant a re-examination by the EPA. Also, the EPA release limit for ^{135}Cs would appear not to be restrictive enough according to the results of this analysis and, again, may warrant some reconsideration.

- The results suggest that higher release limits could be tolerated if the health effects per curie calculated in the present analysis were to be the basis for such a decision. However, the results do not establish that the release limits in the draft Standard are overly conservative.

- It is necessary to clearly state the intended interpretation in the draft Standard as to how the terms "reasonably foreseeable" and "very unlikely" releases should actually be applied. In other words, is it the scenario probability or the probability of release? Further, should the release probabilities be considered for individual scenarios (conditional) or all pertinent scenarios with a composite release probability?

- The results of the analyses for the reference basalt site performed under Interpretation 1 showed a small probability of violating the draft EPA Standard for Scenarios 2 and 3A. Under Interpretation 2, the same analyses indicate total compliance with the draft Standard, underscoring the need for a clear interpretation.

- Sorption of radionuclides by several thousand feet of zeolitized tuff may limit the release of actinides below the EPA release limits even in the absence of solubility constraints.

- Violations of the draft Standard for Scenarios 1, 1B, 3, 4, and 5 in tuff are due to discharges of ^{99}Tc and ^{14}C. Retardation due to matrix diffusion, however, could significantly reduce the discharge of these nuclides under realistic ground-water flow rates.

- If the radionuclides do not flow through thick sequences of zeolitized tuff, discharges of U and Np under oxidizing conditions may be much larger than the EPA limits.

- Drilling-related, direct-hit scenarios in sedimentary basins indicate slight violations of the draft Standard.

- Brine pockets in bedded salt may pose a significant problem in complying with the draft Standard. Therefore, site characterization should directly address the question of identifying any brine pockets that may be present.

- Analyses performed with different source models show the importance of the source-term assumption on compliance estimates. In general, the mixing-cell source model gives significantly lower releases, and hence discharges, to the accessible environment.

- A majority of the vectors examined in all scenarios produced radionuclide releases below the limits set by the draft Standard. In general, violations of the Standard occurred only when the most conservative assumptions were used or when combinations of input data produced groundwater flow rates that were unrealistically high.

- A practical difficulty in implementing the draft Standard is the lack of our ability to assign reliable numerical values to the scenario probabilities. The methodology to assess compliance with the Standard is, nevertheless, available as has been demonstrated by this and other similar studies.

- The predicted radionuclide releases over 10,000-yr intervals, from 10,000 to 50,000 y   :s, are not significantly higher than for the first 10,(years. The maximum release ratio over the 50,000 ,ears increases by a factor of two to three.

- SNLA strongly recommends that detailed performance analyses be carried out for repositories in basalt and tuff (similar to the one performed for bedded salt in [3,4]) to assure that important variables, processes, or events have not been overlooked in the simplified analyses.

REFERENCES

1. "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," 40CFR191, (Working Draft #19), Federal Register, March 19, 1981.

2. Weast, W. E., 1974, Handbook of Chemistry and Physics (55th edition), CRC Press, Cleveland, OH.

3. Cranwell, R. M., J. E. Campbell, and others, "Risk Methodology for Geologic Disposal of Radioactive Waste: Final Report," Sandia National Laboratories, SAND-81-2573, NUREG/CR-2452, 1982.

4. Cranwell, R. M., R. V. Guzowski, J. E. Campbell, and N. R. Ortiz, "Risk Methodology for Geologic Disposal of Radioactive Waste: Scenario Selection Procedure," Sandia National Laboratories, SAND80-1429, NUREG/CR-1667, 1982.

5. Iman, R. L., J. M. Davenport, and D. K. Zeigler, "Latin-Hypercube Sampling: Program User's Guide," Sandia National Laboratories, SAND79-1473, 1980.

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16. ABSTRACT (200 words or less)

The Environmental Protection Agency (EPA) has prepared a draft Standard (40CFR191, Draft 19) which, when finalized, will govern the geologic disposal of radioactive waste. This document (Vol. 1) provides an "Executive Summary" of the work performed at Sandia National Laboratories, Albuquerque, N.M. (SNLA) under a contract to the U.S. Nuclear Regulatory Commission (NRC) to analyze certain aspects of the draft Standard. The issues of radionuclide release limits, interpretation, uncertainty, achievability, and assessment of compliance with respect to the requirements of the draft Standard are addressed based on the detailed analyses presented in five companion volumes to this report.

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- A Simplified Analysis of a Hypothetical Repository in a Basalt Formation
- A Simplified Analysis of a Hypothetical Repository in a Tuff Formation
- A Simplified Analysis of a Hypothetical Repository in a Bedded Salt Formation

Prepared by Fuel Cycle Risk Analysis Division

Sandia National Laboratories

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Volume 3

A Simplified Analysis of a Hypothetical Repository in a Tuff Formation

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TECHNICAL ASSISTANCE FOR REGULATORY DEVELOPMENT: REVIEW AND EVALUATION OF THE EPA STANDARD 40CFR191 FOR DISPOSAL OF HIGH-LEVEL WASTE

VOL. 3

A SIMPLIFIED ANALYSIS OF A HYPOTHETICAL REPOSITORY IN A TUFF FORMATION

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ABSTRACT

Potential radionuclide releases from a hypothetical tuff repository have been calculated and compared to the limits set by the EPA Draft Standard 40CFR191. The importance of several parameters and model assumptions to the estimated discharges has been evaluated. The areas that were examined included the radionuclide solubilities and sorption, the description of the local hydrogeology and the simulation of containment transport in the presence of fracture flow and matrix diffusion. The uncertainties in geochemical and hydrogeological parameters were represented by assigning realistic ranges and probability distributions to these variables. The Latin Hypercube sampling technique was used to produce combinations (vectors) of values of the input variables. Ground-water flow was described by Darcy's Law and radionuclide travel time was adjusted using calculated retardation factors. Radionuclide discharges were calculated using the Distributed Velocity Method (DVM). The discharges were integrated over five successive 10,000 year periods. The degree of compliance of the repository with the standard in each scenario was illustrated by the use of Complementary Cumulative Distribution Functions (CCDF).

Our calculations suggest the following conclusions for the hypothetical tuff repository: (1) sorption of radionuclides by zeolitized tuff is an effective barrier to the migration of actinides even in the absence of solubility constraints: (2) violations of the EPA Draft standard can still occur due to discharge of ^{99}Tc and ^{14}C. Retardation due to matrix diffusion, however, may eliminate discharge of these nuclides for realistic ground-water flow rates: (3) in the absence of sorption by thick sequences of zeolitized tuff, discharges of U and Np under oxidizing conditions might exceed the EPA standard. Under reducing conditions, however, the low solubilities of these elements may effectively control radionuclide release.

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Michael Reade of C.G.S., Inc. collected and synthesized much of the hydrogeologic data from the Nevada Test Site that was used in this report. The equivalent porous media approximation used in these calculations was derived by K. L. Erickson, Division 1843, Sandia National Laboratory. Appendix C was written from information and text contained in several articles and notes by Dr. Erickson. Paul Davis, Division 9413, Sandia National Laboratory, provided valuable criticisms of an earlier draft of this report.

1. INTRODUCTION

In the near future, the EPA is expected to issue 40CFR191, a draft standard for the geologic disposal of radioactive wastes. During a 180 day period, government agencies such as NRC are expected to comment on the standard. Sandia is funded by the NRC to provide information and insights useful in preparing these comments. The objective of this effort is to perform calculations similar to those performed by EPA in developing the draft standard. We have calculated integrated discharges of radionuclides in plausible scenarios. A number of media have been proposed as candidate hosts for nuclear waste repositories: bedded salt, domed salt, basalt, tuff and granite. This report documents analysis of a repository in the saturated zone of a volcanic tuff formation.

The conceptual model of the repository site is consistent with our current understanding of the characteristics of volcanic tuff environments currently being studied by the Department of Energy. It must be stressed that we have not attempted to accurately model any specific real site. At the present time the available data are not sufficient for this purpose. Large uncertainties exist in the characterization of the solubilities and sorption of radionuclides, in the description of the regional and local hydrogeology and in the mathematical treatment of contaminant transport due to fracture flow and matrix diffusion. We feel, however, that in this analysis, we have calculated reasonable upper limits of radionuclide discharge for a generic tuff repository under realistic conditions. In our calculations we have also attempted to evaluate the relative importance of the aforementioned areas of uncertainty to the estimated radionuclide release.

Appendices A through C describe in detail the assumptions and mathematical approximations that we used in our analysis. In Appendix A we discuss the data obtained from studies of Yucca Mountain at the Nevada Test Site which were used in setting realistic limits to hydrogeological parameters used in our calculations. The assumptions used to calculate hydraulic gradients for the hypothetical repository site are also discussed. In Appendix B, the geochemical environment at Yucca Mountain is described. The data which were used to estimate realistic values of radionuclide sorption ratios (R_d's or K_d's) and solubilities are also discussed. In some of our calculations we have used a retardation factor which includes the effects of matrix diffusion for ^{99}Tc, and ^{14}C and ^{129}I. Appendix C contains a derivation of the approximations we have used to adapt our one-dimensional porous media transport model to the analysis of transport in jointed porous rock.

2. GEOLOGY AND HYDROLOGY OF THE REPOSITORY SITE

2.1 Regional Geology and Hydrology

A map of the topographic setting and a regional cross-section of the repository site are shown in Figures 1 and 2 respectively. The repository (point R) is located in Mountain A on the flanks of a large volcanic caldera. The repository horizon lies approximately 3000 feet below the surface within a Tertiary volcanic tuff aquitard (Unit 3) in the saturated zone. In Mountain A, the water table is 1500 feet below the surface and 1500 feet above the repository. The tuff aquitard is composed of layers of moderately welded to nonwelded tuff units and extends several thousands of feet below the repository horizon. On a regional scale, the tuff aquitard is underlain by a Paleozoic clastic aquitard (Unit 2) and a Paleozoic carbonate aquifer (Unit 1). The basal no-flow boundary of the regional ground-water system lies at the base of the carbonate aquifer.

Above the tuff aquitard lies a densely welded and highly fractured Tertiary tuff aquifer. This unit reaches a maximum thickness of about 1000 feet at Mountain A. In the washes adjacent to the mountain, the water table lies within the tuff aquifer. The piezometric surface approaches the land surface gradually along the A-D section in Figures 1 and 2; at point D water flows freely in wells at the surface.

The lateral boundaries of the regional ground-water system are approximately coincident with the edges of Figure 1. The areas north of Mesa A and Mesa B comprise the northern border of the system. The eastern and southeastern limits of the basin are marked by a series of mountains and ridges. A mountain range in the southwest marks another boundary of the system. The northwest border of the regional system is not well defined, however, the area to the west of Mesa A is known to belong to another hydrogeologic system.

Recharge to the ground-water system through precipitation occurs only above the 5000 foot contour marked in Figure 1. Due to the high evaporation potential in this region, only about 15 percent of 15 inches of rainfall infiltrates to the water table in areas above this elevation. The ground-water system is sluggish because of the small amount of recharge. The hydraulic gradients are low to moderate (10^{-4} to 10^{-3}) except in regions where the rocks in the saturated zone are relatively impermeable. The regional ground-water flow is south-southeast through the repository and south-southwest in the southern portions of Figure 1.

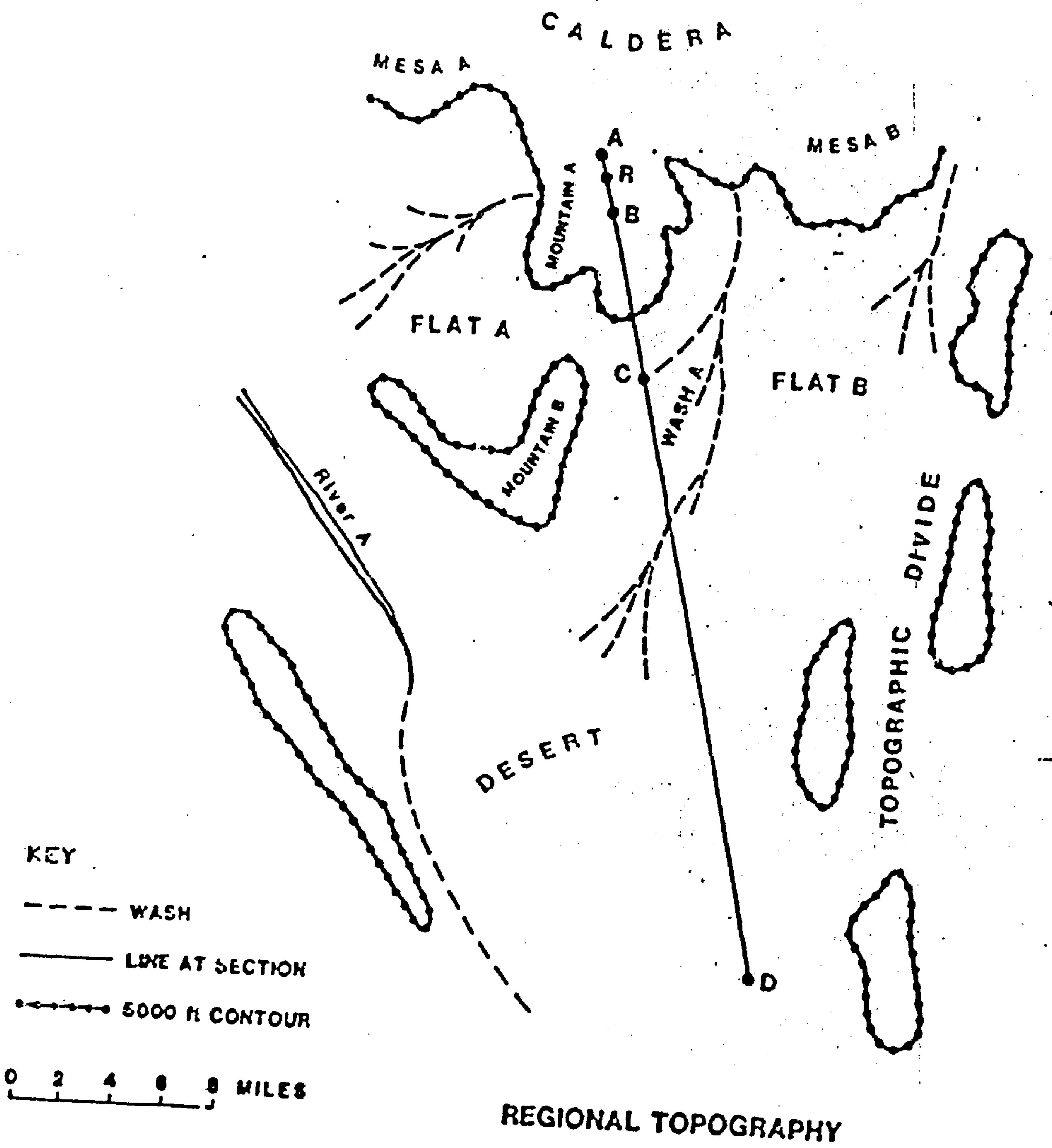


Figure 1. Regional Topography of the Hypothetical Tuff Repository Site.

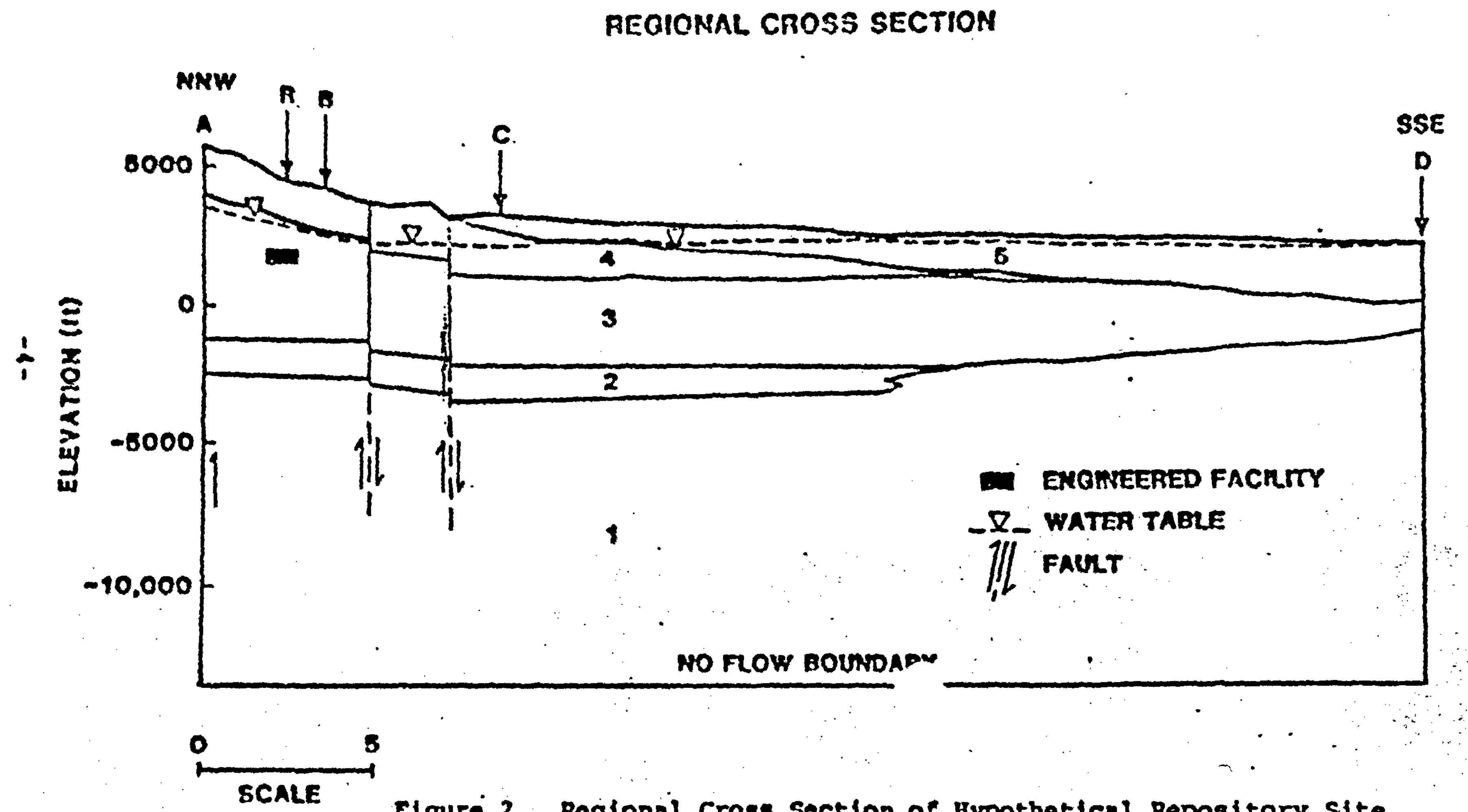


Figure 2. Regional Cross Section of Hypothetical Repository Site.

Unit 1: Paleozoic carbonate aquifer; Unit 2: Paleozoic clastic aquitard; Unit 3: Tuff aquitard; Unit 4: Tuff aquifer.

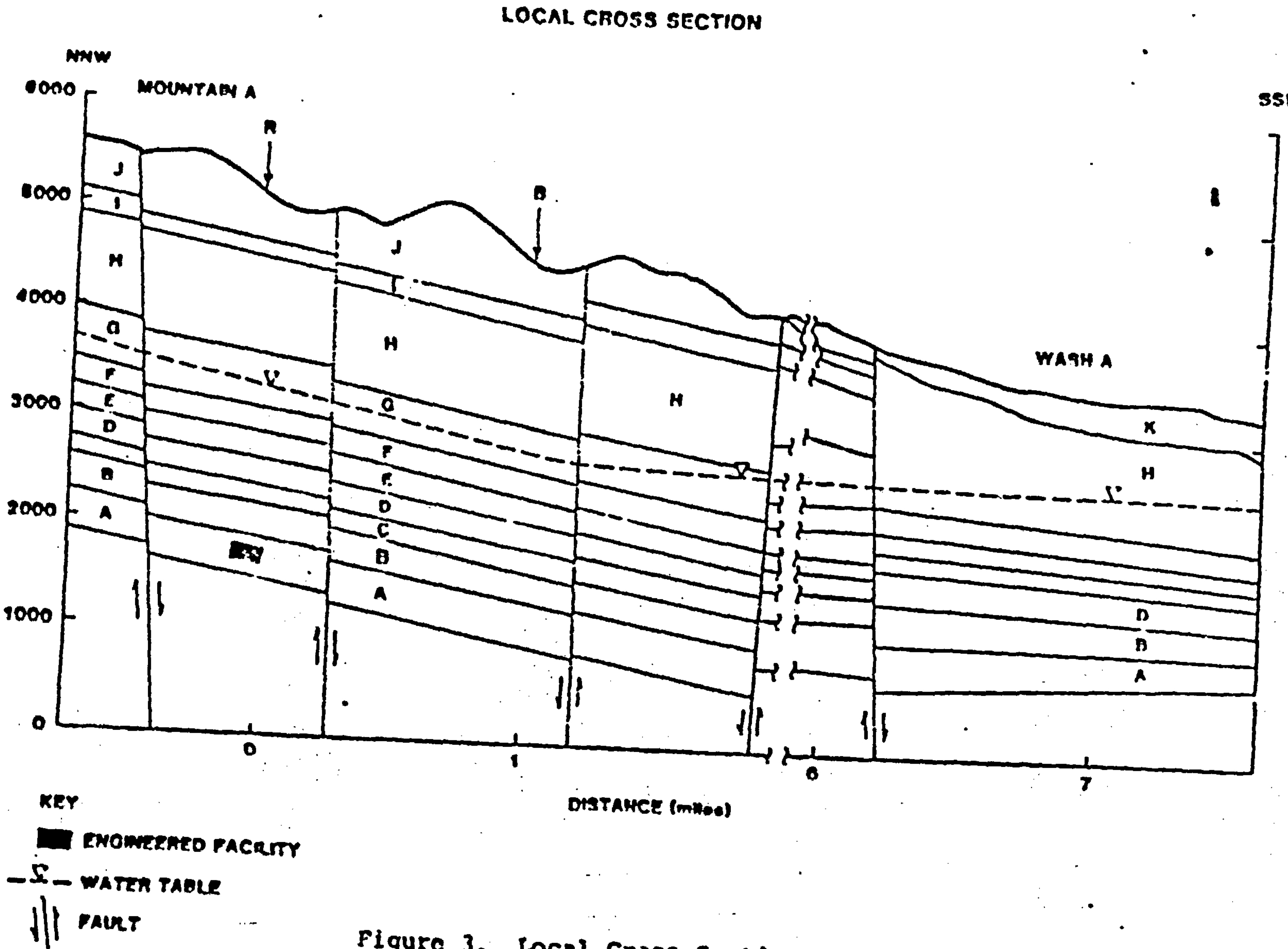


Figure 3. Local Cross Section of Hypothetical Tuff Repository Site.

2.2 Local Geology and Hydrology

A detailed cross section at the repository is shown in Figure 3. In Table 1, the stratigraphy for the site is described in more detail. An explanation of the petrological terms can be found in the section on Geochemistry.

In the vicinity of the volcanic caldera, the tuff layers are underlain only by granitic batholiths; all pre-existing rocks have been destroyed by volcanic eruptions. The tuff units thin with increasing distance from the volcanic centers as shown in Figure 2.

The engineered facility is located in the middle of Unit A, a densely welded member of the tuff aquitard. This unit is a devitrified tuff, composed primarily of alkali feldspar, tridymite and cristobalite. Layer B, directly above the repository horizon, is a nonwelded zeolitized tuff composed primarily of clinoptilolite. The water table lies in layer G which is similar in composition to Layer C. Layers E and I have not undergone devitrification. They have retained their original glassy nature and are designated as "vitric" in Table 1.

The geochemical and hydrological characteristics of these layers are determined primarily by the mineralogy and the degree of welding of the rocks. The local flow system and radionuclide retardation will in turn be strongly influenced by these characteristics. In Table 2, the ranges and types of distribution for several hydrogeologic parameters are described for the different types of tuff. Data from pump tests, laboratory measurements of matrix porosity of intact cores, and calculations based on fracture aperture and density were used to bound reasonable limits for hydraulic conductivity and porosity. Observations of the orientation of fractures in volcanic tuffs at the Nevada Test Site (1,2) suggest that two sets of vertical fractures dominate the joint system. In such systems, fluid flowing in the horizontal direction will effectively encounter only one set of fractures. Fluid flowing in the vertical direction will encounter both sets of fractures. In our calculations, therefore, we have assumed that values of hydraulic conductivity and effective porosity in the vertical direction are twice the values in the horizontal direction. The assumptions and methods used to delimit the ranges of hydraulic properties are discussed in more detail in Appendix A. The wide ranges of values for these parameters correspond to the limits of values of published data obtained from the different measurement techniques described above. It will be

Table 1

STRATIGRAPHY OF HYPOTHETICAL TUFF SITE

	UNIT	DEGREE OF WELDING	ROCK TYPES	THICKNESS (FT)	COMMENT
(TUFF AQUIFER)	K	NA	ALLUVIUM	60-425	
	J	DENSE	DEVITRIFIED	145	
	I	NONWELDED	VITRIC	150	
	H	DENSE	DEVITRIFIED	900	WATER TABLE AT DISTANCE=8 MILES
(TUFF AQUITARD)	G	NONWELDED	ZEOLITIZED	475	WATER TABLE AT DISTANCE=0 MILES
	F	MODERATE	DEVITRIFIED	270	
	E	MODERATE	VITRIC	180	
	D	NONWELDED	ZEOLITIZED	150	
	C	DENSE	DEVITRIFIED	250	
	B	NONWELDED	ZEOLITIZED	300	
	A	DENSE	DEVITRIFIED	400	REPOSITORY HORIZON

Table 2

RANGES OF HYDROGEOLOGIC PARAMETERS

Parameter	Densely Welded Tuff	Moderately Welded Tuff	Nonwelded Tuff
Horizontal hydraulic conductivity (ft/day)''	2×10^{-5}-30 (LU)'	3×10^{-5}-5 (LN)	10^{-5}-2 (LN)
Horizontal effective porosity (%)''	4.4×10^{-4}-0.32 (LN)	0.03-25 (LU)	20-48 (N)
Horizontal hydraulic gradient	1×10^{-3}-1×10^{-1} (LU)	1×10^{-3}-1×10^{-1} (LU)	1×10^{-3}-1×10^{-1} (LU)
Vertical hydraulic gradient	1×10^{-2}-4×10^{-2} (U)	1×10^{-2}-4×10^{-2} (U)	1×10^{-2}-4×10^{-2} (U)
Grain density (g/cm^3)	2.3	2.2	1.7
Horizontal fracture porosity''(%)	4.4×10^{-4}-0.32	0.0-0.06	---
Total Porosity (%)	3-10	10-38	20-50

' Type of distribution is indicated in parenthesis for variable sampled by Latin Hypercube Sampler (LU)-log uniform; (LN)-lognormal; (U)-uniform.

'' Values of these properties in the vertical direction are 2x the values in the horizontal direction.

shown in Chapter 6 that this uncertainty in the input data can be related to the uncertainty in the results by the Latin Hypercube sampling technique (18) and the Complementary Cumulative Distribution Function (6).

The repository site is extensively block faulted, consequently, the water table lies in the tuff aquitard near Mountain A (an uplifted block) and in the tuff aquifer beneath the adjacent washes and flats (down-dropped blocks).

The water table in the vicinity of the repository is indicated in Figure 3. Near Mountain A, the piezometric surface lies within Unit H and parallels the top of this layer. The horizontal hydraulic gradient near the repository is within the range 10^{-1} to 10^{-3}. Approximately 2 miles from the repository, the water table enters the tuff aquifer (in Layer G) and the gradient decreases to a range of 10^{-2} to 10^{-4}. This change in gradient is due to the combined effects of stratigraphy, contrasts in hydraulic conductivity, and increased recharge at elevations above 5000 feet. In our calculations, however, we have sampled the horizontal gradient over a range of 10^{-1} to 10^{-3} for conservatism.

The block faulting can create local abrupt changes in head at vertical faults where relatively permeable water-bearing zones are abutted against impermeable layers. For the purpose of our calculations, however, we have ignored these local heterogeneities. The water lies more than 1000 feet below the surface at all points along section ABC. Local changes in the water table will not substantially affect radionuclide transport on the scale of our model; the water table, therefore, is represented by straight lines in Figure 3.

In all of the release scenarios (except scenarios 2 and 2B) we have assumed that radionuclides travel vertically from the engineered facility to the water table under the influence of thermal buoyancy related to the heat generated by the emplaced waste. We have also assumed that the volume of annual groundwater flow through the repository is not large enough to appreciably perturb the regional flow system. Supply of ground water to the repository will be sufficient to saturate the repository at all times during the 50,000 year period of interest. This assumption adds another element of conservatism to our calculations and will be discussed further in Appendix A.

3. WASTE AND REPOSITORY DESCRIPTION

3.1 Waste

The inventory (Table 3) assumed in this work is equal to half the projected accumulation of 10-year-old spent fuel in the United States by the year 2010. This would contain a total of 103,250 BWR and 60,500 PWR assemblies; a total of 46,800 metric tons of heavy metal (MTHM). All radionuclides specified in the Release Limit Table of the EPA Standard are included in this inventory list.

Based on the inventory and toxicity of each radionuclide the following chains of radionuclides were considered:

(1) $^{240}Pu \rightarrow {}^{236}U \rightarrow {}^{232}Th \rightarrow {}^{228}Ra$

(2) $^{245}Cm \rightarrow {}^{241}Pu \rightarrow {}^{241}Am \rightarrow {}^{237}Np \rightarrow {}^{233}U \rightarrow {}^{229}Th$

(3) $^{246}Cm \rightarrow {}^{242}Pu \rightarrow {}^{238}U \rightarrow {}^{234}U \rightarrow {}^{230}Th \rightarrow {}^{226}Ra$

$^{238}Pu \rightarrow {}^{234}U$

$^{226}Ra \rightarrow {}^{210}Pb$

(4) $^{243}Am \rightarrow {}^{239}Pu \rightarrow {}^{235}U \rightarrow {}^{231}Pa \rightarrow {}^{227}Ac$

The fission and activation product radionuclides ^{99}Tc, ^{129}I, ^{126}Sn, ^{90}Sr, ^{14}C, ^{135}Cs, and ^{137}Cs were also considered in this work.

All canisters containing the wastes are assumed to have a life of 1,000 years after emplacement. At year 1,000, all canisters fail simultaneously and radionuclide release begins. Radionuclide release is assumed to be determined by a constant rate of breakdown of the waste form. The waste matrix is assumed to dissolve at an annual rate of 10^{-3} to 10^{-7} of the original mass. Radionuclides are assumed to be uniformly distributed throughout the matrix so that their release rate is directly proportional to the matrix dissolution rate.

3.2 Subsurface Facility

The reference subsurface facility is a mined facility at a depth of 3,000 feet below the surface. A description of the facility is summarized as follows:

Areal dimensions -- 2,000 acres ($8.71 \times 10^7 ft^2$)
(Reference 3, Table C1)

Height = 23 ft.
Rep. Volume = 8.71×10^7 ft^2 x 23 ft = $2.0 \times 10^9 ft^3$

Extraction Ratio = 20% (Reference 3, p. 88)
Porosity of Backfill = 20%

Porosity volume of depository = $8.0 \times 10^7 ft^3$

Table 3

INVENTORY OF REFERENCE REPOSITORY
(SPENT FUEL FROM 46,800 MTHM)

Radionuclide	Half Life	Curies
Pu240	6.76E3	2.1E7
U236	2.39E7	1.0E4
Th232	1.41E10	1.7E-5
Ra228	6.7	4.7E-6
Cm245	8.27E3	8.4E3
Pu241	14.6	3.2E9
Am241	433.	7.5E7
Np237	2.14E6	1.5E4
U233	1.62E5	1.8
Th229	7300.	1.3E-3
Cm246	4710.	1.6E3
Pu242	3.79E5	7.5E4
U238	4.51E9	1.5E4
Pu238	89.	9.4E7
U234	2.47E5	3.5E3
Th230	8.E4	0.19
Ra226	1600.	3.5E-4
Pb210	21.	3.3E-5
Am243	7650.	6.6E5
Pu239	2.44E4	1.4E7
U235	7.1E8	7.5E2
Pa231	3.25E4	0.25
Ac227	21.6	5.2E-2
Tc99	2.14E5	6.1E5
I129	1.6E7	1.5E3
Sn126	1.0E5	7.2E4
Sr90	28.9	2.4E9
C14	5730.	3.5E4
Cs135	2.0E6	1.3E4
Cs137	30.	3.5E9

4. SITE GEOCHEMISTRY AND RADIONUCLIDE RETARDATION

4.1 Geochemical Environment of the Hypothetical Tuff Site

The migration rate of radionuclide in the tuff repository site will depend on the interactions between the dissolved species and the rock matrix and between the different aqueous species in the liquid phase. Important geochemical parameters which must be characterized include the major and minor element composition, pH, Eh, and temperature of the ground water and the mineralogy of tuff layers through which the radionuclides migrate.

The lithology of each tuff unit in our hypothetical tuff site is described in Table 1. They are classified as zeolitized, vitric or devitrified. A more detailed discussion of the mineralogy may be found in Appendix B. The ground water in the repository site is assumed to be a sodium-potassium-bicarbonate water similar to that described by Winograd and Thordarson (4) at the Nevada Test Site. The Eh is assumed to be mildly oxidizing and the pH is between 7.2 and 8.3. The chemical composition of water from the vicinity of Yucca Mountain and the justification for the above assumptions are described in detail in Appendix B. The temperature assumed in the transport legs in the far field of the repository site is between 30°C and 40°C. This range is based on the geothermal gradient at Yucca Mountain (3).

4.2 Sorption Ratios

The sorption ratio (R_d) is an experimentally determined ratio of the amount of radionuclide bound to a solid phase to the amount of nuclide in a volume of liquid in contact with the solid.

$$R_d \text{ (ml/g)} = \frac{\text{grams radionuclides per gram rock}}{\text{grams radionuclide per ml water}}$$

Values for ranges of R_d for the different types of tuff found at the reference repository site are given in Table 4. These ranges are based primarily on a review of the results of sorption ratio studies by scientists at Los Alamos Laboratories (5-10).

The degree of conservatism for these ranges is discussed in Appendix B. Elements for which no sorption data are published are enclosed in brackets in Table 4. They have been assigned to R_d values of chemical homologs for which data are available (11). To our knowledge, there are no acceptable data for

Table 4

RANGES OF R_d (ml/g) VALUES SAMPLED BY LATIN HYPERCUBE

Element	Vitric Tuff	Devitrified Tuff	Zeolitized Tuff with Clinoptilolite
Sr, [Ra, Pb, Sn]	117-300	50-450	290-213,000
Cs	429-8600	120-2000	615-33,000
Pu	70-450	80-1400	250-2000
Am, [Cm, Pa, Th, Ac]	85-360	190-4600	600-9500
Np	5-7	5-7	4.5-31
U	0-11	1-14	5-15
I, ^{14}C	0	0	0
Tc	0-2	0.3-1.2	0.2-2

Np sorption on vitric tuff; the sorption ratio range for devitrified tuff was assigned to this medium.

4.3 Solubility Limits of Radionuclides

The solubility limits that were assigned to each element in this study are listed in Table 5. Based on data available at this time, the values in the table are approximate upper bounds for the solubilities of these elements in a volcanic tuff environment. The determination of solubilities of radionuclides in ground water associated with a repository in tuff requires experimental studies and calculations describing the possible interactions between nuclides and ligands over a range of temperatures, water compositions and redox conditions. The theoretical calculations are not within the scope of this contract and to our knowledge have not been carried out. Few experimental data describing radionuclide solubility in tuff are available at this time. Due to the time constraints of this contract, we have compiled this list of solubility values from a limited amount of experimental data and solubilities calculated from a limited review of thermochemical data (12-16). A discussion of the conservatism of these data may be found in Appendix B.

4.4 Radionuclide Retardation

The following expression was used to describe radionuclide retardation in layers of zeolitized tuff in all scenarios.

$$R = 1 + R_d \cdot \rho \cdot \frac{(1-\phi_{eff})}{\phi_{eff}} \qquad (4.1)$$

Where ϕ_{eff} is the effective porosity of the rock
ρ is the grain density of the rock
R_d is the radionuclide sorption ratio (ml/g)

The calculation of retardation in moderately and densely welded tuff layers was different in each scenario. In scenarios 3 and 4, expression 4.1 was used for moderately welded tuff layers. It was assumed that all radionuclides were unretarded in densely welded layers in scenarios 1, 3, 4, 5, and 6. In scenarios 1, 5, and 6 it was assumed that all radionuclides were unretarded in moderately welded tuff layers also. Detailed descriptions of the scenarios and rationales for these representations of retardation are found in the next section.

Table 5

ELEMENT SOLUBILITIES USED IN
MIXING CELL CALCULATIONS

Element	Solubility g/g	Reference
Pu	2.4×10^{-4}	*
U	2.4×10^{-5}	15
Th	2.3×10^{-7}	13
Ra	2.3×10^{-8}	16
Cm	2.5×10^{-11}	*
Am	2.4×10^{-12}	15
Np	2.4×10^{-8}	15
Pb	2.1×10^{-6}	*
Pa	2.3×10^{-2}	13
Ac	no limit	*
Tc	no limit	*
I	no limit	*
Sn	1×10^{-3}	13
Sr	2×10^{-6}	13,16
Cs	no limit	*
C	3×10^{-5}	*

* See discussion in Appendix B

In scenarios 1B, 2, 2B, and 5B matrix diffusion for Tc, ^{14}C, and I was included explicitly in the calculations of radionuclide retardation:

$$R = 1 + \phi_m \left(\frac{1-\epsilon}{\epsilon}\right) \cdot \left(1 + R_d \cdot \rho \cdot \left(\frac{1-\phi_m}{\phi_m}\right)\right) \qquad (4.2)$$

Where ϕ_m = matrix porosity
ϵ = fracture porosity
ρ = grain density of rock matrix
R_d = radionuclide sorption ratio (ml/g)

The derivation of this expression and constraints on its use are discussed in Appendix C.

5. GROUNDWATER TRANSPORT MODEL

In the calculations of radionuclide transport it is assumed that ground-water flow is described by Darcy's Law:

$$q = Q/A = KI \tag{5.1}$$

where Q is the volumetric flow rate through an area A, normal to the flow direction, I is the hydraulic gradient, K is the hydraulic conductivity, and q is the Darcy velocity. When the flow passes through a series of layers with different hydraulic properties, an "effective" hydraulic conductivity may be calculated by

$$K = \frac{\sum_i L_i}{\sum_i \frac{L_i}{K_i}} \tag{5.2}$$

with

L_i = thickness of layer i

K_i = hydraulic conductivity of layer i

The total ground-water travel time is given by

$$\text{Time} = \sum_{i=1} \frac{L_i}{V_i} \tag{5.3}$$

where V_i is the interstitial ground-water velocity in layer i and is equal to q/ϕ_i, where ϕ_i is the effective porosity of layer i. We have assumed that ϕ_i and K_i are correlated and $r^2 = 0.70$. The geometry of the flow path is described for each scenario in Section 6.

When a radionuclide (RN) is transported by ground water, the radionuclide travel time (T_{RN}) is increased by its retardation factor. This is given by

$$T_{RN} = \sum_i \frac{L_i \cdot R_i^{RN}}{V_i} \tag{5.4}$$

where R_i^{RN} is the retardation factor of radionuclide RN in layer i.

The Distributed Velocity Method (DVM) (17) has been developed by Sandia to simulate long chains of radionuclides transported by ground water. In this study we calculated the average velocity of radionuclides using Equation (5.4). The DVM code was then used to calculate the discharges of radionuclides.

6. DESCRIPTIONS OF SCENARIOS AND CALCULATIONS

6.1 Introduction

The conceptual model of our hypothetical repository site is consistent with our current understanding of the characteristics of volcanic tuff environments being studied by the Department of Energy. We have not attempted to accurately model any particular real site; at the present time the available data are not sufficient for this purpose. Large uncertainties exist in the characterization of the solubilities and sorption of radionuclides, in the description of the regional and local hydrogeology and in the mathematical treatment of contaminant transport in the presence of fracture flow and matrix diffusion. In our calculations, we have attempted to evaluate the relative importance of these areas of uncertainty to the estimated radionuclide discharge. We have calculated radionuclide release for several scenarios using different combinations of the following assumptions:

A. Release rate of radionuclides from the engineered facility
   1. limited by leach rate
   2. solubility limited

B Representation of retardation of radionuclides in moderately welded units
   1. no retardation
   2. porous media approximations with zeolite R_d's
   3. porous media approximations with R_d's for vitric or devitrified tuff

C. Matrix diffusion
   1. no credit given for retardation by matrix diffusion
   2. calculation of retardation of ^{99}Tc, ^{129}I, and ^{14}C in welded units

D. Distance to accessible environment
   1. one mile
   2. eight miles

E. Flow path
   1. vertical path and gradient controlled by thermal effect
   2. horizontal migration only

F. Location of water table
   1. in zeolitized tuff
   2. in densely welded tuff (300 ft above present day level)

The characteristics of each scenario are summarized in Table 6. The release rate of radionuclides from the engineered facility was set equal to the leach rate (10^{-3} to 10^{-7} of the original inventory) in all scenarios except scenario 2B.

The mixing cell option of NWFT/DVM was used in the scenario 2B and will be described in more detail in Section 6.5.

The uncertainties in geochemical and hydrogeological parameters were represented by assigning realistic ranges and probability distributions to these variables. The Latin Hypercube Sampling Technique (18) was used to produce 106 combinations (vectors) of values of the input variables. Integrated radionuclide discharges for five successive 10,000 year periods were calculated as described in Section 5. A release ratio was calculated for each vector by dividing the magnitude of the discharge of each radionuclide by the corresponding EPA release limit (19, 23) and then summing over all radionuclides.* The results are presented as probability distributions of the release ratios for each scenario (Complementary Cumulative Distribution Functions) (20). The curve indicates the ability of the repository site to limit the release of radionuclides and to comply with the Draft EPA Standard. They also illustrate how our ability to assess the compliance of a repository with the EPA Draft Standard is affected by the uncertainty in the input data.

We have not made quantitative estimates of the probability of occurrence of any of the scenarios. We have assumed only that each of the scenarios is an "anticipated event" (corresponding to a "reasonably foreseeable release" in the EPA Draft Standard (19)). We feel that the scenarios have a reasonable probability of occurrence within the 10,000 year regulatory period.

The water table is at least 1,000 feet below the land surface at all points within the hypothetical repository site of our analyses. All of the scenarios require that a well be drilled at least to the depth of the water table and that the radionuclides are withdrawn continuously for 10,000 years or longer. We have based our subjective estimate of the probability of drilling at the hypothetical tuff site on estimates of the water, hydrocarbon and heavy metal ore potential of the Nevada Test Site. Our estimate of the probability of a pluvial period and subsequent rise in the water table at the repository site (scenario 5) is based on information concerning past climatic changes at NTS (22).

*EPA release ratio = $\sum Q_i/EPA_i$, where Q_i is the integrated release of radionuclide i and EPA_i is the EPA release limit for radionuclide i for the 10,000 year interval. For "reasonably foreseeable releases" the EPA release ratio must be less than or equal to unity for compliance.

Table 6

DESCRIPTIONS OF SCENARIOS

SCENARIO	DISTANCE BETWEEN REPOSITORY AND POINT OF DISCHARGE: 1 MILE PUMP	8 MILE PUMP	REPRESENTATION OF RETARDATION IN WELDED UNITS — DENSELY AND MODERATELY WELDED: MATRIX DIFFUSION MODEL	FRACTURED MEDIUM WITH NO RETARDATION	MODERATELY WELDED ONLY: POROUS MEDIUM WITH ZEOLITES	POROUS MEDIUM WITH DEVITRIFIED TUFF OR VITRIC TUFF	VERTICAL GRADIENT CONTROLLED BY THERMAL PULSE: YES	NO	CLIMATIC CHANGE CAUSES 300 FT RISE IN WATER TABLE: YES	NO
#1	X			X			X			X
#1B	X		X				X			X
#2	X		X					X		X
#2B	X		X					X		X
#3	X				X		X			X
#4	X					X	X			X
#5	X			X			X		X	
#5B	X		X				X		X	
#6		X		X			X			X

* Scenarios 2 and 2B differ from each other in their treatment of the source term. Scenario 2 was a leach limited source term with no solubility limits. In scenario 2B we used the mixing cell option of NWFT/DVM which allows solubility limits to constrain the rate of radionuclide release from the repository.

6.2 Scenarios 1, 3, 4, and 1B: Alternate representations of retardation in welded tuff layers

Scenario 1 - The "Base Case"

Scenario 1 can be considered the base case scenario in our analyses of the hypothetical tuff site (Figure 4). The major geological barriers to radionuclide migration are the layers of zeolitized tuff above the repository. The magnitude of the vertical hydraulic gradient is determined by a buoyancy effect of water heated by the repository as described in Appendix A. Ground water and radionuclides from the repository will travel along the vertical gradient to the top of the water table and then migrate horizontally down the horizontal hydraulic gradient. The horizontal gradient is calculated as the sum of the regional gradient plus a component related to the upwelling heated water from the repository (see Appendix A.3).

At a distance of one mile from the repository, a well pumps water from this upper saturated unit. The major barrier to horizontal transport of the radionuclide is retardation in the zeolitized layer G. Layers of zeolitized tuff are treated as porous media in the fluid transport and retardation calculations. Layers of moderately or densely welded tuff are treated as porous media in the transport calculations but it is assumed that no retardation occurs in these layers. Since no credit is given to retardation in the welded units, the calculated discharge may be an upper bound for release associated with the fluid transport path described above.

Scenarios 3 and 4 -Porous media approximations for moderately welded tuff layers

Scenarios 3 and 4 differ from scenario 1 only in the treatment of retardation in the moderately welded tuff layers (Figures 5 and 6). In both scenarios these layers are treated as porous media. Moderately welded tuffs are characterized by physical and chemical properties that are intermediate between densely welded devitrified tuffs and nonwelded zeolitized tuffs. In scenario 3, R_d values of zeolitized tuff (Table 4) are used to calculate retardation factors. These calculations may provide a lower bound to discharge from the site for scenarios 1, 3, and 4. R_d values for vitric tuffs and devitrified tuffs are used to calculate retardation in layers E and F respectively in scenario 4. Values of all other variables are the same as in corresponding vectors of scenario 1.

Scenario 1B - Matrix diffusion in welded tuff layers

Scenario 1B (Figure 7) differs from scenario 1 only by the inclusion of matrix diffusion in calculations of radionuclide retardation in moderately and densely welded tuff layers. The calculation of a retardation factor which includes the effects of matrix diffusion has been described in Equation 4.2 and in Appendix C. At present, it can only be shown that this expression is valid for radionuclides with $R_d = 0$ (K. Erickson, personal communication). For scenario 1B, therefore, retardation due to matrix diffusion was considered only for ^{129}I, ^{99}Tc and ^{14}C (see Table 4).

Results

Radionuclide discharge rates for each vector were calculated. Discharge rates were integrated for 10,000 year periods from 0 to 50,000 years. The results of the calculations are presented as Complementary Cumulative Distribution Functions for each 10,000 year period in Figures 8A-8E. (20) The number of vectors that violate the EPA Standard, the maximum violation and the sum of the release ratio over all vectors are presented in Table 7. For these scenarios, all violations of the EPA Standard are due to discharges of ^{99}Tc and ^{14}C. The effect of retardation in the moderately welded units on the integrated discharge can be assessed by comparing the values for scenarios 3 and 4 to corresponding values for scenario 1. It can be seen that discharge is decreased for the first 40,000 years and increased in the period from 40,000 to 50,000 years relative to scenario 1. Comparison of the results for scenario 1B with those for scenario 1 shows that although discharge of the radionuclides is decreased significantly by matrix diffusion, violations of the EPA release limit still occur.

The characteristics of the three vectors whose radionuclide discharges violate the EPA Standard are shown in Table 8. When these values of hydraulic gradient and Darcy velocity are compared to the ranges of hydrogeologic parameters sampled by the LHS for input, it can be seen that the high radionuclide discharges are due primarily to large ground-water fluxes. These annual ground-water discharges range from 2 percent to 7 percent of the present day recharge of the Pahute Mesa ground-water system at the Nevada Test Site (21, 22). In Appendix A it is shown that this fraction is unrealistically high for Yucca Mountain. Therefore, we can conclude that violations of the EPA Standard for a ground-water flow path similar to scenario 1B is very unlikely.

SCENARIO 1

1 mile well; moderate * fractured; thermal buoyancy; no pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - no retardation	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - no retardation	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - no retardation	180
6	F	moderate - no retardation	270
7	G	nonwelded - porous - zeolites	5280

FLOW PATH

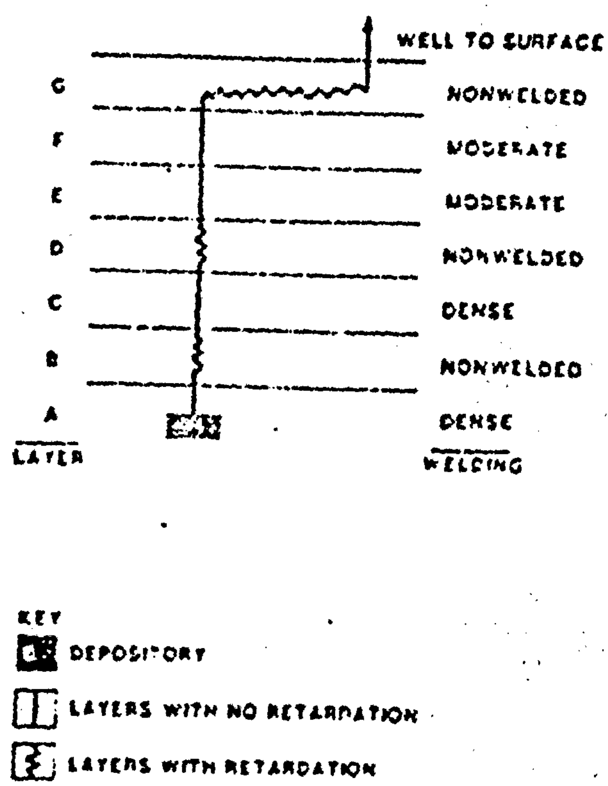


Figure 4

SCENARIO 3

1 mile well; moderate - porous zeolite; thermal buoyancy; no pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - no retardation	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - no retardation	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - porous - zeolites	180
6	F	moderate - porous - zeolites	270
7	G	nonwelded - porous - zeolites	5220

FLOW PATH

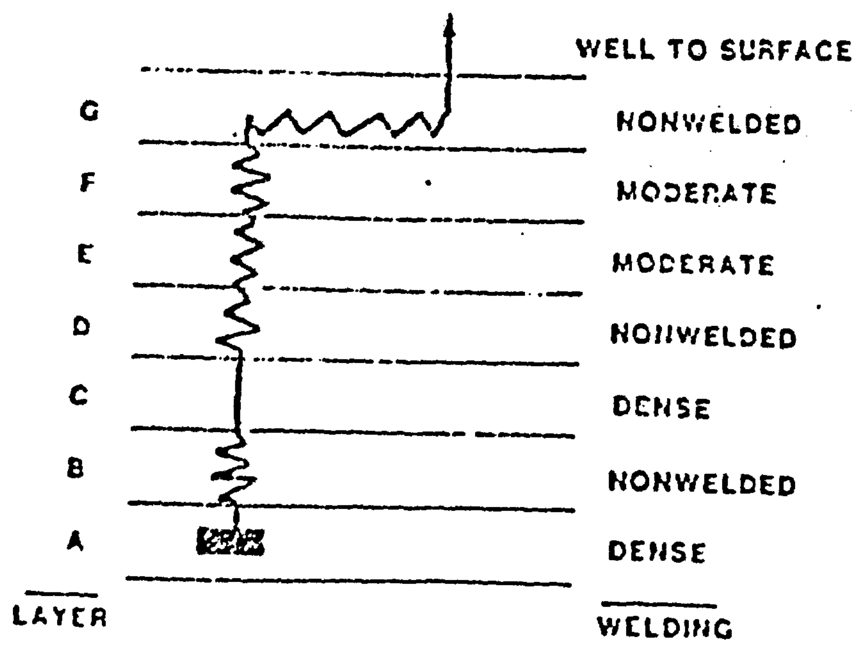


Figure 5

SCENARIO 4

1 mile well; moderate - porous, vitric or devitrified tuff, thermal buoyancy

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - no retardation	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - no retardation	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - porous - vitric	180
6	F	moderate - porous - devitrified	270
7	G	nonwelded - porous - zeolites	5280

FLOW PATH

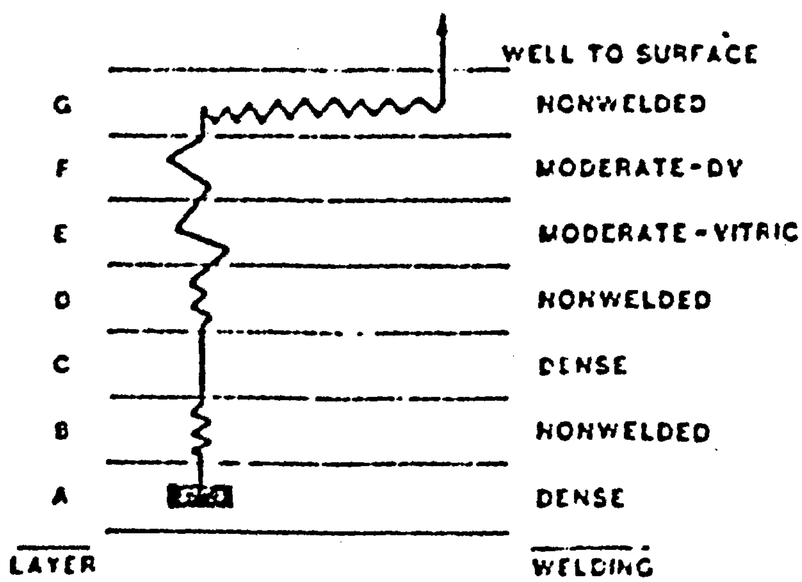


Figure 6

SCENARIO 1B

1 mile well; matrix diffusion, thermal buoyancy; no pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - matrix diffusion	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - matrix diffusion	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - matrix diffusion	180
6	F	moderate - matrix diffusion	270
7	G	nonwelded - porous - zeolites	5280

FLOW PATH

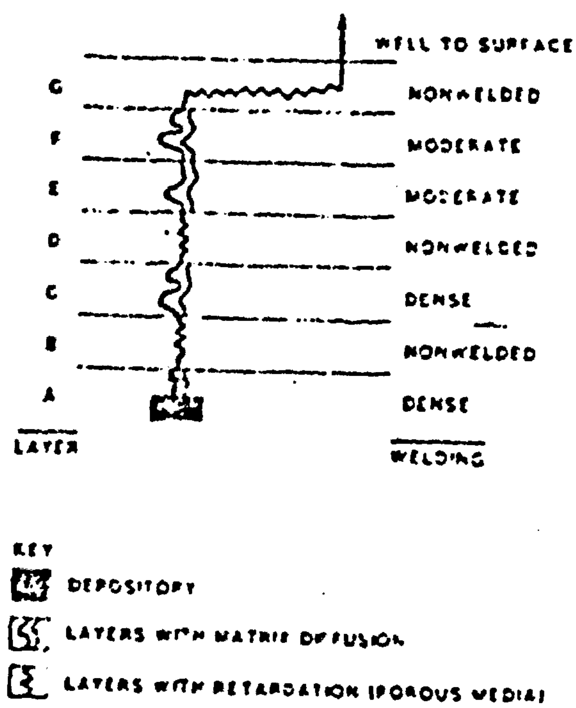


Figure 7

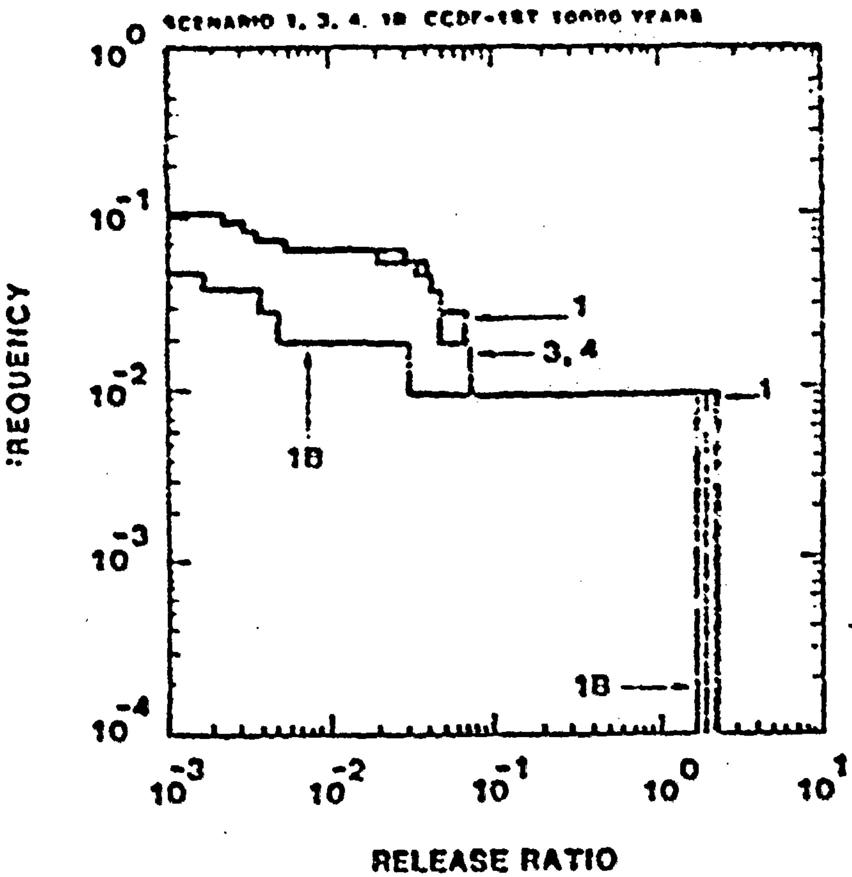


Figure 8.a

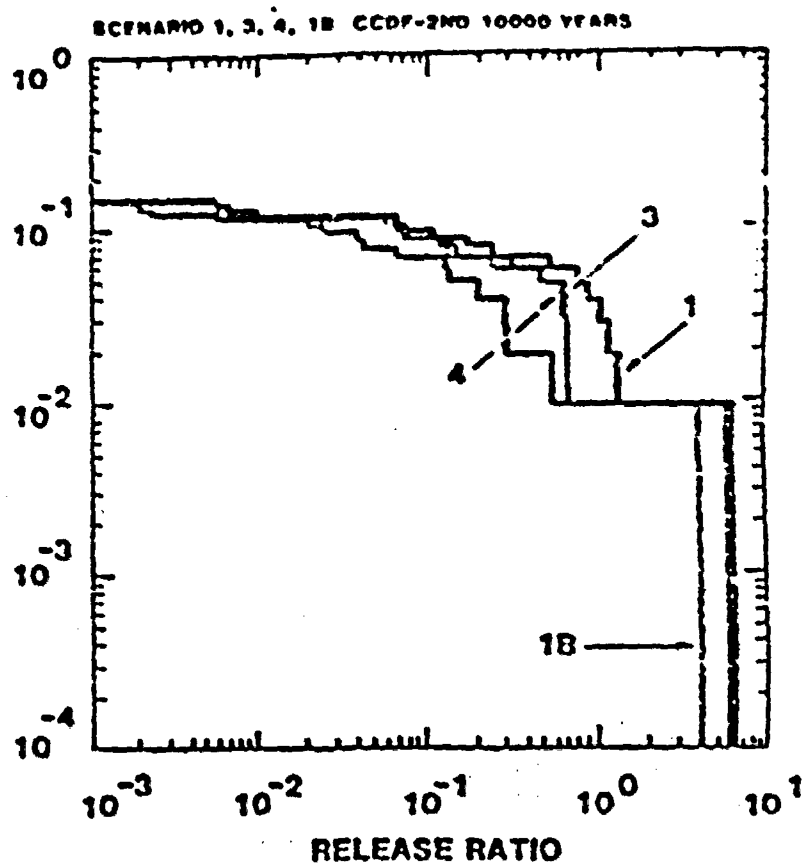


Figure 8.b

Figure 8 Complementary Cumulative Distribution Functions for Scenarios 1, 1B, 3, and 4: Alternate Representations of Retardation in Welded Tuff Units.

1 = base case; 1B = base case with matrix diffusion; 3 = zeolites; 4 = vitric or devitrified

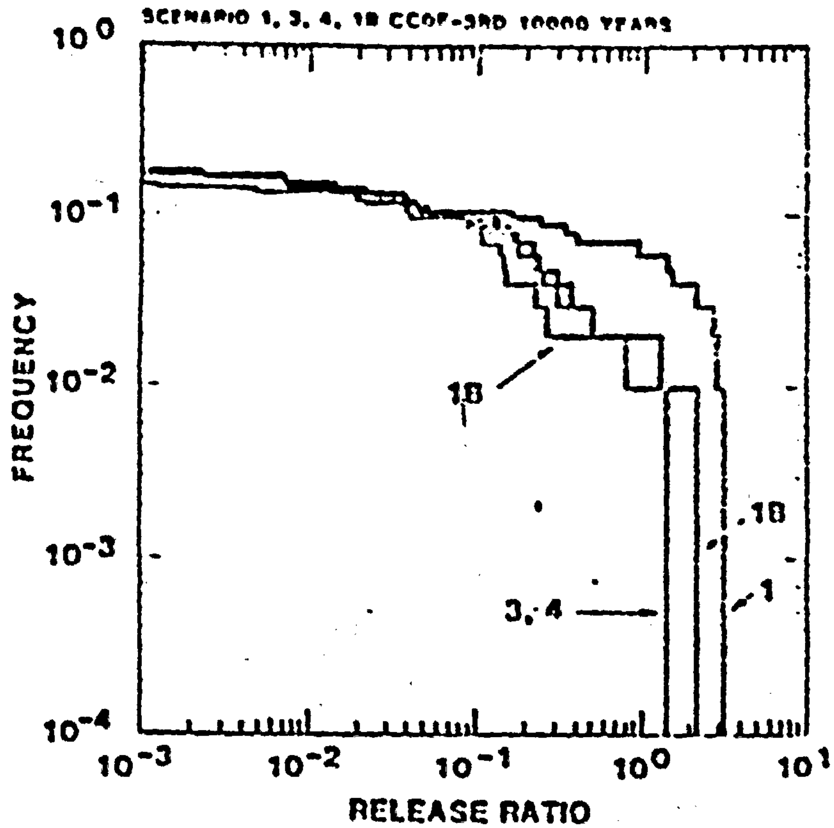


Figure 8.c

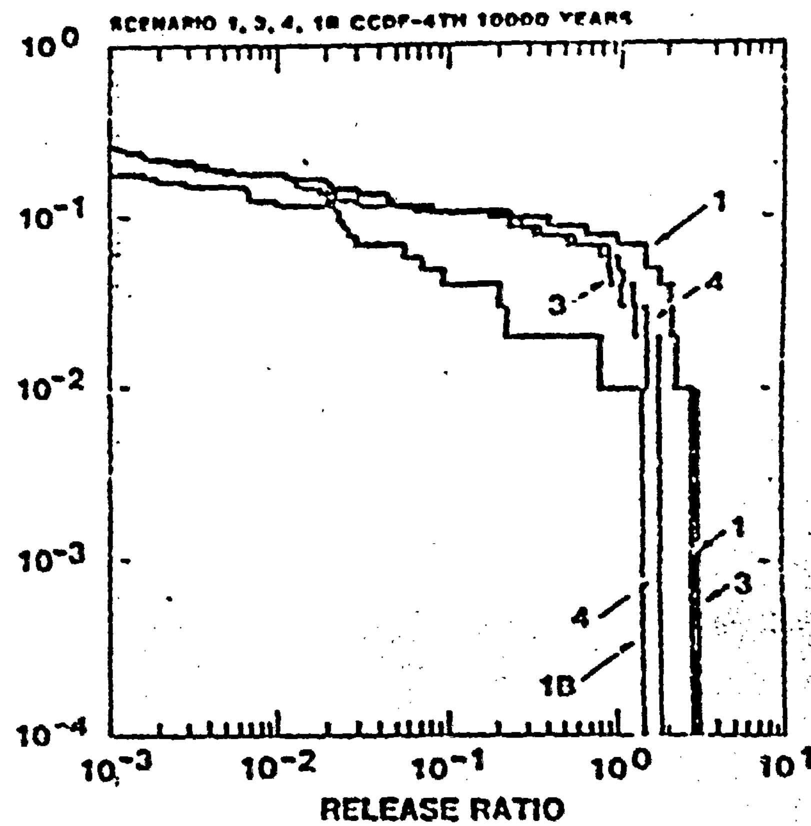


Figure 8.d

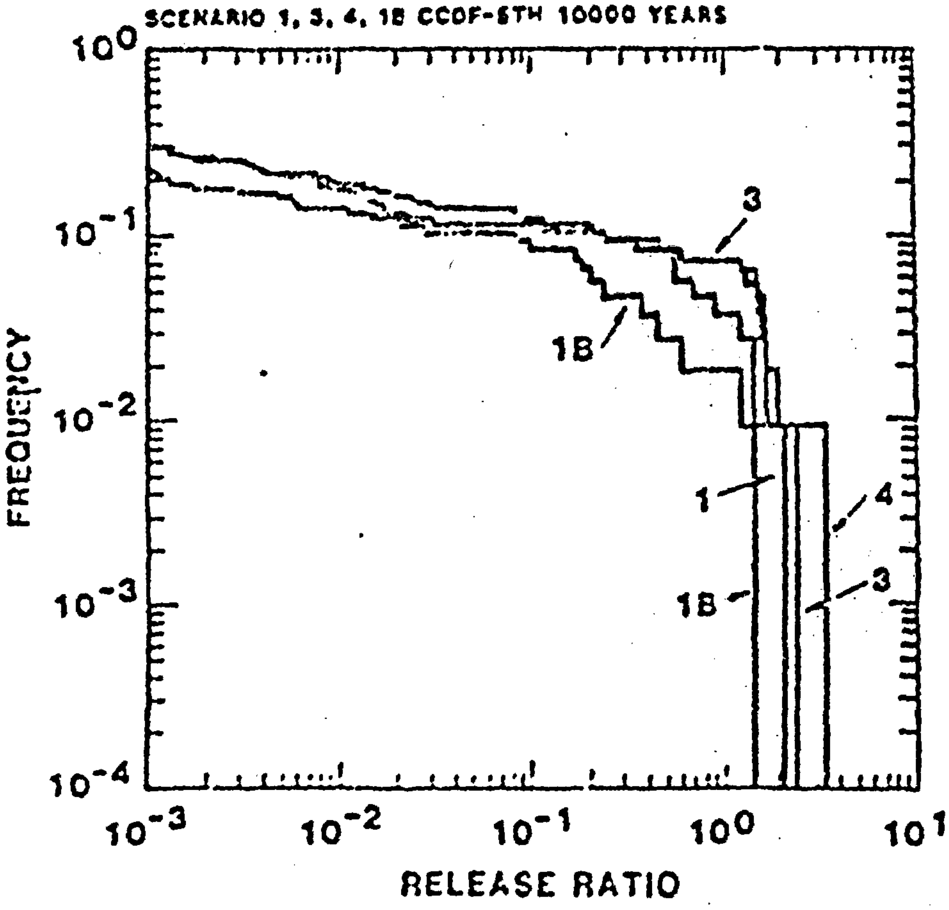

SCENARIO 1, 3, 4, 1B CCDF-5TH 10000 YEARS
FREQUENCY
RELEASE RATIO
3
1B
1
4
1B
3

Figure 8.c

Table 7

NUMBER OF VIOLATING VECTORS, MAXIMUM OF RELEASE RATIOS AND SUM OF RELEASE RATIOS OVER ALL VECTORS FOR EACH 10,000 YEAR PERIOD

Scenario	0-10,000yr	10,000-20,000yr	20,000-30,000yr	30,000-40,000yr	40,000-50,000yr
1	1*	4	7	8	4
	2.4**	5.9	3.1	2.9	2.0
	2.5***	12.1	16.5	17.0	10.7
3	1	1	1	4	8
	1.9	6.2	1.4	3.1	2.3
	2.2	10.2	4.8	12.0	14.4
4	1	1	1	6	8
	1.9	6.1	1.4	1.5	3.4
	2.1	10.1	4.6	10.6	15.6
18	1	1	2	1	2
	1.7	3.9	2.2	1.5	1.5
	1.8	5.7	5.0	3.1	5.2

* number of violating vectors out of 106 vectors analyzed

** maximum release ratio

*** sum of release ratios for all 106 vectors

Table 8

PROPERTIES OF VECTORS WHICH VIOLATE EPA STANDARD
IN SCENARIO 1B

VECTOR	3	24	51
PARAMETER			
Maximum R* for Tc	10827	7570	14364
Average vertical Darcy velocity (ft/yr)	0.32	0.13	0.41
Vertical hydraulic gradient	0.04	0.03	0.03
Average horizontal Darcy velocity (ft/yr)	0.17	0.88	0.36
Horizontal hydraulic gradient	0.02	0.08	0.02
Total ground-water travel time (yr)	10197	3781	6069
Discharge** (ft^3/yr)	2.7×10^7	1.1×10^7	3.6×10^7
Maximum release ratio***	1.2	3.9	1.5

*R = retardation factor
**annual recharge of regional ground-water system is approximately 5×10^8 ft^3/yr.
***maximum during 50,000 year period

5.5 Scenario 5: Effect of Changes in the Water Table

In scenario 5, the water table has risen 300 feet during a pluvial period and is located in the densely welded tuff of layer H. Radionuclides migrate from the repository to this layer under the influence of the vertical hydraulic gradient (Figure 9). The zeolitized tuff of layer G is not a barrier to horizontal radionuclide migration in this scenario. In this calculation we have assumed that no retardation occurs in layer H. Ground water and dissolved radionuclides are pumped from the aquifer from a well located one mile from the repository. In all other respects, this scenario is equivalent to scenario 1.

Scenario 5B (Figure 10) differs from scenario 5 by the inclusion of matrix diffusion in calculations of radionuclide retardation in the moderately and densely welded layers A, C, E, F, and H. As in scenario 1B, retardation by matrix diffusion was considered only for ^{129}I, ^{99}Tc, and ^{14}C.

Results

The results of the calculations for scenario 5 are presented in Figures 11A-11E and in Table 9. It can be seen that the lack of retardation in the horizontal transport leg has resulted in discharges that are much larger than those calculated for scenario 1. Violation of the EPA Release limit results from discharges of ^{236}U, ^{233}U, ^{238}U, ^{234}U, ^{237}Np, ^{99}Tc, and ^{14}C. In the first 10,000 year period, violations are due primarily to releases of ^{99}Tc and ^{14}C. After 30,000 years, releases of other radionuclides comprise the major part of the discharge.

Results from scenario 5B are summarized in Figures 11A-11E and in Table 9. Matrix diffusion decreases the discharges of ^{99}Tc and ^{14}C to levels below the EPA release limit during the first 10,000 years. After 20,000 years, the release of ^{236}U, ^{237}Np, ^{233}U, ^{238}U, and ^{234}U may exceed the EPA Standard.

The properties of the vectors which violate the EPA Standard in scenario 5B are described in Table 10. The large radionuclide releases associated with vectors 3, 24, and 51 are due to their large ground-water discharge rates and short travel times. In vectors 72 and 85, the high horizontal Darcy velocity is indicative of the short travel time associated with the horizontal legs (0.03-0.6 yr). Although the retardation factors

SCENARIO 5

1 mile well; moderate - fractured; thermal buoyancy; pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - no retardation	
2	B	nonwelded - porous - zeolites	200
3	C	dense - no retardation	300
4	D	nonwelded - porous - zeolites	250
5	E	moderate - no retardation	150
6	F	moderate - no retardation	180
7	G	nonwelded - porous - zeolites	270
8	H	dense - no retardation	475
			5280

FLOW PATH

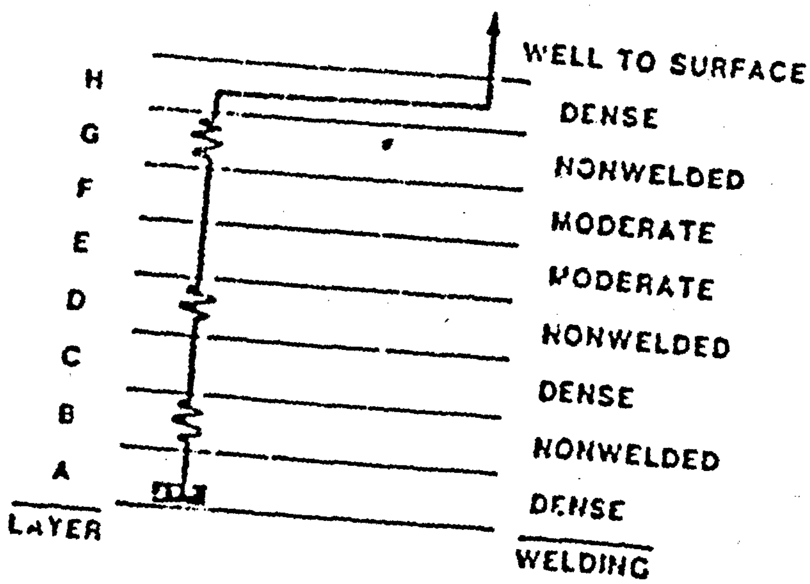


Figure 9

SCENARIO 5B

1 mile well: matrix diffusion, thermal buoyancy: pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - matrix diffusion	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - matrix diffusion	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - matrix diffusion	180
6	F	moderate - matrix diffusion	270
7	G	nonwelded - porous - zeolites	475
8	H	dense - matrix diffusion	5280

FLOW PATH

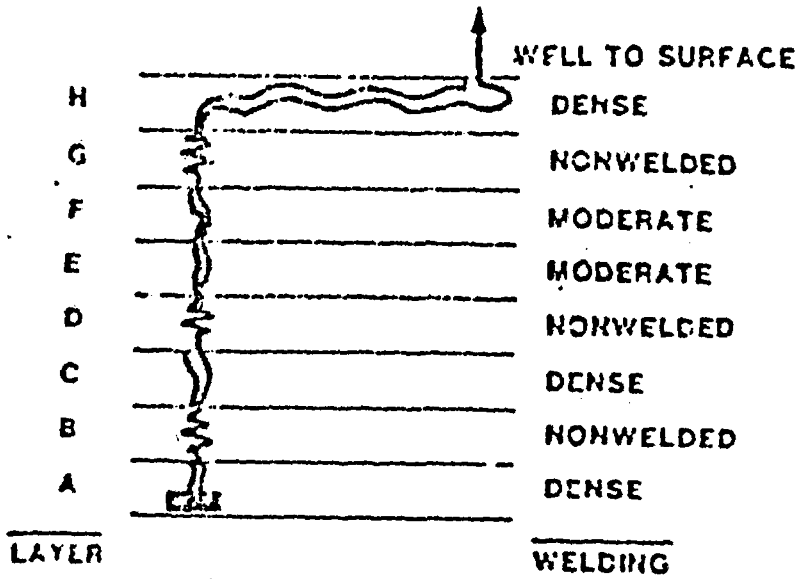


Figure 10

Table 9

NUMBER OF VIOLATING VECTORS, MAXIMUM OF RELEASE RATIOS AND SUM OF RELEASE RATIOS OVER ALL VECTORS FOR EACH 10,000 YEAR PERIOD

Scenario	0-10,000yr	10,000-20,000yr	20,000-30,000yr	30,000-40,000yr	40,000-50,000yr
5	3* 7.9** 13.4***	6 6.2 29.6	11 20.9 54.2	14 43.7 102.1	16 54.0 178.8
5B	0 0.90 1.1	1 2.1 5.9	3 19.3 28.8	4 42.1 75.9	4 53.4 153.0
6	0 0.1 0.1	1 1.5 2.5	1 1.6 3.7	4 4.4 12.5	3 2.2 7.6
2	11 207 667	14 85 392	19 87 461	20 57 424	19 55 434
2B	8 22 62	10 24 114	16 21 116	17 20 123	19 21 130

* number of violating vectors out of 106 vectors analyzed

** maximum release ratio

*** sum of release ratios for all 106 vectors

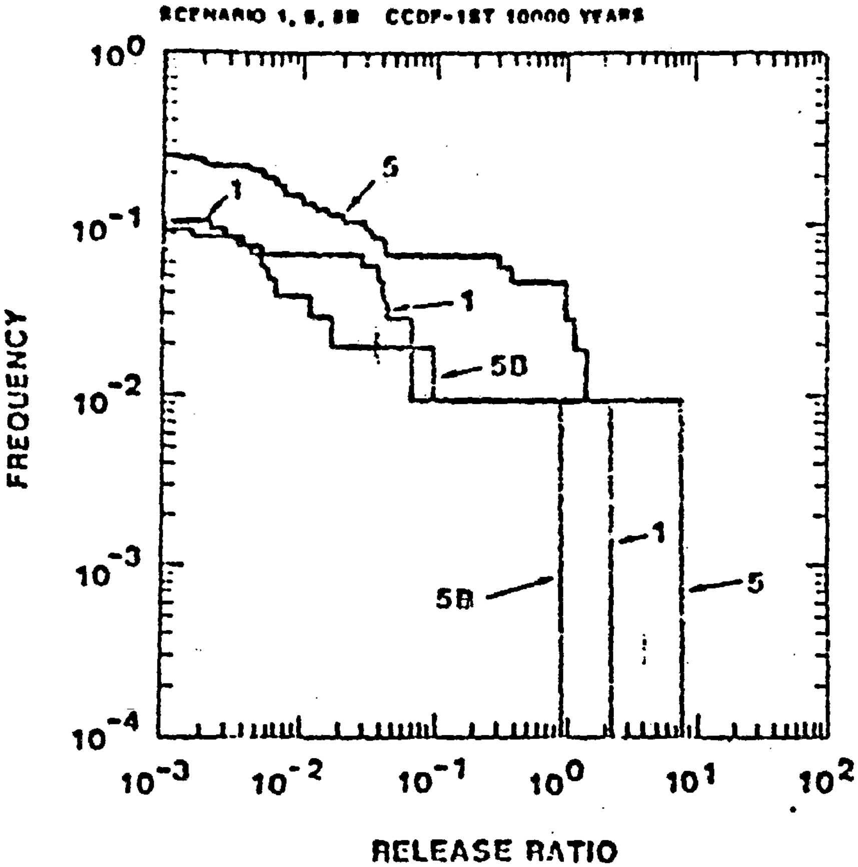


Figure 11.a

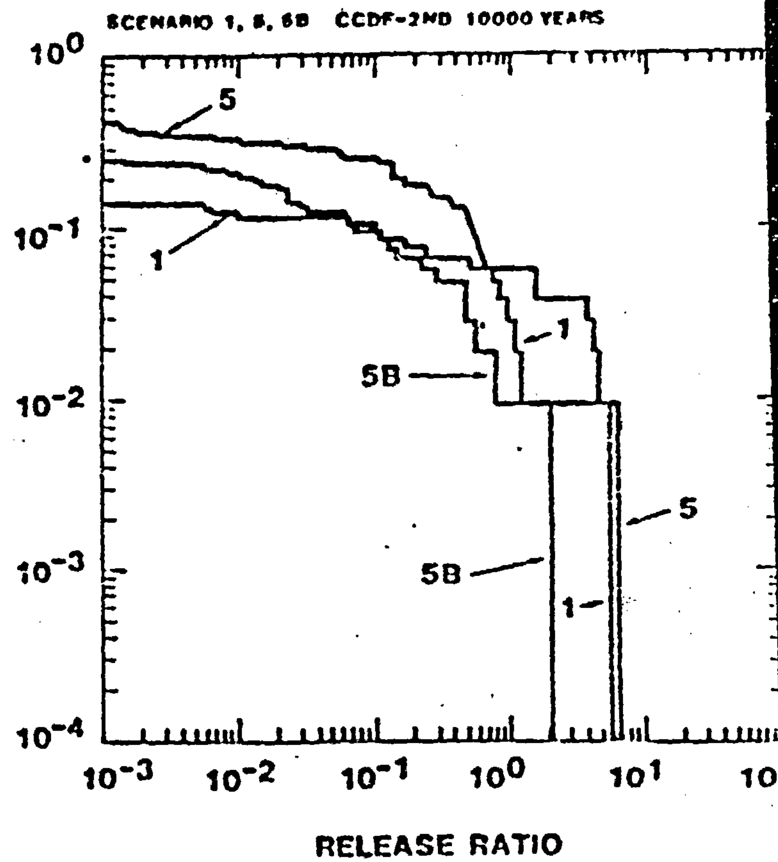


Figure 11.b

Figure 11. Complementary Cumulative Distribution Functions for Scenarios 1, 5 and 5B: Effects of Changes in the Water Table on Discharge.

1 = base case; 5 = water table rise; 5B = water table rise with matrix diffusion.

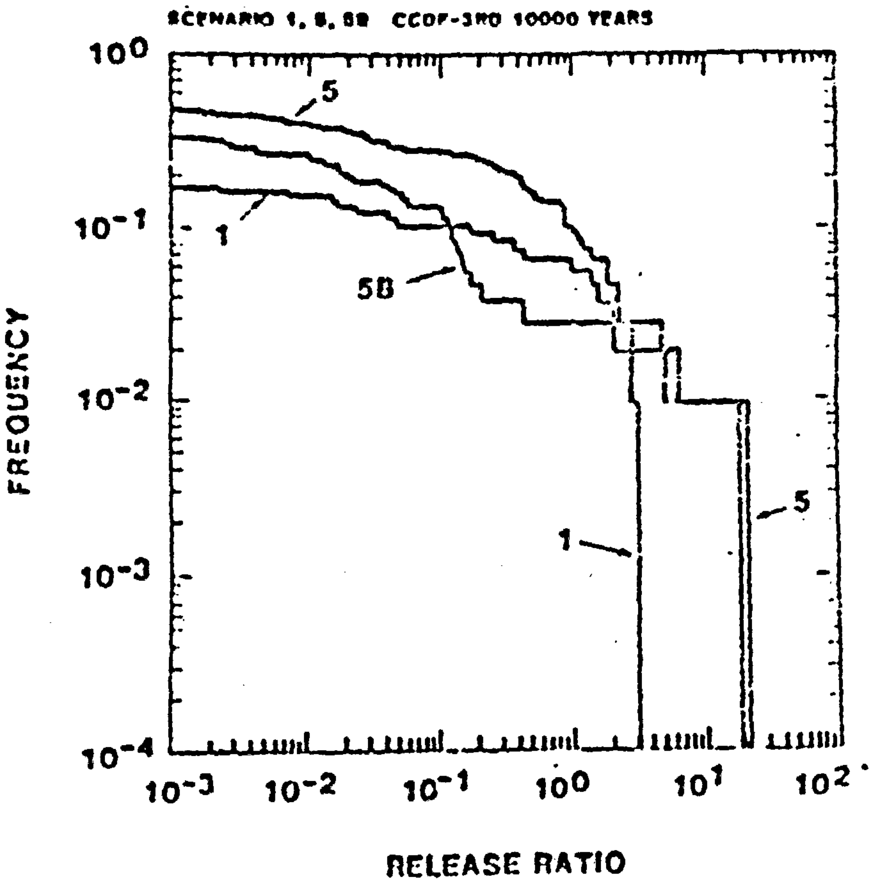


Figure 11.c

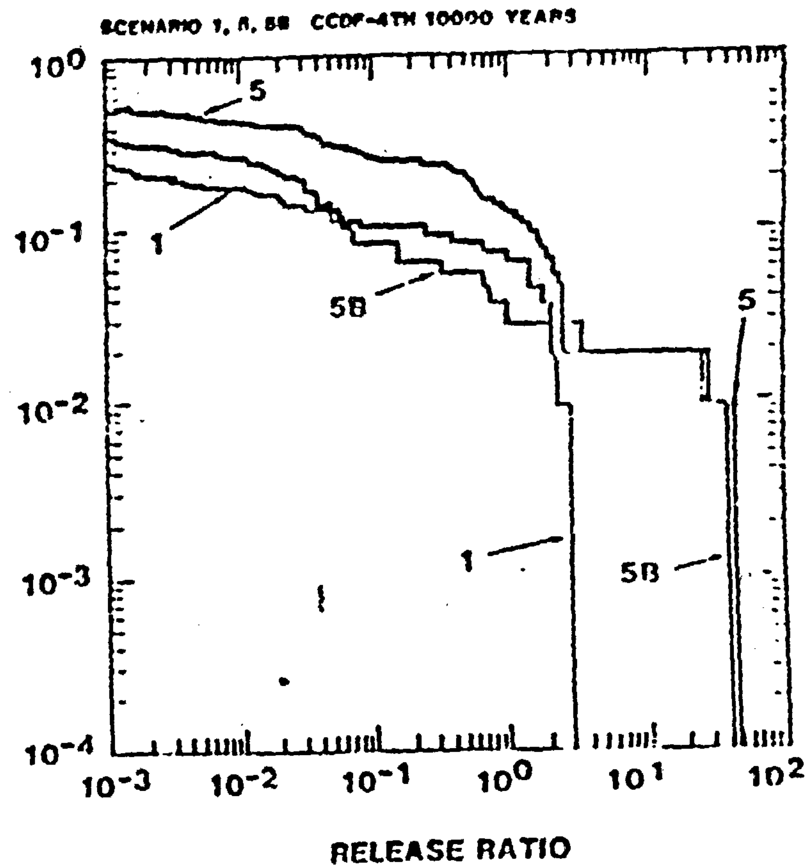
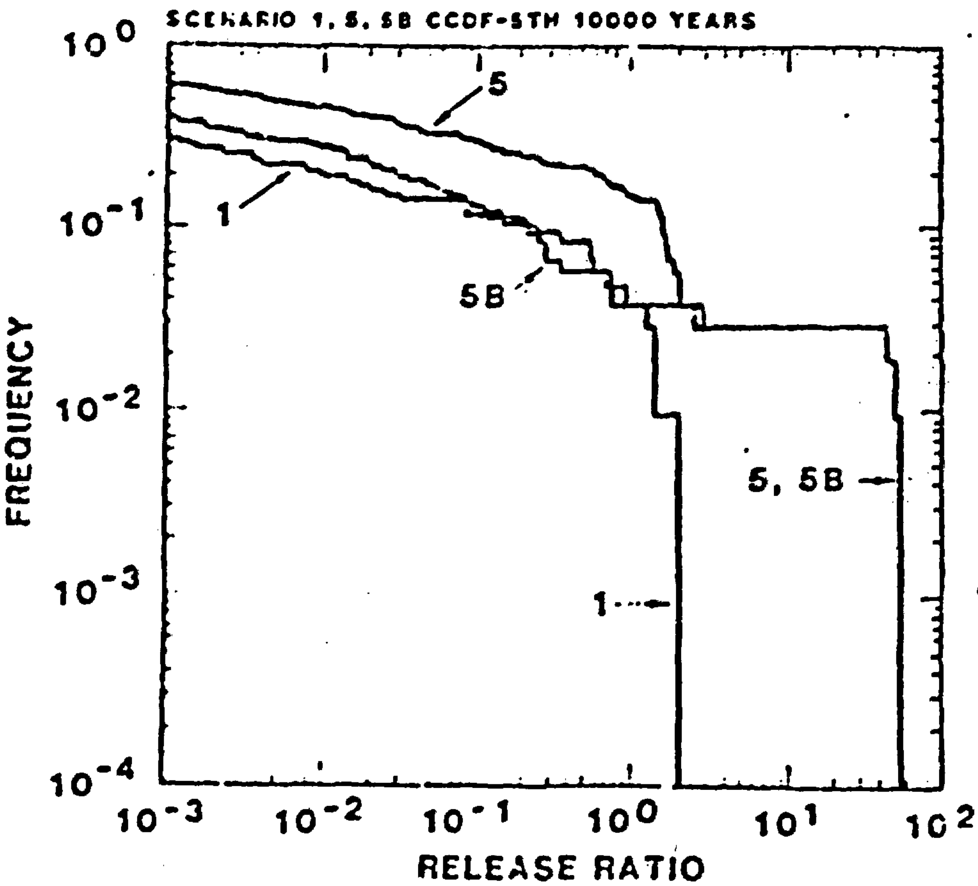


Figure 11.d



SCENARIO 1, 5, 5B CCDF-STH 10000 YEARS
5
1
5B
5, 5B
1
FREQUENCY
RELEASE RATIO
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

Figure II.e

Table 10

PROPERTIES OF VECTORS WHICH VIOLATE EPA STANDARD
IN SCENARIO 5B

VECTOR	3	24	51	72	85
PARAMETER					
Maximum R for U	32	77	23	47	35
Maximum R for Np	41	37	39	52	68
Maximum R for Tc	10827	20063	26659	13866	14888
Average vertical Darcy velocity (ft/yr)	0.3	0.16	0.43	0.04	0.07
Vertical gradient	0.04	0.03	0.03	0.03	0.04
Average horizontal Darcy velocity (ft/yr)	0.03	0.002	$2x10^{-4}$	1.5	169
Horizontal gradient	0.02	0.08	0.02	0.02	0.03
Total ground-water travel time (yr)	1024	2585	2203	7877	4939
Discharge (ft^3/yr)	$2.7x10^7$	$1.4x10^7$	$3.8x10^7$	$3.5x10^6$	$6.1x10^7$
Maximum release ratios					
U234	16	26	19	0	0
Np237	8.7	$7x10^{-5}$	12	0	0
Tc99	0	0	0	2.6	3.5
TOTAL	44.4	48.7	53.4	2.6	3.5

for Tc in leg 8 are high for these vectors (5076 and 2569 respectively), the high Darcy velocity indicates that this leg is not a barrier to migration of this radionuclide.

6.4 Scenario 6: Accessible environment at eight miles

At the hypothetical repository site, the water table passes from the nonwelded zeolitized aquitard (layer G) into the overlying densely welded aquifer (layer H) at a distance of approximately two miles from the depository. In scenario 6, we have postulated that a well eight miles from the repository withdraws ground water and radionuclides from this aquifer. This scenario differs from scenario 1 by the additional one mile transport in the nonwelded unit and by six miles of transport in the densely welded tuff layer. No retardation occurs in the densely welded layer.

Results

The results of the calculation are presented in Figures 13A-13E and in Table 9. It can be seen that the additional seven miles of travel through layers G and H reduce the discharge during the first 10,000 years to levels below the EPA release limit. Discharges of the unretarded radionuclides ^{99}Tc and ^{14}C in vectors 12, 76, 77, and 105, however, exceed the EPA limit after 10,000 years. Due to time constraints, the effect of matrix diffusion on discharge was not calculated for the flow path of scenario 6. It was shown previously in scenario 1E that matrix diffusion in 900 feet of welded tuff decreased the discharge of ^{99}Tc and ^{14}C for the above vectors below the EPA Standard. It can be assumed, therefore, that matrix diffusion would eliminate all violations of the EPA Standard for a flow path similar to scenario 6.

SCENARIO 6

8 mile well; moderate = fractured; thermal buoyancy; no pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - no retardation	200
2	B	nonwelded - porous - zeolites	300
3	C	dense - no retardation	250
4	D	nonwelded - porous - zeolites	150
5	E	moderate - no retardation	180
6	F	moderate - no retardation	270
7	G	nonwelded - porous - zeolites	11000
8	H	dense - no retardation	31000

FLOW PATH

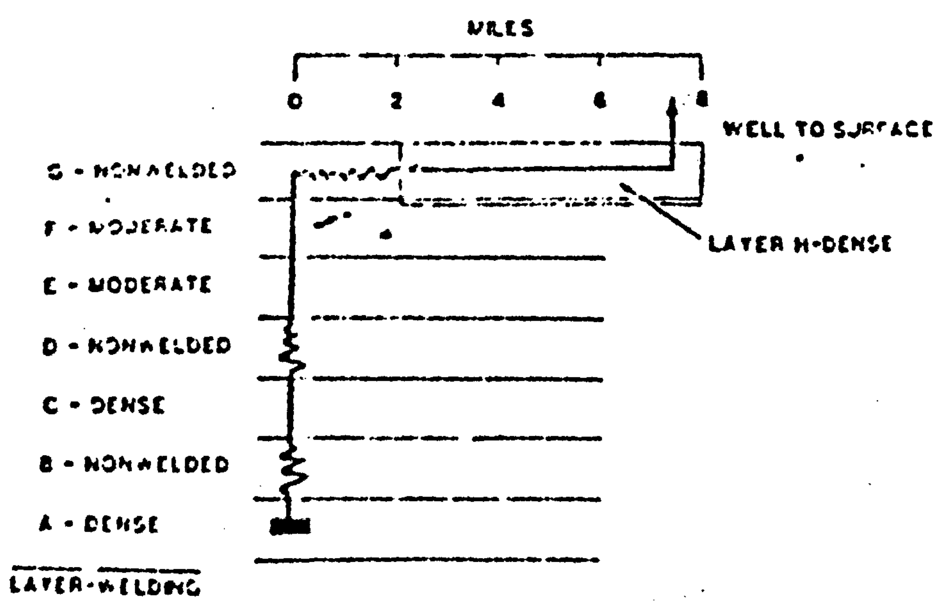


Figure 12

- 43 -

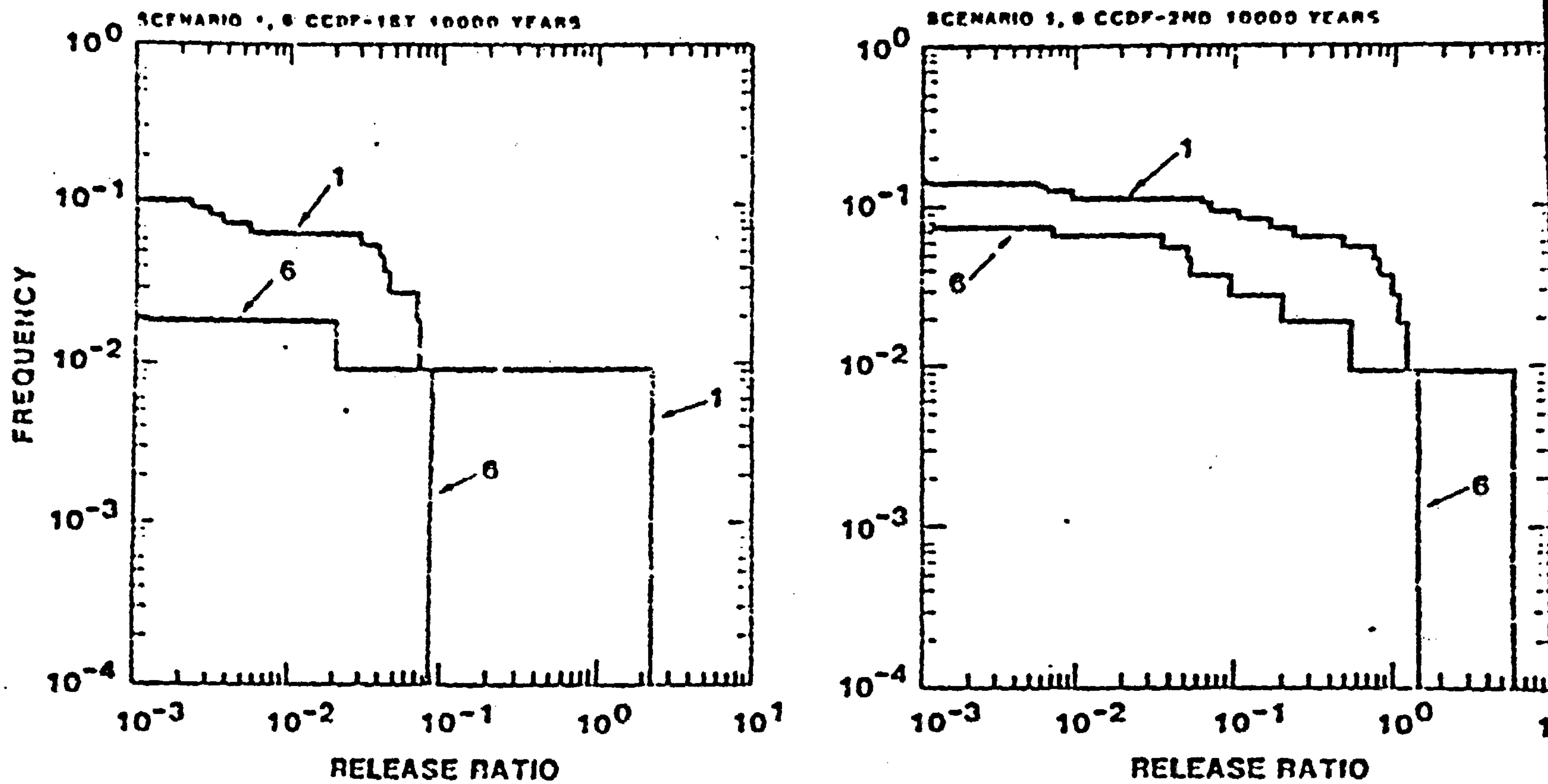


Figure 13.a

Figure 13.b

Figure 13. Complementary Cumulative Distribution Functions for Scenarios 1 and 6: Accessible environment at eight miles.

1 = base case; 6 = 8 miles

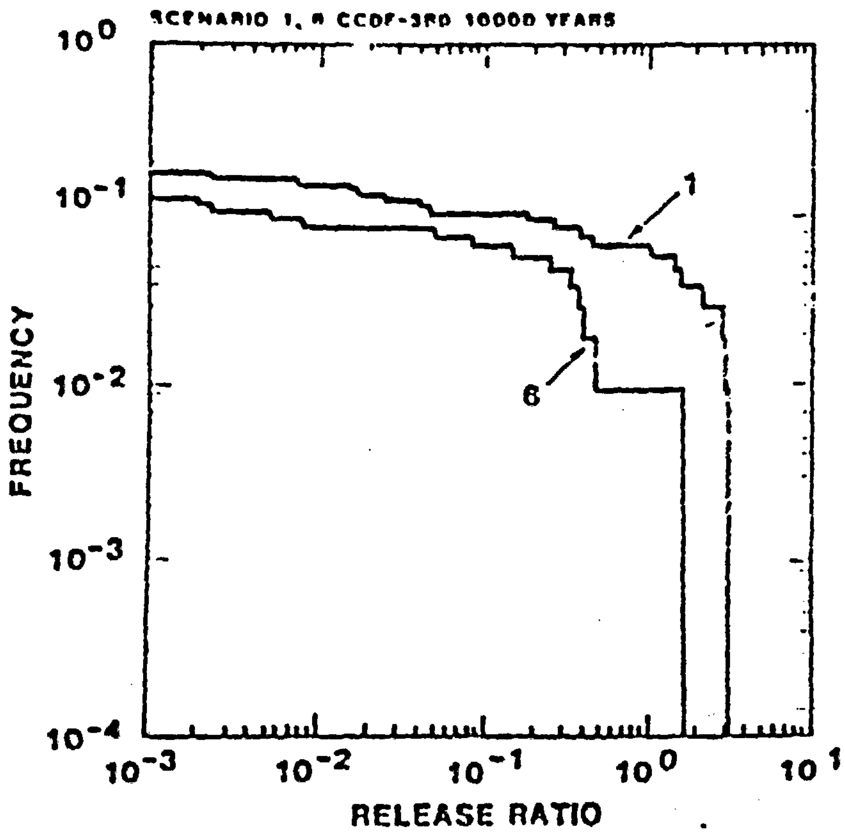


Figure 13.c

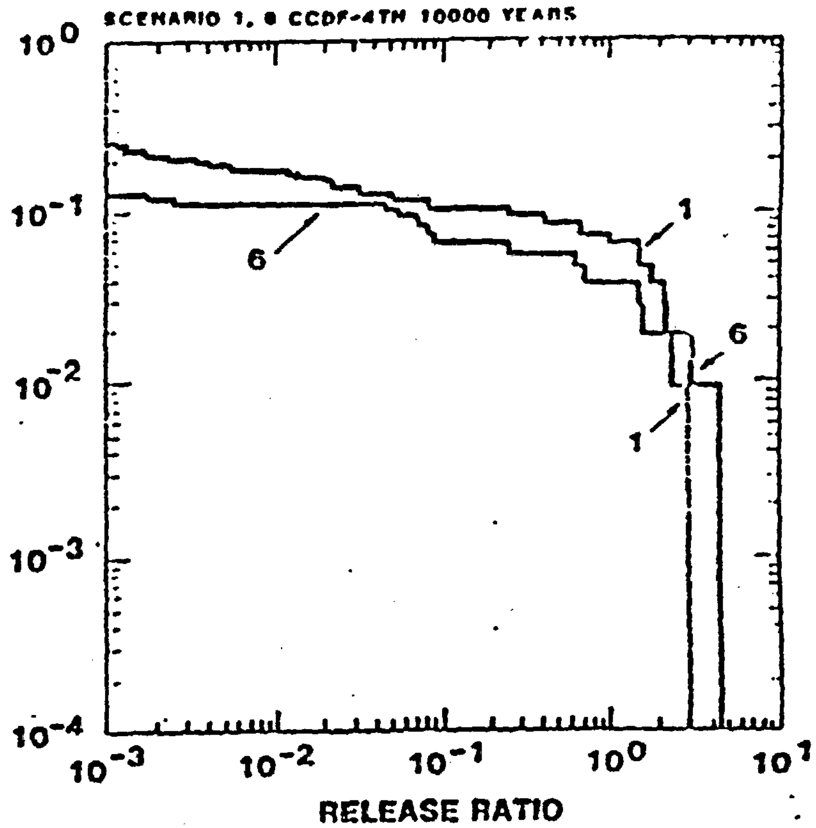


Figure 13.d

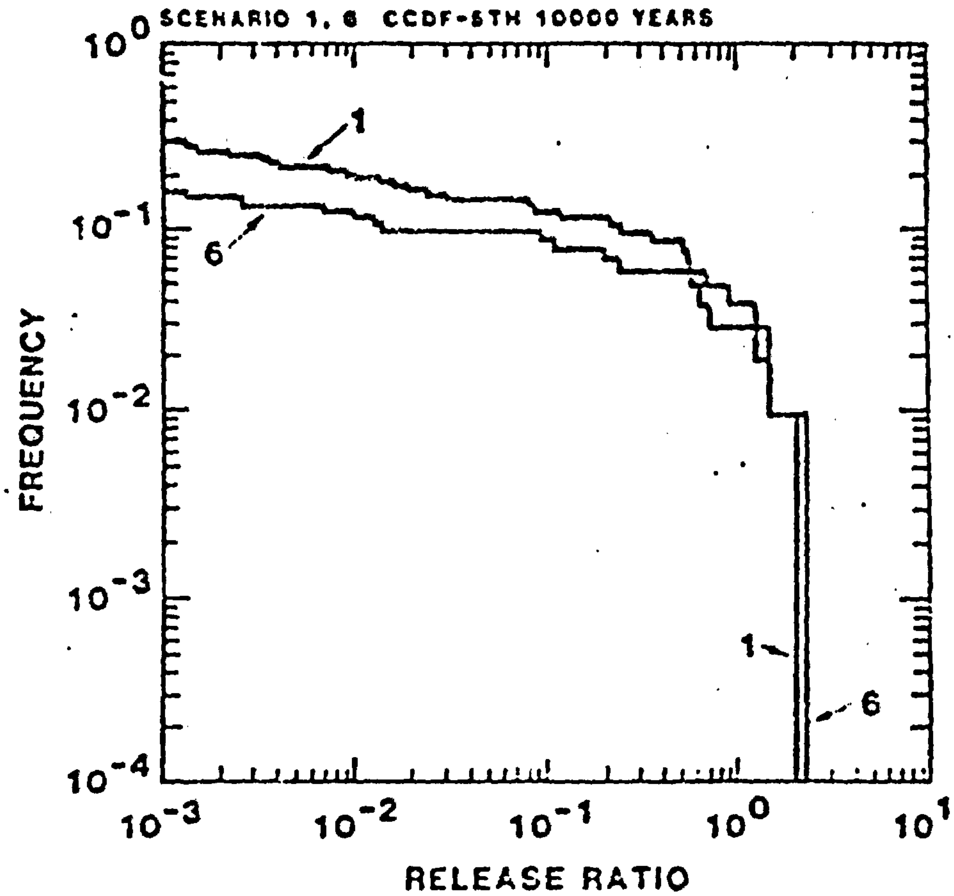

SCENARIO 1, 6 CCDF-5TH 10000 YEARS
FREQUENCY
RELEASE RATIO
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
1
6
1
6

Figure 13.e

6.5 Scenarios 2 and 2B: Importance of solubility limits to discharge

We consider scenario 2 (Figure 14) our "worst case" scenario. The source term is entirely leach-limited; the solubility limits of radionuclides are not specified. Ground water migrates laterally from the depository. Due to the block faulting and dip of the tuff units in the repository site, the lateral fluid flow path cuts across several stratigraphic layers. At a distance of one mile from the repository, water and radionuclides are pumped by a well that extends to a depth of 3,000 feet. Technetium, ^{129}I and ^{14}C are retarded by matrix diffusion in the densely welded layers A and C. Layer B is highly sorbent zeolitic tuff which retards the movement of the other isotopes. This scenario has a shorter path length and thinner sequence of zeolitized tuff than the other scenarios.

Scenario 2B differs from scenario 2 only in the calculation of the source term. We have used the mixing-cell option of NWFT/DVM for this scenario (17,23). For each time step, the mass of a radionuclide that is assumed leached from the waste form is compared to the maximum amount that is consistent with a user-specified solubility limit. The solubility limits are listed in Table 5 and are discussed in detail in section 4.3 and in Appendix B. The smaller of these two amounts of radionuclide is transported in that time step.

Results

Results of calculations for scenarios 2 and 2B are summarized in Figures 15A-15E and in Table 9. Discharges in scenario 2 are the highest calculated in this study and lead to large violations of the EPA Standard. During the first 10,000 years, releases of ^{234}U, ^{237}Np, ^{238}U and ^{236}U account for 94 percent of the sum of the EPA release ratios. During the fifth 10,000 year interval they continue to dominate discharge and account for 85 percent of the violation of the EPA Standard. The importance of solubility limits in controlling discharge in scenario 2B can be seen in the figures and table. The sum of the release ratios for all uranium species is reduced by an order of magnitude and Np discharge is decreased by a factor of 30 for the first 10,000 year interval. Discharges of these radionuclides, however, still are in excess of the EPA standard. The solubilities that were assumed for uranium and neptunium were based on experimental studies under oxic conditions. They are upper bounds for the solubilities; under reducing conditions the solubilities of U and Np are several orders of magnitude lower. We feel that the transport of

SCENARIOS 2 and 2B

1 mile borehole; matrix diffusion;
no thermal buoyancy or pluvial

LEG	LAYERS	WELDING - RETARDATION	LENGTH (ft)
1	A	dense - matrix diffusion	2600
2	B	nonwelded - zeolitized	300
3	C	dense - matrix diffusion	2600

FLOW PATH

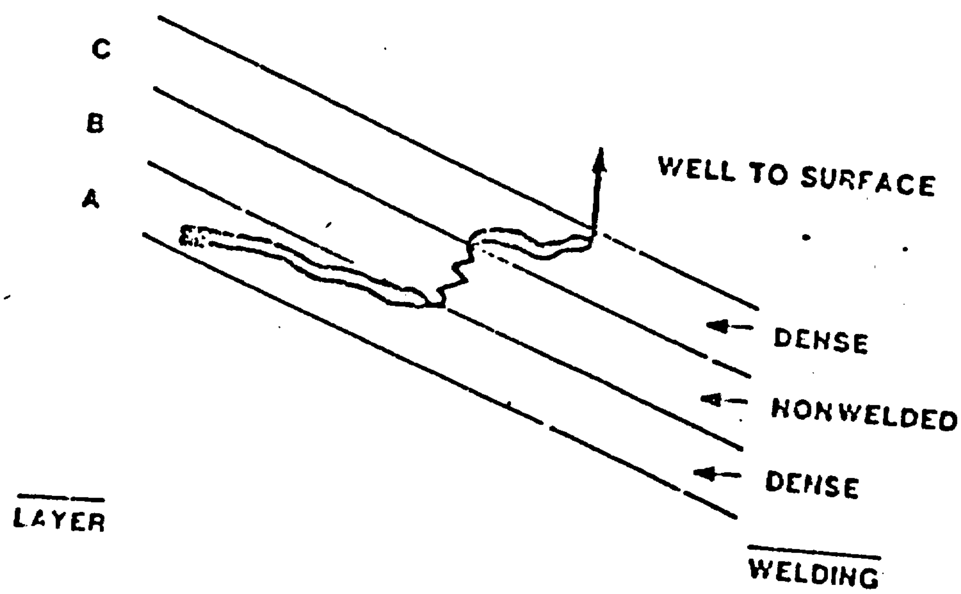


Figure 14

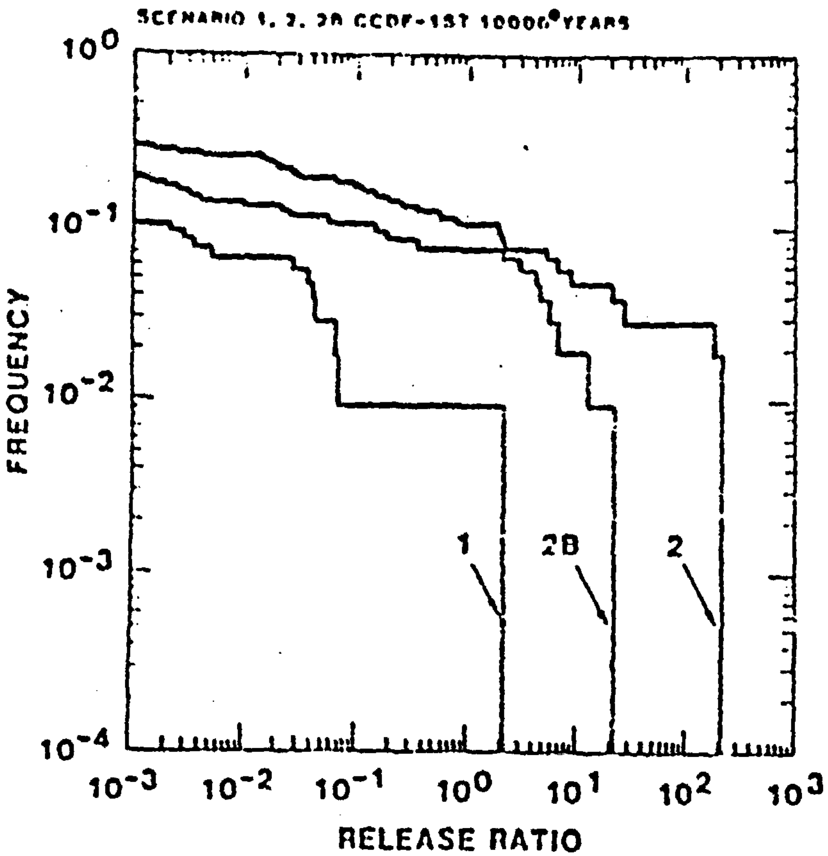


Figure 15.a

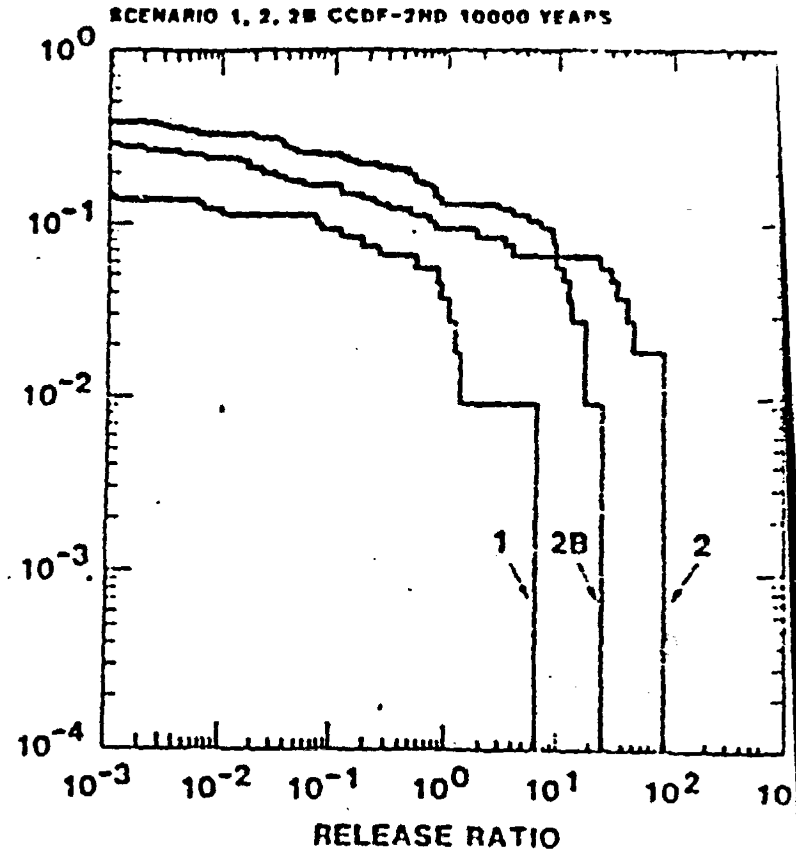


Figure 15.b

Figure 15. Cumulative Complementary Distribution Functions for Scenarios 1, 2 and 2B: Importance of Solubility Limits to Discharge.

1 = base case; 2 = leach-limited; 2B = solubility-limited

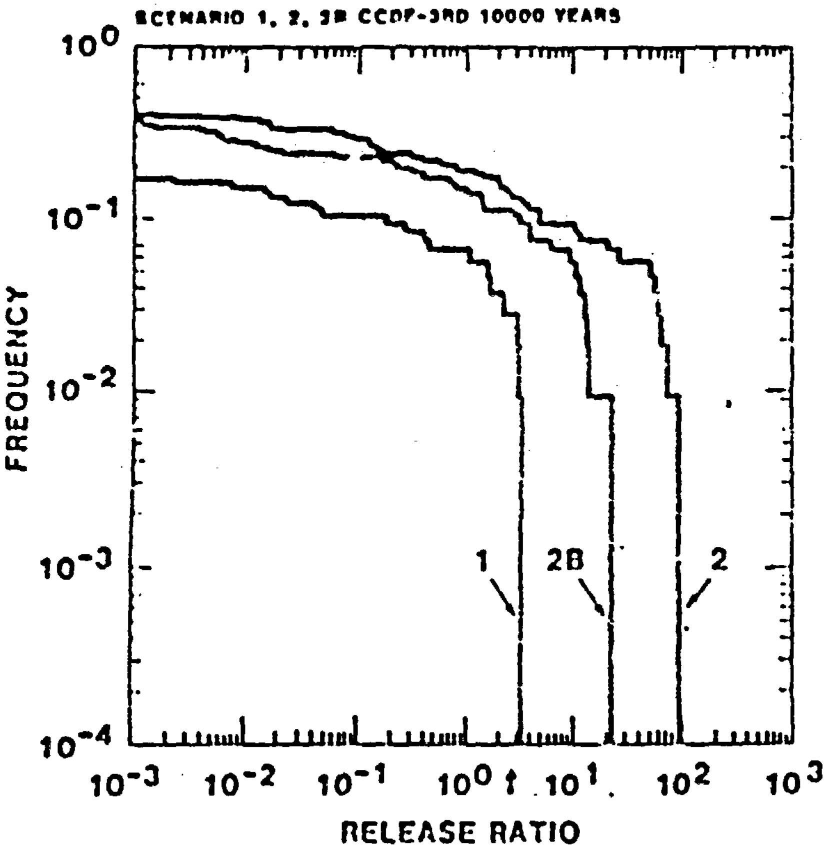


Figure 15.c

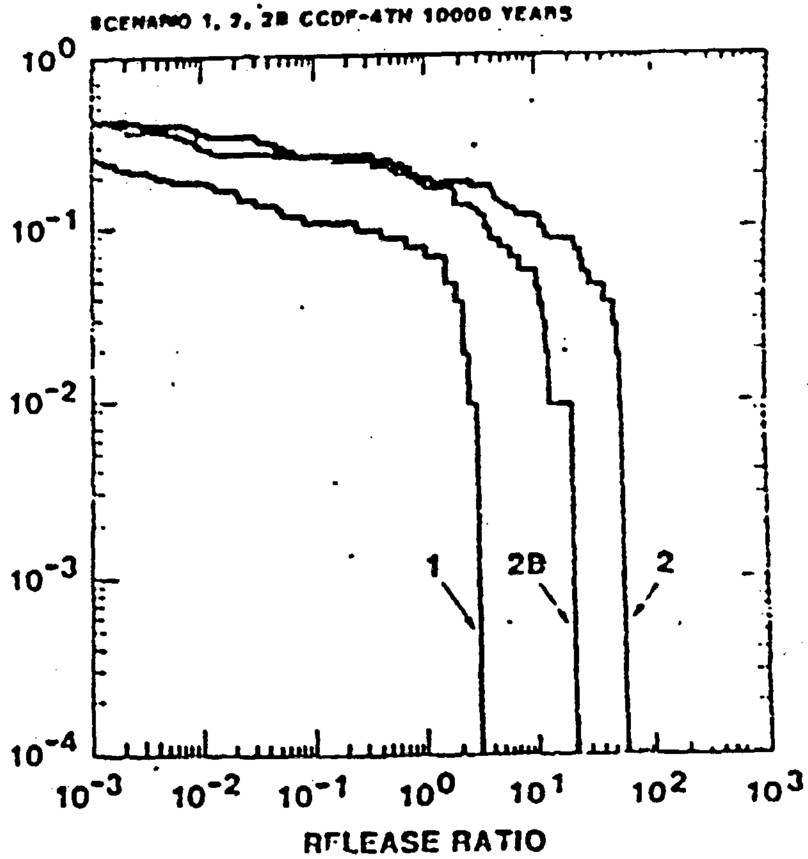


Figure 15.d

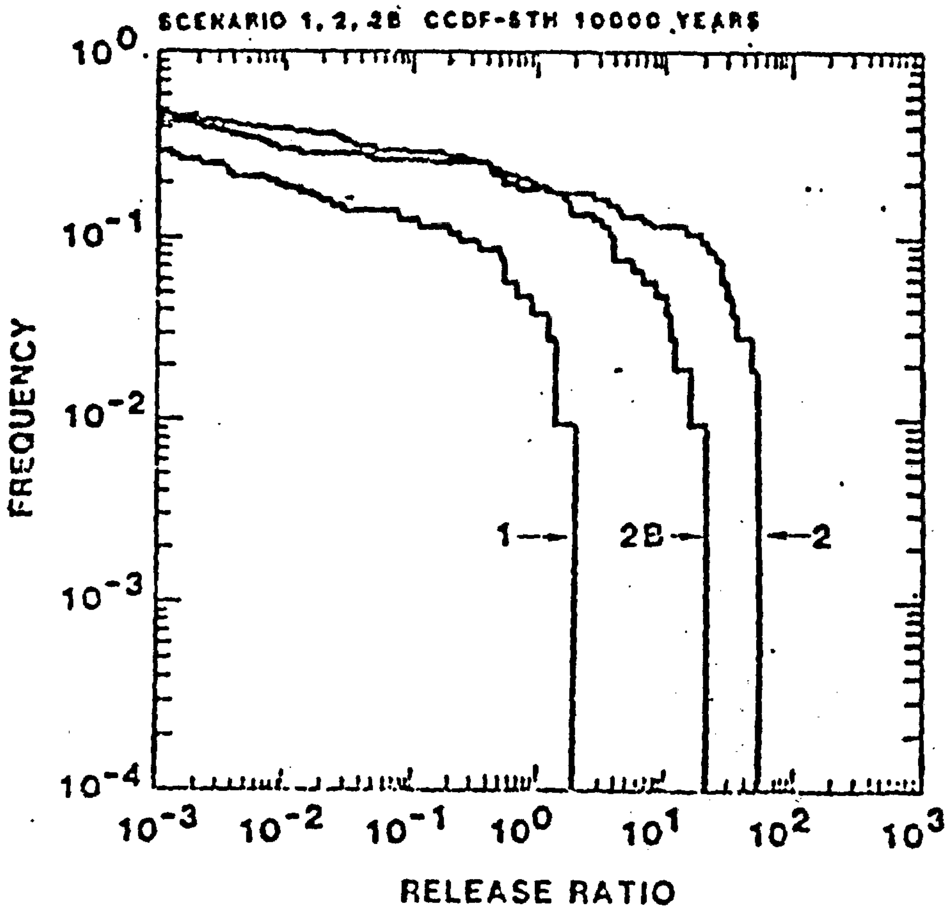

SCENARIO 1, 2, 2B CCDF-5TH 10000 YEARS
FREQUENCY
RELEASE RATIO
1
2B
2
10^0
10^-1
10^-2
10^-3
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3

Figure 15.e

radionuclides along the flow path described in scenarios 2 and 2B is less likely than transport as described in the other scenarios. The calculated violations of the EPA Standard, therefore, should not be interpreted as an indication that releases from a repository in tuff are likely.

7. CONCLUSIONS AND RECOMMENDATIONS

Estimates of potential radionuclide releases from HLW storage facilities in geologic formations are an integral part of the technical basis for the regulation of nuclear waste disposal. At present, the available data is insufficient to accurately model any real repository sites. Large uncertainties exist in the characterization of the solubilities and sorption of radionuclides, in the description of the regional and local hydrogeology and in the mathematical treatment of contaminant transport in the presence of fracture flow and matrix diffusion. We feel, however, that it is possible to place realistic upper limits on radionuclide discharge for a generic hypothetical tuff repository. We have also attempted to assess the importance of the variation of several variables and model assumptions to the calculations of radionuclide release from a repository in the saturated zone of a volcanic tuff site.

Our calculations suggest the following conclusions for the hypothetical tuff repository described in this paper:

1) Sorption of radionuclides by several thousand feet of zeolitized tuff may limit the release of actinides below the EPA release limits even in the absence of solubility constraints.

2) All violations of the EPA Draft Standard in the "base case" are due to discharges of ^{99}Tc and ^{14}C. Retardation due to matrix diffusion, however, could eliminate discharge of these nuclides under realistic ground-water flow rates.

3) If the radionuclides do not flow through thick sequences of zeolitized tuff, discharges of U and Np under oxidizing conditions may be much larger than the EPA limits. Under reducing conditions, however, the low solubilities of these elements may reduce their discharges to levels below the EPA limit.

4) The radionuclide release limits set by Draft 19 of the EPA Standard are probably achievable for a repository site similar to the hypothetical site described in this report. The majority of the vectors examined in all scenarios produced radionuclide releases below the limits set by the draft standard. In general, violations of the standard occurred only when the most conservative assumptions were used or when combinations of input data produced ground-water flow rates that were unrealistically high.

We feel that the following topics merit further investigation by the NRC:

1) Detailed calculations of limiting solubilities of uranium, neptunium and radium under geochemical conditions expected at the tuff site.

2) Calculations of the potential retardation of actinides due to matrix diffusion in welded tuff.

3) Calculations of the sensitivity of radionuclide discharges to assumptions about radionuclide speciation.

4) A study of the frequency of oil and water drilling and mineral exploration in areas like Yucca Mountain. All of the scenarios examined in this involve human intrusion. A study of the probability of such activities in areas like Yucca Mountain would yield valuable insights about the safety of such a repository site.

APPENDIX A

HYDROGEOLOGICAL MODEL OF THE HYPOTHETICAL TUFF REPOSITORY SITE AND ITS RELATIONSHIP TO DATA FROM THE NEVADA TEST SITE

A major objective in the program of simplified repository analyses performed at Sandia is the definition of a hypothetical site which exhibits hydrogeological characteristics which might be found at real potential repository sites. We have defined our reference tuff site to be consistent with available hydrogeologic data from the Nevada Test Site. Where certain data are not available from the real site, we have postulated properties that are physically reasonable for the reference site. We have not attempted to accurately represent the Nevada Test Site in our analyses; instead we have modeled a hypothetical site which is internally self-consistent.

A.1 Physical properties of welded tuff

The tuff units at the reference tuff repository are described as densely welded, moderately welded or nonwelded. Densely welded tuff units are highly fractured; the blocks between fractures have low interstitial matrix porosity. Nonwelded tuff units have few fractures but have a high matrix porosity. This dual porosity of the rock must be considered when modeling fluid flow. We have used data from the UE25a-1 drill core [illegible] to obtain reasonable values of fracture density, aperture width and orientation in the tuff units (1,2). The maximum, minimum and median of the range of values of these parameters for different tuff lithologies are shown in Table A-1.

We have represented the fracture system as two sets of perpendicular vertical fractures. Values of horizontal fracture porosity (ϕ_h) are calculated by

$$\phi_h = N_o W / \sin(90° - \theta)$$

where N_o is the observed fracture density in the core, [illegible] of the average inclination of the fractures [illegible] and W is the fracture aperture width [illegible]. Horizontal hydraulic [illegible] for a parallel array of planar fractures is given by [illegible]

$$[illegible]$$

ρ = density of water = 1.0 gm/cm^3
g = 9.81×10^2 cm/sec^2
μ = viscosity of water = 1.0 centipoise

In the assumed joint system, fluid flowing in the horizontal direction will effectively encounter only one set of fractures. Fluid flowing in the vertical direction will encounter both sets of fractures. For this reason, values of hydraulic conductivity and fracture porosity in the vertical direction are twice the horizontal values.

The hydraulic conductivity is very sensitive to changes in fracture aperture. In welded zones, the majority of fractures are 5-20 microns wide; the maximum observed width was 150 microns (1, 2). Fractures in nonwelded zones were generally filled with secondary minerals. For these units, aperture widths of 0-5 microns are probably realistic and were used to estimate the hydraulic properties in Table A-1. Results of calculations using a 150-micron aperture width are also shown in the table. Ranges of values presented for total porosity are taken from data in references 4 and 25.

In Figure A-1, the ranges of values of <u>matrix</u> hydraulic conductivity of unfractured cores of tuff measured in the laboratory are compared to the values calculated from fracture properties. The values are based on data compiled in references 4, 22, and 25. Values of the <u>bulk</u> hydraulic conductivity, as measured by actual pump tests at the Nevada Test Site, are also shown. Data obtained in these tests reflect contributions from fluid flow in both the fractures and the rock matrix between joints. It can be seen that flow in fractures may dominate the bulk hydraulic conductivity of densely welded tuffs, whereas fluid flow in the porous rock matrix dominates the properties of nonwelded units. Both fracture flow and porous flow are important for moderately welded tuffs. The insights gained from Figure A-1 were used to estimate reasonable ranges for effective porosity and hydraulic conductivity for the Latin Hypercube Sample Program (18). The data ranges and the shape of their distributions are tabulated in Table 2 of the main text. References for similar values in the literature are described in Table A-2. The shapes of the frequency distributions were estimated by comparing the median values to the upper and lower limits of the data ranges of the different types of hydraulic conductivity and porosity.

A.[illegible] <u>Vertical Hydraulic Gradient</u>

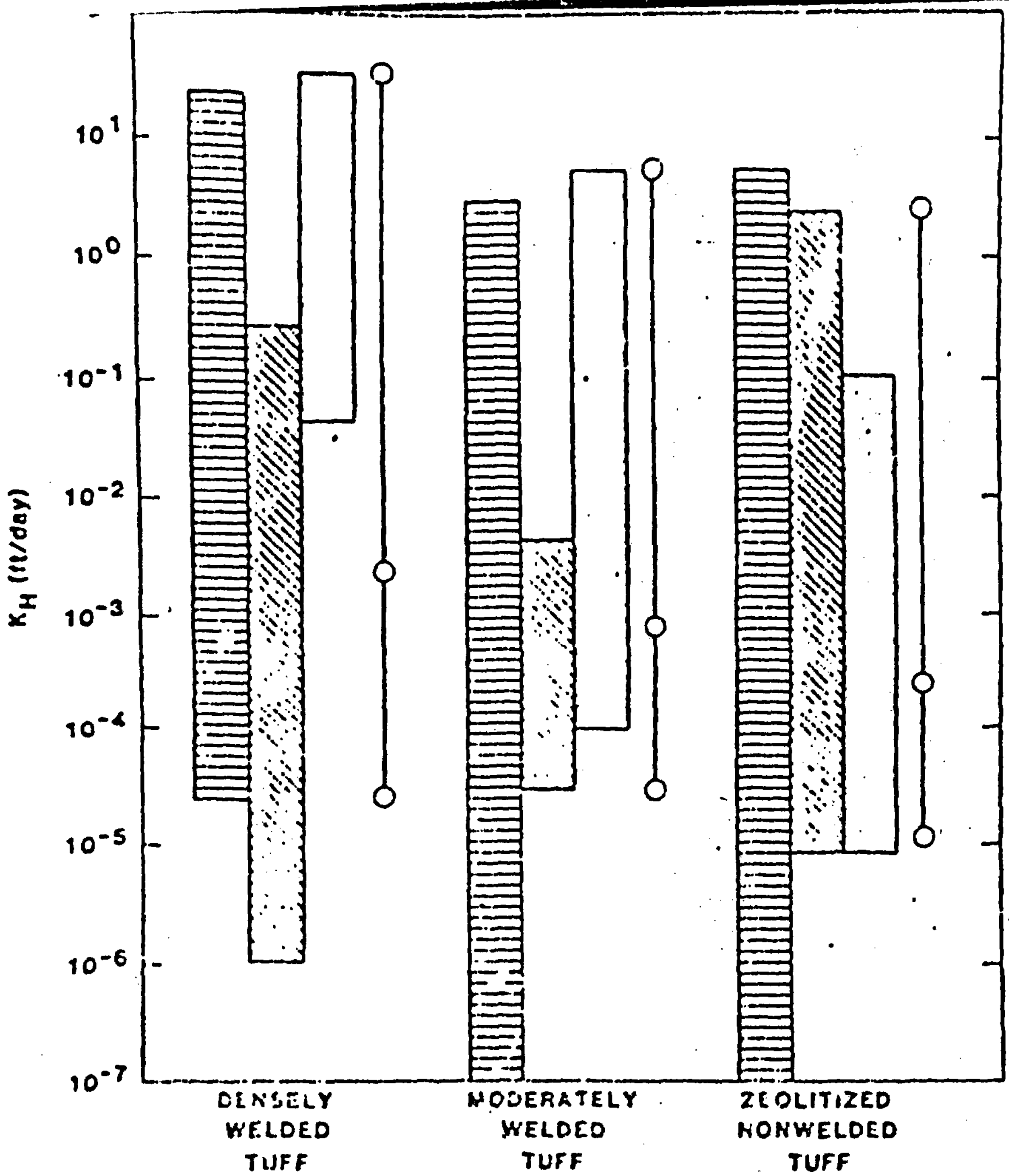
There are insufficient data in the open literature at present to estimate vertical hydraulic gradients at the Nevada Test

Table A-1

PROPERTIES OF FRACTURED TUFF

	Densely Welded Tuff	Moderately Welded Tuff	Nonwelded Tuff
*Fracture Aperture H (microns)			
min	5	5	0
median	12	12	5
max	150	150	5 (150)+
*Apparent Fracture Density $-N_a$ (ft^{-1})			
min	0.2	0	0
median	1.2	0.4	0.1
max	4.8	0.6	0.3
*Inclination of Fractures from Horizontal — θ	42°	45°	80°
Horizontal Fracture Porosity ϵ_h (%)			
min	4.4×10^{-4}	0	0
median	6.4×10^{-3}	2.2×10^{-3}	9.5×10^{-4}
max	0.32	0.06	2.8×10^{-3} (0.09)+
Horizontal Fracture Hydraulic Conductivity (K_H) - (ft/day)			
min	2.6×10^{-5}	0	0
median	2.1×10^{-3}	7.5×10^{-4}	5.5×10^{-5}
max	16.7	2.9	1.7×10^{-4} (4.5)+
Total Porosity (%)	3-10	10-38	20-50

*References (1, 2)
+Values corresponding to aperture width of 150 microns.



RANGES OF VALUES OF HYDRAULIC CONDUCTIVITY
DETERMINED BY DIFFERENT METHODS

FRACTURES MATRIX BULK MAX MEDIAN MIN VALUES USED IN CALCULATIONS AND LHS

Figure A-1

Table A 2

SOURCES OF DATA FOR RANGES* OF
HYDROGEOLOGIC PARAMETER VALUES

Parameter	Value	Similar Value From Literature	Reference	Comment
Hydraulic conductivity of densely welded tuff (ft/day)	2×10^{-5}		--	Calculated from data in Table A-1 in this report.
	30	19	22	Table 3 (Tiva Canyon)
Hydraulic conductivity of moderately welded tuff (ft/day)	3×10^{-5}	3×10^{-5}	22	Table 3 (Topopah Springs)
		1.4×10^{-5}	10	pp. 38 – 39
	5	2.9	--	Calculated from data in Table A-1 rounded up to value of 5
		2.1	22	Table 3 (Topopah Springs)
Hydraulic conductivity of nonwelded tuff (ft/day)	10^{-5}	1.7×10^{-5}	10	pp. 38 – 39
	2	2.3	25	Table A-1
Effective porosity of densely welded tuff (%)	4.4×10^{-4}	--	--	Calculated from data in Table A-1 in this report.
	0.32	--	--	Calculated from data in Table A-1 in this report.
Effective porosity of moderately welded tuff (%)	0.01	--	--	Maximum fracture porosity calculated from data in Table A-1 in this report for moderately welded tuff
	25	25	22	Table 3 (Tiva Canyon)

Table A 7 (Continued)

Effective porosity of nonwelded tuff (%)	20	19.8	A	Table 5, p. C45, minimum for zeolitized tuff
	48*	48.3	A	Table 5, p. C45, maximum for zeolitized tuff
Total porosity of densely welded tuff (%)	3	5	A	p. C32
	10	10	A	p. C32
Total porosity of moderately welded tuff (%)	10	10	A	p. C32
	38	35	A	p. C32
Total porosity of nonwelded tuff (%)	20	35	A	p. C32
	50	50	A	p. C32

*Ranges for Table 7. Values tabulated here are for hydraulic properties in the horizontal direction.

site with an acceptable degree of certainty. In our reference site, we have assumed that the vertical gradient in the vicinity of the repository will be dominated by a thermal bouyancy gradient related to the heat generated by the decay of the radioactive waste. The calculation of the thermal bouyancy gradient is described below.

Consider a cylindrical volume of fluid with length L and average temperature $\bar{T}$ immersed in a medium of average temperature $\bar{T}_o$ ($\bar{T} > \bar{T}_o$). (Figure A-2). The difference in temperature produces an upward force on the volume of fluid. The velocity of the fluid in the cylindrical volume can be described (26) by:

$$v \sim \alpha \Delta T K \qquad \text{(A-1)}$$

with

v = Darcy velocity of fluid

α = average coefficient of thermal expansion of fluid

$\Delta T = \bar{T} - \bar{T}_o$

K = hydraulic conductivity of medium

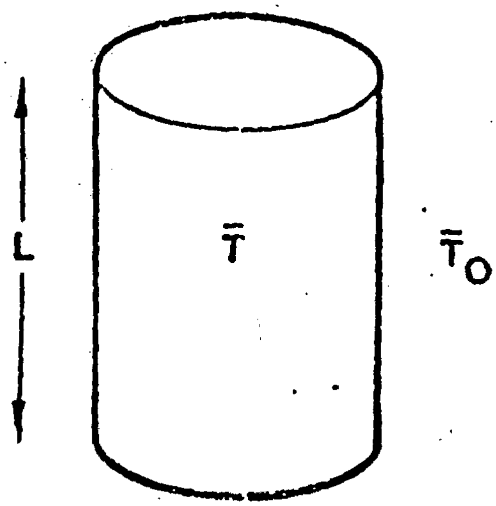


Figure (A-2)

Since Darcy velocity is equal to the product of hydraulic gradient (I) and conductivity, the upward gradient is given by

$$I = \alpha \Delta T \qquad \text{(A-2)}$$

The temperature field around a repository in tuff for spent fuel at 75 kW/Acre thermal loading has been calculated (3).

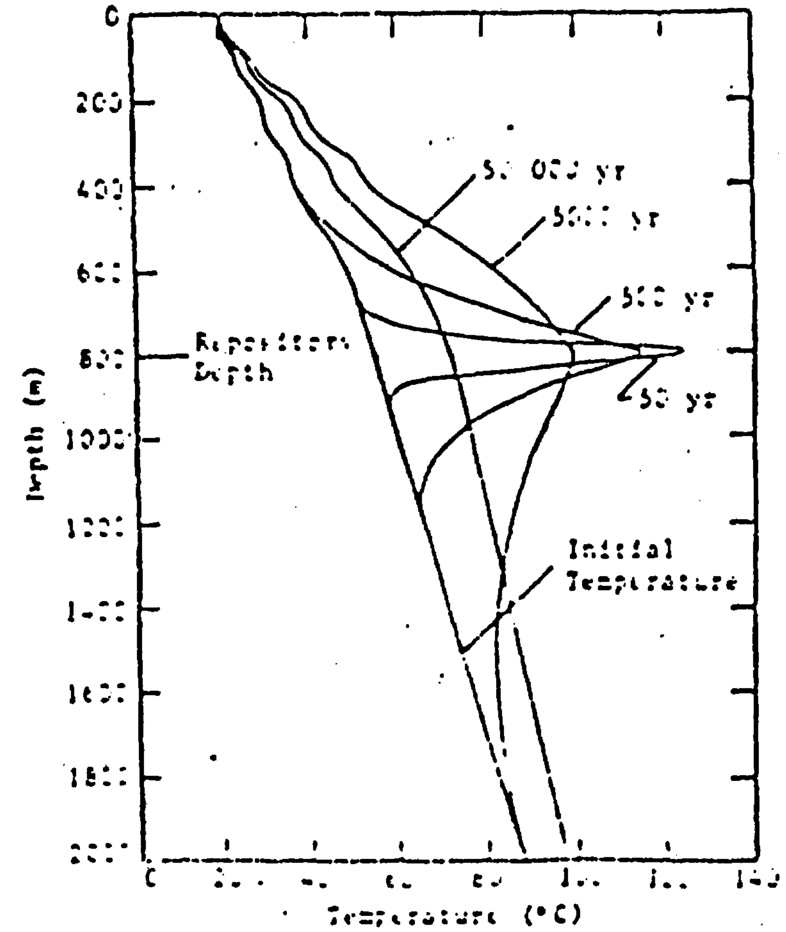


Figure (A-3) Far-Field Temperature Profile Along the Vertical Centerline for Gross Thermal Loading of 75 kW/Acre

Figure A-3 shows the temperature profile along the vertical centerline of the repository as a function of depth and time after closure. The "disturbed zone" is assumed to extend from the repository to 470 meters below surface where the water table lies. The average temperature of this disturbed zone is calculated by:

$$\bar{T} = \frac{1}{L}\int T\, dL$$

where L is the distance from the repository to the water table and is equal to 330 meters. $\bar{T}_o$ is the average background temperature of the same zone as calculated from the natural geothermal field. The ambient temperature at the repository horizon is 50°C. Under these assumptions, the hydraulic gradients calculated are shown in Table A-3:

Table A-3

Time After Closure (yr)	$\bar{T}$ (°C)	$\bar{T}_o$ (°C)	β (1/°C)	Gradient
500	73	50	6.01×10^{-4}	1.4×10^{-2}
5,000	85	50	6.68×10^{-4}	2.3×10^{-2}
50,000	65.4	50	5.54×10^{-4}	8.5×10^{-3}

More recent field work indicates that the ambient rock temperature at the repository horizon will be 35°C (27). This temperature corresponds to an average ambient temperature of 30°C. Table A-4 shows the calculated upward gradient when this temperature is assumed.

Table A-4

Time (yr)	$\bar{T}$ (°C)	$\bar{T}_o$ (°C)	β (1/°C)	Gradient
500	73	30	6.01×10^{-4}	2.6×10^{-2}
5,000	85	30	6.68×10^{-4}	3.7×10^{-2}
50,000	65.4	30	5.54×10^{-4}	1.9×10^{-2}

Thermal histories at 307 and 711 meters below the surface for a repository with a 100 kW/Acre thermal loading have been calculated and are presented in Figure A-4 (27). From these curves, it is apparent that the peak temperature occurs before 10,000 years after closure of the facility. The hydraulic gradient at 500 years for an average ambient temperature of 50°C was selected as a lower bound for our calculations. The gradient at 5,000 years with the average ambient temperature of 30°C was used as the upper bound for the vertical hydraulic gradient. A range of vertical hydraulic gradients of 1×10^{-2} to 4×10^{-2} was sampled by the Latin Hypercube Sample technique for the transport calculations.

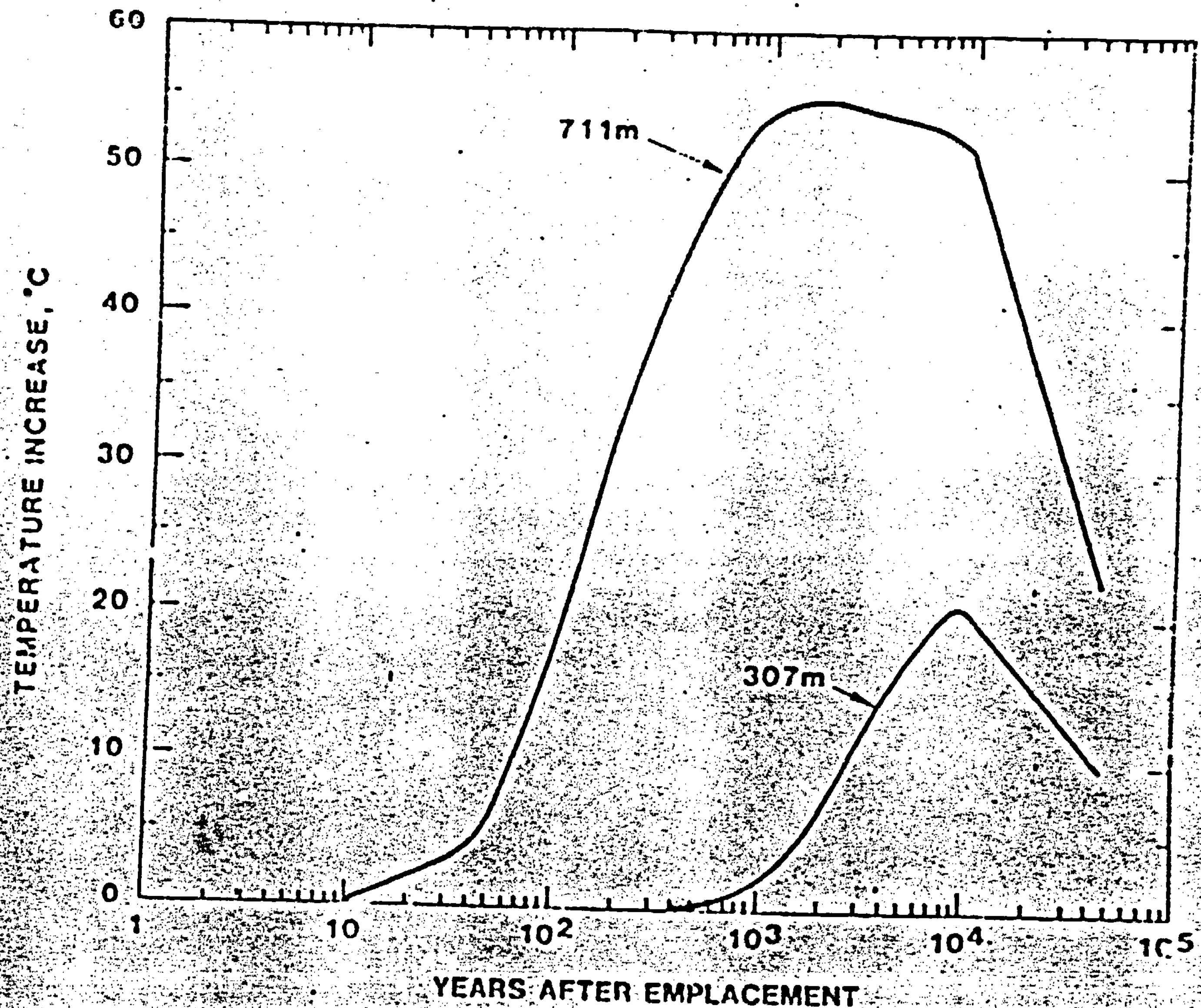


Figure A-4. Temperature Increase Histories at 307 and 711 Meters Below the Surface of the Earth for SF at 100 kW/acre.

The volume of annual recharge at the repository site places a constraint on the maximum flow through the repository under the influence of this thermal gradient. The maximum vertical discharge calculated from the vectors sampled by the LHS technique was 3.6×10^7 ft^3/yr (vector #51). This is approximately 7 percent of the volume of ground water moving through the Pahute Mesa ground-water system of the Nevada Test Site. The area of the repository comprises less than 0.1 percent of the area of this flow system. Although all of the recharge in this system is limited to areas above 5000-ft elevation, this volume of ground-water flow through the repository is probably unrealistically high. As discussed in Section 6 (Table 7), nearly all of the vectors whose radionuclide releases violated the EPA Standard in scenarios 1, 3, 4, 5, 6, 1B, and 5B were characterized by similarly unrealistic flows. Most of the other vectors considered in these calculations had ground-water discharges at least an order of magnitude smaller than vector #51.

A.3 Horizontal Hydraulic Gradient

We have considered two contributions to the horizontal hydraulic gradient in our calculations. One component is the regional gradient of the undisturbed site. Static water levels from four wells near Yucca Mountain were used to estimate ranges of the regional horizontal gradient. Three of the wells have similar static water levels (~ 2400 ft) while the fourth and only well which is actually on Yucca Mountain has an anomalously high head (~ 340? ft) (22). The range of regional hydraulic gradients was set to span the highest and lowest values that could be calculated from these data. The LHS routine, therefore, sampled a range of 10^{-1} to 10^{-3}.

The second component to the horizontal gradient is a local gradient related to the local rise in the water table above the repository due to the thermal bouyancy effect described previously. We can place an upper bound on this rise in water table (ΔZ) by assuming that the heated water in the cylinder described in Figure A-2 is constrained to expand only in the upward (Z) direction. By applying Archimedes' Principle, we can show that the height of the heated cylinder can be related to the height of a cylinder of water of equal weight at the background temperature $\bar{T}_o$. Since the height of the cylinder of water at temperature $\bar{T}_o$ equals the distance from the repository to the water table we can calculate ΔZ as follows:

$$W = \pi r^2 \bar{\rho} g (L + \Delta Z) = \pi r^2 \rho_o g L \qquad \text{(Archimedes' Principle)} \qquad \text{(A-3)}$$

$$\Delta Z = L(\rho_o/\bar{\rho} - 1) \qquad \text{(A-4)}$$

where

$\rho, \bar{\rho}$ = average density of water at T_o and $\bar{T}$, respectively;
L = height of cylinder of water at temperature T_o
r = radius of cylinder of water
Δz = rise of water table
W = weight of water in both cylinders

If V equals the volume of the cylinder of water at temperature T_o, then

$$W = \rho V = \bar{\rho}(V + \Delta V) \qquad \text{(A-5)}$$

$$\Delta V = \alpha V \Delta T \qquad \text{(A-6)}$$

$$\bar{\rho} = W/V(1 + \alpha \Delta T) = \rho/(1 + \alpha \Delta T) \qquad \text{(A-7)}$$

where ΔT and ΔV refer to differences in temperature and volume between the two cylinders and α is the average coefficient of thermal expansion of the fluid. Substituting (A-7 into A-4) we obtain:

$$\Delta z = L \alpha \Delta T \qquad \text{(A-8)}$$

We have shown that $\alpha \Delta T$ is equal to I_V, the vertical hydraulic gradient (equation A-2). We can therefore calculate Δz for each [illegible] in our calculations by using the value of I_V sampled by the [illegible] technique. The horizontal hydraulic gradient (I_H) used in our transport calculations is set equal to the sum of the [illegible] gradient and the local gradient:

$$I_H = I_{HR} + I_V L/X \qquad \text{(A-9)}$$

where:

I_{HR} = value of regional horizontal hydraulic gradient sampled by the [illegible]

I_V = value of vertical gradient sampled by [illegible]

L = sum of vertical leg lengths in transport path

X = sum of horizontal leg lengths in transport path

APPENDIX B

GEOCHEMISTRY AND RADIONUCLIDE RETARDATION

B.1 - Geochemical Environment of the Hypothetical Tuff Site

The mineralogy of each rock unit at the hypothetical tuff site is described in Table 1. The mineralogy and chemical composition of a tuff unit depend in part upon its cooling history and degree of post-depositional alteration. Vitric tuffs are porous tuffs which are composed of pumice or fragments of glass shards which have undergone a moderate to slight degree of welding. Their chemical composition is simple; the sum SiO_2 + Al_2O_3 + K_2O + Na_2O is greater than 95 weight percent. Minor elements include Ca, Mg, Cl, F and transition metals. Alteration of the glass to clay is ubiquitous in minor amounts and locally may be nearly complete. Devitrified tuffs are chemically very similar to vitric tuffs but are quite different in their mineralogy and physical properties. They are composed primarily of fine-grained aggregates of sanadine and cristobalite. They may contain phenocrysts of amphiboles, clinopyroxene and feldspar as well as lithic clasts. Low temperature alteration of devitrified tuffs is not significant; access of ground water to the rocks is limited by the low interstitial porosity. Zeolitized tuffs are the products of low temperature alteration of nonwelded volcanic ash. They are composed primarily of the zeolites clinoptilolite, mordenite, and analcime.

An average chemical composition of the ground water (6) is shown in Table B-1. The water is classified as a sodium-potassium bicarbonate water by Winograd et al. (4). Locally the composition of ground water is dependent upon lithology. Water associated with vitric tuffs is highest in silica, sodium, calcium and magnesium whereas ground water in zeolitic tuffs is depleted in the bivalent cations ([illegible]). The pH of these waters ranges from near-neutral to slightly alkaline ([illegible]). The Eh of the ground water in the repository horizon is unknown. Dissolved oxygen contents from several shallow wells at the Nevada Test Site are fairly high (~ 5 ppm) ([illegible]). The concentrations of several redox indicators and the alteration features of the mafic minerals in several units indicate that oxidizing conditions prevailed at one time below the water table (9). Negative redox potentials and low levels of dissolved oxygen, however, have been measured in sections of a drill hole in the Crater Flat Tuff (33). These observations are consistent with measured values of sulfide in the ground water and the occurrence of pyrite (FeS_2) in the rock matrix. The measurements are subject to a large amount of

TABLE B-1

ANALYSES OF WATERS FROM THE NEVADA TEST SITE (mg/l)

Well Species	J-13[1]	USW-H1[2]	USW-VH1[2]
Na^+	47.00	74.90	97.10
K^+	4.70	5.10	4.30
Ca^{2+}	13.00	7.20	10.30
Mg^{2+}	2.00	0.40	1.90
Ba^{2+}	0.20	0.01	0.04
Sr^{2+}	0.06	0.02	0.08
$HCO_3^- + CO_3^{2-}$	130.00		
Cl^-	7.70		
SO_4^{2-}	21.00		
NO_3^{2-}	5.60		
F^-	1.70		
SiO_2	61.00	11.00	53.40
pH	7.1 6.3	-	-
TDS	>294.00		

1 LA-7480-MS - reference 6
2 LA-8847-PR - reference 8

uncertainty and must be confirmed by further investigations. In light of this uncertainty, we assumed that the ground waters at the hypothetical repository are oxidizing. The importance of redox to both the solubilities and R_d values for the radionuclides that were considered in our calculations will be discussed below.

B.2 Radionuclide Solubilities

As discussed in Section 4.3, we have attempted to estimate upper bounds for the radionuclide solubilities at the tuff repository. These limits were set after a limited review of available experimental data and theoretical calculations. Most of the redox-sensitive elements are least soluble under reducing conditions. In light of the uncertainty concerning the redox conditions at Yucca Mountain and in order to ensure that our calculated releases are conservative, we have used the estimated radionuclide solubilities for oxic conditions in our calculations.

The estimated solubility limit for each element is discussed below. In this discussion, a pH = 8 and a ground water composition similar to J-13 water (Table B-1) are assumed.

Pu: Experimental studies reviewed by Wood and Rai (15) suggest that Pu solubility is relatively insensitive to redox conditions. They suggested a value of 4×10^{-10} M from their data. A more conservative value of 10^{-3} M (2.4×10^{-4} g/g) was used in order to account for the possible dominance of a Pu-carbonate complex (12).

U: Uranium solubility could be very high if considerable ($>10^{-2}$M) $CO_3^{=}$ is present. However, the groundwater composition at NTS (6,8) does not support this possibility. We have used the experimental data presented in (15) to set the U solubility limit at 2.4×10^{-5} g/g. Under reducing conditions the solubility would be several orders of magnitude lower.

Th: The dominant species at Th is probably $Th(OH)_4^0$ at pH values above 5 (13,31,32). We used the reaction:

$$Th(OH)_4^0 \rightleftharpoons ThO_2(s) + 2H_2O$$

to estimate the solubility limit at 2.3×10^{-7}g/g at pH=8. The solubility is not sensitive to redox.

Ra: Radium is another element whose solubility is relatively insensitive to redox. Its solubility is controlled primarily by $RaSO_4(s)$ or $RaCO_3(s)$. The value from (16) is a very conservative upper bound for Ra solubility at the tuff site.

Cm: Few data are available to estimate Cm solubility in natural waters. In a 0.1M NaCl solution at pH=3, the Cm solubility was 10^{-11}M. The solubility decreases at lower pH (14). A conservative value of $10^{[illegible]}$ M ($2.5 \times 10^{[illegible]}$ g/g) was used in the calculations.

Am: Am solubility has been studied by Wood and Rai (15). They suggest that a value of $7 \times 10^{[illegible]}$ M is reasonable over a wide range of redox conditions. Complexing by Cl^-, $SO_4^{=}$, or NO_3^- will not be significant.

Np: Neptunium is least soluble under reducing conditions (10^{-10}M) (15) At an Eh = +0.26 and pH=7 the solubility of NpO_2(c) is approximately $2.4 \times 10^{[illegible]}$ g/g.

Pb: $PbCO_3$ or $PbSO_4$ will limit the solubility of lead in an oxic tuff environment to less than 10^{-6} M. If any sulfide is present, PbS will precipitate and further decrease the solubility.

Pa: Little data are available for protactinium solubility in natural waters. We use the reactions:

$$Pa^{4+} + 4OH^- \rightleftharpoons Pa(OH)_4^0$$
$$PaO_2 + 2H_2O \rightleftharpoons Pa^{4+} + 4OH^-$$

to set the solubility limit at 2.3×10^{-2} M.

Ac: We had no data to estimate the solubility of actinium; we therefore assumed that it had no solubility limit in our calculations.

Tc: Tc is least soluble under reducing conditions and precipitates as TcO_2. Under oxidizing conditions it is probably present as TcO_4^- and is very soluble. We have assumed that it has no solubility limit in our calculations (13, 16).

I, Cs: These elements probably have no limiting solubilities under repository conditions (13, 16).

Sn: We have assumed that these redox-insensitive reactions determine the solubility of tin (13, 16):

$$Sn^{4+} + 4H_2O = Sn(OH)_4^0 + 4H^+: \quad \log K = -57$$
$$Sn(OH)_4(s) = Sn^{4+} + 4OH^-: \quad \log K = -0.87$$

Sr: The solubility of Sr is probably set by strontianite $SrCO_3$ (13, 16). At pH=8, the reported 130 ppm of $HCO_3^- + CO_3^{2-}$ (Table B-1) is dominantly bicarbonate and $[CO_3^{2-}]$ is about 10^{-5}M. Log K_{sp} of $SrCO_3$ is -9.6 which means the solubility of Sr is about 2×10^{-6}g/g.

C: We set the solubility limit of C at a level consistent with the concentration of HCO_3^- in J-13 water (~26 ppm carbon in a solution of 130 ppm HCO_3^-).

B.3 Radionuclide Sorption Ratios

The ranges of radionuclide distribution coefficients (R_d) used in our calculations are listed in Table 4. The values were chosen after a review of the published experimental studies that were conducted at Los Alamos National Laboratory (LANL) through June, 1981, (5-10).

R_d values from batch experiments obtained under the following conditions were included in the ranges shown in Table 4.

temperature = 22°C
solid: solution ratio = 1:20
atmosphere = oxidizing
particle size = 106-500 microns
water = J-13 water pre-equilibrated with the rock sample
rocks = samples from UE25a-1, G-1 and J-13 drill holes

Parametric studies by LANL scientists (5-10) suggest that the measured R_d values are dependent upon all of the parameters listed above. The conservatism of the data collected under these experimental conditions with respect to natural conditions expected at the tuff repository site is described in Table B-2.

For several elements, R_d values obtained under these experimental conditions can vary up to 3 orders of magnitude between samples of the same bulk mineralogy. The measured R_d value are strongly dependent upon the abundance of minor minerals such as montmorillonite, the duration of the experiment and upon the method used to measure the concentration of the sorbed radionuclide. Values obtained from desorption experiments are almost always significantly higher than those obtained from sorption experiments. The data ranges in Table 4 bracket the highest average R_d values obtained from desorption experiments and the lowest average sorption R_d value. The references for similar values in the literature are described in Tables B-3 to B-5.

TABLE B-2

CONSERVATISM[1] OF LABORATORY
DETERMINATIONS OF R_d (LANL)

PARAMETER	ELEMENT								
	Pu	Am	U	Sr	Cs	Ba	Ce	Eu	Tc
Radionuclide Concentration	*O	ND	ND	-	-	-	ND	O	ND
Solid/Solution Ratio	ND	ND	ND	-O	-O	-	-	-	ND
Ionic Strength	ND	ND	ND	-*	-*	-*	-*	-*	ND
Temperature	ND	O	+	+	+	+	*	*	ND
Particle Size	-O	+O	+O	+O*	+O*	+O*	O	O	ND
TYPE EXPERIMENT:									
Batch vs. Column	ND	ND	-*	-	-	-	-*	ND	ND
Eh (Atmosphere)	+	O	+	O	O	O	O	O	+

KEY:
+ Conservative
\- Not conservative
O Little effect
* Inconclusive or interaction effects
ND Not determined

1 Assuming the following experimental conditions.

T = 22°C	Atmospheric conditions (in air)
Solid : Solution = 1:20	106-500 micron particle size range
Batch experiment	Element-specific concentration
J-13 water	

Table B-3

SOURCES OF DATA FOR RANGES[1] OF R_d
VALUES FOR VITRIC TUFF

Element	Value	Reference[2]	Comment[3]
Am	85	6(27)	JA-18, minimum sorption value
	360	6(27)	JA-18, maximum sorption value
Pu	70	6(27)	JA-18, minimum sorption value
	450	6(27)	JA-18, maximum sorption value
U	0.01	-	conservative lower limit
	11	9(8)	YM-54, YM-22 (devitrified) max. or ave. desorption value
Np	5	10(12)	YM-49, G1-1883 (devitrified), (ave. sorption value - s.d.)
	7	10(12)	G1-1883 (devitrified), (ave. sorption value + s.d.)
Sr	117	8(10)	G1-1292, sorption average
	300	9(1)	YM-5, desorption average
Cs	429	8(10)	G1-1292, sorption average
	8600	9(1)	YM-5, Cs desorption average
Tc	0.01	-	conservative lower limit
	2	7(16)	YM-48, desorption average (glass + zeolites)
I	0	6(25)	conservative value

[1]Ranges in Table 4.

[2]References are numbered in bibliography; number in parantheses is table number in the reference.

[3]Information given includes: rock sample number, mineralogy if different from that stated at top of table, type of value (s.d. = standard deviation of average value). Averages include contribution from several particle size fractions and contact times.

Table B-4

SOURCES OF DATA FOR RANGES[1] OF R_d VALUES FOR ZEOLITIZED TUFF

Element	Value	Reference[2]	Comment[3]
Am	600	6(32)	JA-37, sorption average
	9500	9(6)	YM-38, desorption average
Pu	250	9(6)	YM-38, sorption average
	2000	9(6)	YM-38, desorption average
U	5	9(8)	YM-38, sorption average
	15	9(8)	YM-38, desorption average
Np	4.5	10(12)	YM-49, (average sorption value - s.d.)
	31	10(12)	U12G-RNM9, single sorption value for 3 wk. contact time
Sr	290	6(21)	JA-37, sorption average
	213,000	8(10)	G1-2698, desorption average
Cs	615	6(21)	JA-37, sorption average
	33,000	3(A1)	YM-49, desorption average
Tc	0.2	3(A1)	YM-49, sorption average
	2	3(A1)	YM-49, desorption average
I	0	6(25)	conservative value

[1]Ranges in Table 4.

[2]See note 2, Table B-3.

[3]See note 3, Table B-3.

Table B-5

SOURCES OF DATA FOR RANGES[1] OF R_d VALUES FOR DEVITRIFIED TUFF

Element	Value	Reference[2]	Comment[3]
Am	180	9(4)	YM-54, minimum sorption value
	4600	9(6)	YM-22, desorption average
Pu	84	9(6)	YM-54, sorption average
	1400	9(6)	YM-22, desorption average
U	1.2	9(7)	YM-22, sorption average (106-500 μm)
	14.3	9(7)	YM-54, desorption average (<106 μm)
Np	5	10(12)	YM-49, G1-1883 (devitrified), (ave. sorption value - s.d.)
	7	10(12)	G1-1883 (devitrified), (ave. sorption value + s.d.)
Sr	53	6(19)	JA-32, desorption average
	450	6(10)	G1-1982, maximum sorption value
Cs	123	6(19)	JA-32, sorption average
	2020	8(10)	G1-1982, desorption average
Tc	0.3	3(A1)	sorption average
	1.2	3(A1)	desorption average
I	0	6(25)	conservative value

[1]Ranges in Table 4.

[2]See note 2, Table B-3.

[3]Information includes: rock sample number, type of value, particle size fraction if not all fractions were considered in average. Maximum values are maxima for several size fractions, samples or contact times.

APPENDIX C

APPROXIMATIONS FOR ADAPTING POROUS MEDIA RADIONUCLIDE TRANSPORT MODELS TO ANALYSIS OF TRANSPORT IN JOINTED POROUS ROCK

C.1 Introduction

This attachment summarizes results of initial analyses (34, 35, 36) to develop equivalent porous media models for analysis of transport in jointed porous rock. Much of the text and approach are taken from (36). First, the equations and underlying assumptions used to describe radionuclide transport in both porous and jointed porous media are summarized. General conditions are then defined for which transport in jointed porous rock can be approximated as occurring in equivalent porous media having effective porosities defined by joint aperture, orientation and spacing. An expression for the retardation factor in the equivalent porous media transport equations is derived. Next numerical criteria for use of the porous media transport equations are derived. Then numerical criteria for use of the porous media approximation are derived for a specific flow system. The equations describing flow through a system of joints which form plate-like regions of jointed rock are presented. It is shown that the criteria for the use of a porous media approximation can be derived from solution of these equations. The specific criteria for this system are shown to be equivalent to those defined for the general case. Definitions of the symbols used in this discussion are summarized in Table C-1 and described in Figure C-1.

C.2. Radionuclide Transport in Porous and in Jointed Porous Media

Porous Media

Consider a reasonably homogeneous porous medium, shown schematically in Fig. C-1, which has average effective porosity ϵ and grain density ρ_s. Assume that the physical and chemical properties of the rock can be considered uniform and continuous. Let the pore space be fully saturated, and assume that flow is relatively uniform throughout that pore space. Also, let sorption of radionuclides by the rock result from only reversible processes such as adsorption or ion

Table C-1
DEFINITION OF TERMS

Symbol	Definition
θ	matrix porosity (*)
ρ_g	grain density (g/cc)
C	radionuclide concentration in flowing fluid (g/ml)
q'	radionuclide concentration on solid phase (g/g)
K_d	sorption equilibrium distribution coefficient, = q'/C (ml/g)
q_s	radionuclide concentration on surface of solid phase (g/cc)
q_i	local radionuclide concentration in solid phase (g/cc)
q	bulk radionuclide concentration in porous matrix (g/cc)
$\bar{v}$	bulk-mass average velocity of fluid (cm/sec), (interstitial or joint fluid velocity)
v	average velocity of fluid in x direction (cm/sec)
x	direction of fluid flow (cm)
x/v	mean residence time of fluid (sec)
R	retardation factor for radionuclide transport in porous media (*)
ϵ	porosity of rock associated with joints (*)
m	void volume (associated with joints) per unit volume of porous matrix = $\epsilon/(1-\epsilon)$ (*)
V_p	volume of plate-like regions of porous matrix (cm^3)
H	joint aperture (cm)
2b	joint spacing or width of plate-like regions of porous matrix, (cm)

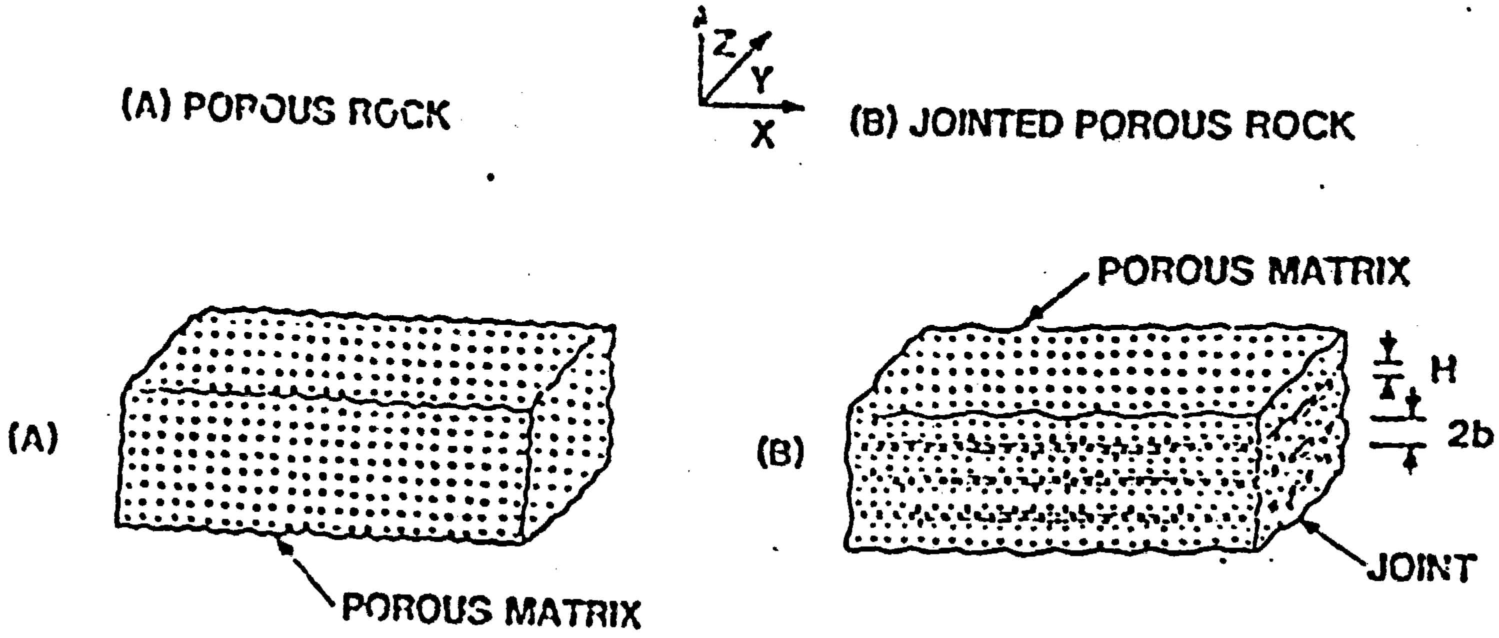
Table C-1 (continued)

Symbol	Definition
$\bar{K}$	bulk sorption distribution coefficient: $= q/c = R\phi$ (*)
D	molecular diffusion coefficient of radionuclide (cm^2/sec)
α	tortuosity (*)
D_e	effective diffusion coefficient of radionuclide in porous matrix $= D\phi/\alpha^2\bar{K}$ (cm^2/sec)
R_f	effective interfacial resistance to mass transfer (sec^{-1})
R_j	retardation factor for equivalent porous media approximation $= 1+\bar{K}/m$ (*)
z	direction of diffusion, perpendicular to rock-fluid interface (cm)
M_m	mass of radionuclide on rock matrix per unit control volume (g)
M_p	mass of radionuclide in pore water per unit control volume (g)
M_f	mass of radionuclide in flowing fluid in joint per unit control volume (g)
λ	radionuclide decay constant (sec^{-1})
$\acute{C}$	solution to transport equations for $\lambda = 0$
a	interfacial area per unit volume of bulk rock $= 1/b = 2m/H$ (cm^{-1})
$t_{0.5}$	elapsed time required for C/C_0 to reach a value of 0.5
σ	D_e/b^2 (sec^{-1})

Table C-1 (continued)

Symbol	Definition
θ	t-x/v (sec)
γ	$D_e\bar{K}/b^2$ (sec^{-1})
w	x/mv (sec)
γw	effective bed length (cm)
g	γR_f (cm)

* = dimensionless variables



Matrix porosity = ϕ
Grain Density = ρ_s

Matrix porosity = ϕ
Fracture porosity = ξ
Grain density = ρ_s
Volume of plate-like regions of porous matrix = V_p
Plate thickness = 2b
Joint aperture = H

Figure C-1. Schematic Diagrams of Porous (A) and Jointed Porous Rock (B). Coordinate system is same for both diagrams. Origin for z coordinate is at center of block.

exchange, and let fluid-phase concentrations be sufficiently dilute so that sorption can be represented by linear isotherms of the form $q' = K_d C$, where C, K_d, and q' are the radionuclide concentration in the flowing fluid, the sorption equilibrium distribution coefficient, and the radionuclide concentration associated with the solid phases, respectively. Furthermore, assume that the radionuclide concentration C is due only to dissolved species. For such media, the following assumptions are generally made:

Assumption A: The interstitial fluid velocity profile can be approximated by the bulk mass-average pore fluid velocity $\vec{V}$.

Assumption B: The cross section of the pores is sufficiently small so that the radionuclide concentration in the pores can be considered cross-sectionally uniform.

Assumption C: Local sorption equilibrium exists between pore water and mineral phases.

When these conditions obtain, then for constant-valued parameters, the basic equation describing radionuclide transport is the material balance for the flowing fluid

$$\frac{\partial C}{\partial t} + \frac{\vec{V}}{R} \cdot \vec{\nabla} C = \text{terms for} \begin{cases} \text{decay} \\ \text{reaction} \\ \text{dispersion} \end{cases} \qquad \text{(C-1)}$$

where R is the retardation factor given by $R = 1 + (1 - \phi)\rho_s K_d/\phi$, and it is assumed that essentially all pore space is available to fluid flow.

<u>Jointed media</u>

Now consider a jointed, but otherwise reasonably homogeneous, porous medium which has porosity ϕ and grain density ρ_s associated with the bulk porous matrix and has porosity ϵ associated with the joints, as determined from joint aperture H, orientation, and spacing $2b$ (Figure C-1b). Let fluid flow occur primarily in the joints, and convective radionuclide transport in the bulk porous rock be negligible. Let the joints be linear, have rectangular cross-sections of approximately uniform dimensions, and have constant and continuous physical and chemical properties. Furthermore, assume that the joints and porous matrix are fully saturated, and let the regions of porous rock bounded by the joints have approximately uniform, plate-like shape and volume V_p. Again assume that the radionuclide concentration C only results from dissolved species. Also assume that radionuclide retardation, relative to convective transport in the joints, is due to molecular diffusion in the pore water and simultaneous sorption by the solid phases of the bulk rock. Again let sorption of radionuclides by the rock result from only reversible processes, and let the concentration C be sufficiently small so that sorption can be represented by linear isotherms, and radionuclide diffusion through the pore water by Fick's law. Assume that the plate thickness 2b is sufficiently small so that radionuclide concentrations resulting from diffusion are non-trivial over the entire thickness of the plate.

Three other assumptions, analogous to Assumptions A-C for porous media need to be made for jointed porous media. In modeling radionuclide transport in jointed media, it is generally assumed that the velocity profiles in the joints also can be approximated by the bulk mass-average fluid velocity $\bar{V}$ in the joints, again obtained from an appropriate hydrologic model. However, it cannot be assumed that concentration in the fluid in the joints generally will be cross-sectionally uniform or that local sorption equilibrium generally exists between bulk phases. Instead the following assumptions are usually made:

Assumption B1: Joint apertures are sufficiently small so that in the joints, diffusion of radionuclides in the fluid phase can be approximated as a quasi-steady state process which is represented by a linear driving force expression.

Assumption C1: Local sorption equilibria exist at the interface between flowing fluid and bulk rock and between pore water and solid phases of the porous matrix.

When these conditions obtain, then for constant-valued parameters, radionuclide transport can be described by the following equations:

(material balance for the fluid in the joint)

$$\frac{\partial C}{\partial t} + \vec{v} \cdot \vec{\nabla} C + \frac{1}{m}\frac{\partial q}{\partial t} = \text{terms for} \begin{cases} \text{decay} \\ \text{reaction} \\ \text{dispersion} \end{cases} \qquad \text{(C-2)}$$

(flux expression at the interface between flowing fluid and bulk rock)

$$\frac{\partial q}{\partial t} - \frac{1}{R_f}\left(C - q_s/\bar{K}\right) = \text{terms for} \begin{cases} \text{decay} \\ \text{reaction} \end{cases} \qquad \text{(C-3)}$$

(material balance for the bulk rock)

$$\frac{\partial q_i}{\partial t} - D_e \nabla^2 q_i = \text{terms for} \begin{cases} \text{decay} \\ \text{reaction} \end{cases} \qquad \text{(C-4)}$$

where

$$q = \frac{1}{V_p}\int_{V_p} q_i \, dV_p \qquad \text{(C-5)}$$

The terms in these expressions are defined in Table C-1 and Figure C-1. D_e is the effective radionuclide diffusion coefficient for the bulk porous rock; $\bar{K}$ is the bulk sorption distribution coefficient between porous matrix and external solution; m is the void volume (based on joint aperture, orientation, and spacing per unit volume of porous matrix; R_f is an effective interfacial resistance to mass transfer; q_i is the local concentration in the porous rock; q_s is the value of q_i at the interface between matrix and flowing fluid, and the Laplacian ∇^2 is defined in a coordinate system convenient for describing diffusion in porous rock.

C.3 Equivalent Porous Media Approximation

Qualitatively, it should be evident from the preceding discussion that radionuclide transport in the jointed porous rock described above could be approximated as occurring in an equivalent porous media if the joint aperture H, joint spacing 2b, and the physical and chemical properties of the radionuclides and bulk rock were such that the conditions described by Assumptions B1 and C1 reduced to the conditions described in Assumptions B and C respectively. These equivalent porous media assumptions can be stated as

Assumption B2: Radionuclide concentrations in the flowing fluid can be considered approximately cross-sectionally uniform.

Assumption C2: The bulk rock can be considered approximately to be in local sorption equilibrium with fluid flowing in the joints.

In the paragraphs below, quantitative criteria, which determine when the above two conditions are valid, are developed in terms of the joint aperture H, spacing 2b, and the fundamental parameters describing the physical and chemical properties of the bulk rock. The expression for the retardation factor R_i to be used in the equivalent porous media equation is also developed.

Criteria for equivalent porous media approximation

Flowing fluid

Let x denote a spatial coordinate in the direction of bulk fluid motion, and let D be the radionuclide diffusion coefficient (assumed constant) for dilute aqueous solutions of the nuclide. A criterion for approximately uniform radionuclide concentrations in the flowing fluid is that the average residence time x/v for the flowing fluid is much greater than the relaxation time for a concentration gradient. The equilibration time for a plane sheet which has thickness H/2 and one face maintained at a constant concentration is approximately $H^2/4D$ (37) and should be a reasonably general estimate of the relaxation time for a concentration gradient. The desired criterion is then $x/v \gg H^2/4D$ or $x/v \geq A_1 H^2/4D$, where A_1 is an appropriate constant, on the order of 10 to 100. In previous analyses (34, 35) of specific cases in jointed porous rock, the preceding criterion was derived using the solutions to the transport equations for porous rock.

The value of the constant A_1 so obtained varied between 23 and 24. Therefore, a reasonable criterion for approximately cross-sectionally uniform radionuclide concentrations in the flowing fluid should be

$$x/v \geq 6H^2/D \; . \tag{C-6}$$

Bulk rock.

For the bulk rock to be approximately in local sorption equilibrium with the fluid flowing in the joints, radionuclide concentrations in the plate-like regions must be nearly cross-sectionally uniform. Again a criterion for such approximately uniform concentrations is that the mean residence time x/v of the flowing fluid is much greater than the relaxation time for a concentration gradient. Following the preceding arguments, that criterion would be $x/v \gg b^2/D_e$. However, diffusion of radionuclides into the porous matrix will retard the convective transport of radionuclides relative to bulk fluid motion. The mean residence time of the radionuclides would be greater than the fluid residence time x/v. In particular, if radionuclide concentrations in the bulk rock are indeed nearly uniform, then the radionuclide residence time would be greater than the fluid residence time by a factor of R_j, the retardation factor defined below for jointed media. Then the preceding criterion can be stated in less restrictive form as

$$R_j \cdot x/v \gg b^2/D_e \text{ or } x/v \gg A_2 b^2/R_j D_e ,$$

where A_2 again is an appropriate constant, on the order of 10 to 100. It is shown later that

$$R_j D_e \approx \bar{K} D_e/m = \phi D/\sigma^2 m = \phi D(1 - \epsilon)/\sigma^2 \epsilon ,$$

and that a typical value for A_2 would be about 50. Therefore, a reasonable criterion for approximate local sorption equilibrium should be

$$\frac{x}{v} \gtrsim 50 \frac{m b^2}{\bar{K} D_e} = 50 \frac{\sigma^2}{\phi} \cdot \left(\frac{\epsilon}{1 - \epsilon}\right) \cdot \frac{b^2}{D} \; . \tag{C-7}$$

Retardation factor for equivalent porous media approximation

By definition, the interfacial resistance R_f to mass transfer (Eq. C-3) is proportional to the fluid phase concentration gradient perpendicular to the interface between bulk rock and flowing fluid. As that concentration gradient decreases, the resistance R_f decreases correspondingly, and for sufficiently small gradients, that is, nearly cross-sectionally uniform concentrations in the joints, Eq. C-3 reduces to $q_s = \bar{K}C$. Furthermore, for approximately cross-sectionally uniform radionuclide concentrations in the bulk rock, Eq. C-4 reduces to $q_i \approx$ a constant, which implies $q_s \approx q_i$, and Eq. C-5 reduces to $q \approx q_i$, which implies $q \approx \bar{K}C$. Then, Eqs. C-2 to C-5 reduce to

$$\frac{\partial C}{\partial t} + \frac{\vec{v}}{R_j} \cdot \vec{\nabla} C = \text{terms for} \begin{cases} \text{decay} \\ \text{reaction} \\ \text{dispersion} \end{cases} \qquad \text{(C-8)}$$

Eq. C-8 is analogous to Eq. C-1 for porous media.

An expression for the retardation factor R_j for jointed porous media can now be derived in terms of measurable fundamental parameters. In general, a retardation factor can be defined as the ratio of the mass of solute in the rock-water system to the mass of solute in the fluid in a unit control volume. In a jointed porous media this definition can be expressed as:

$$R_j = \frac{M_m + M_f}{M_f} = \frac{M_r + M_p + M_f}{M_f} \qquad \text{(C-9)}$$

where:

M_f = mass of radionuclide in water in fractures in a unit control volume

M_r = mass of radionuclide in the porous matrix bound by fractures in a unit control volume

M_s = mass of radionuclide sorbed onto solid phases of porous matrix in unit volume

M_p = mass of radionuclide in pore water of porous matrix in unit volume

When the local equilibrium assumptions defined above obtain, then:

$$M_\ell = \epsilon C \cdot \text{unit volume}$$

$$M_p = \phi C \cdot (1 - \epsilon) \cdot \text{unit volume}$$

$$M_r = (1 - \phi)\rho_s K_d C \cdot (1 - \epsilon) \cdot \text{unit volume}$$

therefore:

$$R_j = \frac{\epsilon C + [(1 - \phi)\rho_s K_d C + \phi C]\,(1 - \epsilon)}{\epsilon C}$$

$$R_j = 1 + \left(\frac{1 - \epsilon}{\epsilon}\right) \cdot \left|\phi\left(1 + \rho_s\left(\frac{1 - \phi}{\phi}\right) K_d\right)\right| \qquad \text{(C-10)}$$

which is the desired expression.

The criterion in Equation C-7 can now be derived.

By definition:

$$\bar{K} = \phi R = \phi + (1 - \phi)\rho_s K_d$$

$$m = \epsilon/(1 - \epsilon)$$

therefore, $R_j = 1 + \bar{K}/m$. (C-11)

Now, if most of the porosity of the bulk rock is available to radionuclide diffusion, and if surface diffusion at the mineral surfaces is negligible, the effective diffusion coefficient D_e for porous rock often is defined by $D_e = D/\tau^2 R$ or $D_e = D/\tau^2[1 + (1 - \phi)\rho_s K_d/\phi]$, where τ^2 is a tortuosity factor for the porous matrix. Furthermore, for most jointed media, the porosity ϵ associated with the joints will be relatively small and much less than ϕ. Since $m = \epsilon/(1 - \epsilon)$, $\bar{K}/m \gg 1$, and $R_j \approx \bar{K}/m$. From the definitions of K and L, it then follows that [illegible] as mentioned in the preceding [illegible] $5\phi m^2/R_j D_e$. Equation C-7 can be [illegible] by substitution.

C.4. Criteria and Retardation Factor Derived from Solution of the Transport Equations

In this section the preceding principles are illustrated using the transport equations for a specific flow system. Consider transport of a radionuclide through a uniform, jointed porous medium illustrated in Figure C-1b. Let the nuclide be initially present in the inventory but not subsequently generated as a daughter product. Let flow in the joints and diffusion into the bulk rock be one-dimensional. Assume that no competing chemical reactions occur and that radionuclide transport resulting from dispersion in the direction of flow is small relative to convective transport. Let x, y, and z be rectangular Cartesian coordinates where x is again parallel to flow and z is perpendicular to the interface between flowing fluid and bulk rock. For relatively uniform joint spacing, Eqs. C-2 to C-4 then become

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial x} + \frac{1}{m}\frac{\partial q}{\partial t} = -\lambda C - \frac{\lambda}{m} q \qquad \text{(C-12)}$$

$$\frac{\partial q}{\partial t} - \frac{1}{R_f}\left(C - q_s/\bar{K}\right) = -\lambda q \qquad \text{(C-13)}$$

$$\frac{\partial q_i}{\partial t} - D_e\frac{\partial^2 q_i}{\partial z^2} = -\lambda q_i \qquad \text{(C-14)}$$

where $q = 1/b \int_0^b q_i dz$; λ is the radionuclide decay constant, and appropriate initial and boundary conditions are as follows: $C(z,0) = 0$ for $z \geq 0$; $C(0,t) = 0$ for $t \leq 0$, and $C(0,t) = C_0 e^{-\lambda t}$ for $t > 0$; $q_i(x,z,0) = 0$ for $0 \leq z \leq b$ and $x \geq 0$; $\partial q_i(x,0,t)/\partial z = 0$ for $x \geq 0$ and $t \geq 0$.

Solution of transport equations

If, for the above initial and boundary conditions, $\hat{C}$, $\hat{q}$, and $\hat{q}_i$ are the solutions to Eqs. C-12 to C-14 for $\lambda = 0$, it can be verified by direct substitution that for $\lambda > 0$, the solutions to Eqs. C-12 to C-14 using the above initial and boundary conditions are given by $C = \hat{C}e^{-\lambda t}$, $q = \hat{q}e^{-\lambda t}$, and $q_i = \hat{q}_i e^{-\lambda t}$. For $\lambda = 0$, details of the method of solution are given by Rosen (38, 39) for the analogous equations for flow around spherical rather than plate-like regions. A similar solution is given by Erickson (34, 35) for a fluid flowing through a single fracture between two parallel plates in which radionuclide diffusion perpendicular to the fracture was limited to a finite penetration depth. By substituting the appropriate expression for m, that is $\epsilon/(1-\epsilon)$, in the single fracture result, the solution can be obtained for flow through a system of joints which form several plate-like regions of porous rock, such as shown on Fig. C-1b. The resulting solution is in the form of an infinite integral which requires numerical evaluation. However, for sufficiently large values of x/v, the integral approaches a relatively simple asympototic expression. In particular, if $x/v \geq 50\ mb^2/\bar{K}D_e$, then

$$\hat{C}/C_0 \approx \frac{1}{2} + \frac{1}{2}\,\mathrm{erf}\left[\frac{\frac{2\sigma\theta}{\gamma w} - 1}{2\left(\frac{1+3g}{3\gamma w}\right)^{1/2}}\right]. \qquad \text{(C-15)}$$

where $\sigma = D_e/2b^2$; $\theta = t - x/v$; $\gamma = D_e\bar{K}/b^2$; $w = x/mv$; $g = \gamma R_f$. It should be noted that the expression $x/v \geq 50mb^2/\bar{K}D_e$ is equivalent to $\gamma w \geq 50$.

Derivation of numerical criteria for assumption B2

For $g/\gamma w$ = a constant >0 and sufficiently large γw, the argument of the error function in Eq. C-15 becomes $[(2\sigma\theta/\gamma w) - 1]/2(g/\gamma w)^{1/2}$, and at a given value of $g/\gamma w$, $\hat{C}$ depends only on the ratio $\sigma\theta/\gamma w$. It then can be seen by analogy with Rosen's discussion (39) that for $\gamma w \geq 50$, the shape of the breakthrough curve $\hat{C}(\theta, w)$ is relatively unaffected by values of $g/\gamma w \leq 0.01$. This implies that a criterion for approximately cross-sectionally uniform concentrations in the flowing fluid would be $g/\gamma w = R_f/w \leq 0.01$, or $x/v \geq 100\ mR_f$.

We can now obtain the criterion in terms of fundamental properties of the bulk rock from Equation (C-13). In general, at the interface between flowing fluid and bulk rock, $\partial q/\partial t = -aD\partial C_i/\partial z$. The term a is the interfacial area per unit volume of bulk rock; C_i the local radionuclide concentration, and C in Eqs. C-2 and C-3 should be defined more precisely here as the average value of C_i for the cross section of the joints. The term $\partial C_i/\partial z$ generally monotonically decreases nonlinearly from its value at the fluid rock interface to a value of zero at distance H/2 from the interface. The value of $\partial C_i/\partial z$ at the interface then would be at least twice the average value. We can obtain expressions for m and a in terms of b and H by referring to

Figure C-1b. For the bulk rock:

$$m = \frac{\epsilon}{1-\epsilon} \cong \frac{H\cdot(2b)^2}{(2b)^3} = \frac{H}{2b} \qquad \text{(C-16)}$$

$$a = \frac{\text{interfacial area}}{\text{unit volume}} \cong \frac{2\cdot(2b)^2}{(2b)^3} = \frac{1}{b} = \frac{2m}{H} \qquad \text{(C-17)}$$

If the average of $-\partial C_i/\partial z$ is approximated by $(C-q_s/\bar{K})/(H/4)$, then at the interface:

$$\partial C_i/\partial z \geq 2(C - q_s/\bar{K})/(H/4) \qquad \text{(C-18)}$$

$$\partial q/\partial t \geq 8aD(C - q_s/\bar{K})/H = 16mD(C - q_s/\bar{K})/H^2 \qquad \text{(C-19)}$$

From Eq. C-13, if $\lambda = 0$

$$\partial q/\partial t = (1/R_f)(C - q_s/\bar{K}) \geq 16mD(C - q_s/\bar{K})/H^2 \qquad \text{(C-20)}$$

therefore

$$mR_f \leq H^2/16D. \qquad \text{(C-21)}$$

The criterion for approximately cross-sectionally uniform concentration in the flowing fluid can now be written as $x/v \geq 100H^2/16D$ or $x/v \geq 6H^2/D$, which is identical to Eq. C-6.

<u>Derivation of retardation factor for equivalent porous media and numerical criterion for assumption C2</u>

The right side of Eq. C-15 is symmetrical about the value of $\hat{C}/C_0 = 0.5$. For a given value of t, $t_{0.01}$ is defined as the elapsed time required for $\hat{C}/C_0$ to reach a value of 0.01, and $t_{0.5}$, $t_{0.99}$, and $\theta_{0.5}$ are defined analogously. For sufficiently small radionuclide concentrations gradients in the joints (i.e. Assumption C2), $R_f \longrightarrow 0$ and $g = \gamma P_f = 0$. From Eq. C-15 and appropriate values of the error function, therefore

$$\frac{t_{0.99} - t_{0.01}}{\theta_{0.5}} = \frac{6.6}{(3\gamma w)^{1/2}} \tag{C-22}$$

and for $\gamma w > 50$

$$\frac{t_{0.99} - t_{0.01}}{\theta_{0.5}} < 0.54$$

This implies that as γw becomes large, the spread in the breakthrough curve becomes small relative to the distance its midpoint has traveled. This is because the time interval by which the value of $\hat{C}/C_o = 0.01$ precedes the value of $\hat{C}/C_o = 0.5$, and the interval by which the value of $\hat{C}/C_o = 0.99$ trails, become small relative to $\theta_{0.5}$ or $(t_{0.5} - x/v)$. For example, when $\gamma w > 50$, the intervals are about twenty-five percent or less of $\theta_{0.5}$. Furthermore, from Eq. C-15 when $\hat{C}/C_o = 0.5$, the argument of the error function is equal to zero and $2\sigma\theta_{0.5}/\gamma w = 1$. Using the definitions in Table C-1 we obtain:

$$t_{0.5} = (1 + \tilde{K}/m)x/v \tag{C-23}$$

and i $v_{0.5} = x/t_{0.5}$, then:

$$v_{0.5} = v/(1 + \tilde{K}/m). \tag{C-24}$$

and

$$R_j = \frac{v}{v_{0.5}} = 1 + \bar{K}/m \tag{C-25}$$

which is equivalent to Eq. C-11. Therefore, as γw becomes large, $\hat{C}(x,t)$ approaches $\hat{C}(0,t - R_j x/v)$ and $C(z,t)$ approaches $e^{-\lambda t}\hat{C}(0,t - R_j x/v)$, which is the solution to the corresponding form of Eq. C-1,

$$\frac{\partial C}{\partial t} + \frac{v}{R_j}\frac{\partial C}{\partial x} = -\frac{\lambda}{R_j} C \qquad \text{(C-26)}$$

Due to the inherent uncertainties associated with analyses of radionuclide transport in geologic media, a 27% spread in the value of C about $t_{0.5}$ probably is not serious, and values of $\gamma w \geq 50$ should be sufficiently large for Eqs. C-12 to C-14 to be approximated by Eq. C-26. Furthermore, the criterion $\gamma w \geq 50$, or $x/v \geq 50mb^2/\bar{K}D_e$, is the same as that given by Eq. C-7 for approximate local sorption equilibrium between bulk phases.

C.5. Discussion

Application of equivalent porous medium criteria to the hypothetical tuff site.

The criteria described for Assumptions B2 and C1 (Equations C-6 and C-7 respectively) were evaluated for the welded tuff units of the hypothetical repository site. Equation C-7 can be written in terms of the parameters listed in Tables 2 and A-1 as

$$x/v > 50\cdot(1/N^2D)\cdot(\rho^2/\phi)\cdot(\epsilon/1-\epsilon) = A_3 \qquad \text{(C-27)}$$

where:

- D = ionic diffusion constant
- ρ = tortuosity
- x = path length in fractured media
- v = Darcy velocity ÷ fracture porosity
- ϕ = matrix porosity of unfractured blocks
- ρ = grain density of rock
- ϵ = fracture porosity = 2NH for our system where N = fracture density; H = fracture aperture

The criterion was evaluated for densely and moderately welded tuff units, for individual beds as well as for the entire welded tuff thickness. The maximum, median and minimum values of the ranges used for the LHS input variables were used to evaluate the term (A_3). The results are presented in Table C-2.

Table C-2

	A_3 max	A_3 min	A_3 median
x	200 ft	200 ft	100 ft
ϵ	6.4×10^{-3}	8.8×10^{-6}	1.3×10^{-4}
θ	0.03	0.10	0.06
N	6.5 ft^{-1}	0.27 $ft.^{-1}$	1.6 $ft.^{-1}$
K	60 ft/day	4×10^{-5} ft/day	4.2 ft/day
i	4×10^{-2}	1×10^{-2}	2×10^{-2}
v	375 ft/day	0.045 ft/day	0.646 ft/day
x/v	0.533 day	4.4×10^{3} day	155 day
A_3	0.19 day	0.045 day	0.031 day

where:

i = vertical hydraulic gradient

D = 10^{-5} cm^2/sec = 3.39×10^{-1} ft^2/yr

α = 1.0

K = hydraulic conductivity in LHS range for densely welded units

v = iK/ϵ

It can be seen from these calculations that the criterion $x/v \geq A_3$ holds for the conditions encountered at the tuff site.

The criterion in equation C-6 can also be evaluated from the above data. The condition $x/v \geq 6H^2/D$ is equivalent to $x/v \geq 0.6$ sec. when an average aperture with H of 10 microns and $D = 10^{-5} cm^2/sec$ are assumed. The values of fluid residence time x/v listed in Table C-2 all exceed this value. Therefore both of the criteria required for the equivalent porous media are met for the hypothetical tuff site.

SUMMARY

If the criteria given by Eqs. C-6 and C-7, for approximately cross-sectionally uniform radionuclide concentrations in the flowing fluid and bulk rock are satisfied, then radionuclide transport in jointed porous rock can be approximated as occurring in equivalent porous media. Flow can be described by the appropriate form of Eq. C-1, where the retardation factor is given by Eq. C-10 to C-11. The criteria and retardation factor are given in terms of fundamental physical and chemical parameters. Those which can be evaluated in the laboratory include the radionuclide diffusion coefficient D for dilute aqueous solution, the distribution coefficient K_d for sorption equilibrium between pore water and mineral phases, the tortuosity factor α, grain density ρ_s, and porosity ϕ of the bulk rock. Parameters which must be evaluated from field data include the joint spacing 2b and aperture H, average fluid velocity $\overline{v}$, and porosity ϵ associated with the joints. The last parameter is determined from joint aperture, orientation, and spacing.

In terms of parameters evaluated from laboratory data, the distribution coefficient K_d and the ratio D/α^2 generally dominate Eqs. C-7 and C-10 and also involve the greatest uncertainties. For very porous rock and for chemically-simple radionuclides, evaluation of K_d and D/α^2 is not difficult. However, for rock having very "tight" porosity and (or) for chemically-complicated radionuclides, much laboratory and analytical work is required to determine appropriate "effective" values. In terms of parameters obtained from field data, Eqs. C-6, C-7, and C-10 are most sensitive to joint aperture H, joint spacing 2b, and porosity ϵ. Evaluation of H inherently involves considerable uncertainty, which correspondingly affects evaluation of ϵ. Evaluation of the average fluid velocity $\hat{v}$ involves many uncertainties which can substantially affect use of Eqs. C-6 and C-7.

REFERENCES

1. Spengler, R. W., Muller, D. C., and Livermore, R. B., Preliminary Report on the Geology and Geophysics at Drill Hole UE25a-1 Yucca Mountain, Nevada Test Site. U. S. G. S. Open File Report 79-1244, 1979.

2. Sykes, M. L., Heiken, G. H., and Smyth, J. R., Mineralogy and Petrology of Tuff Units from the UE25a-1 Drill Site, Yucca Mountain, Nevada, Los Alamos National Laboratory Report LA 8139-MS, 1979.

3. Johnstone, J. K., and Wolfsberg, K. eds., Evaluation of Tuff as a Medium for a Nuclear Waste Repository: an Interim Status Report on the Properties of Tuff, Sandia National Laboratories Report SAND80-1464, 1980.

4. Winograd, I. J. and Thordarson, W., Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site, U. S. G. S. Prof. Pap. 712-C, 1975.

5. Wolfsberg, K., Sorption-Desorption Studies of Nevada Test Site Alluvium and Leaching Studies of Nuclear Test Debris, Los Alamos Scientific Laboratory Report LA-7216-MS, 1978.

6. Wolfsberg, K., Bayhurst, J. P. and others, Sorption-Desorption Studies on Tuff I. Initial studies with samples from the J-13 Drill Site, Jackass Flats, Nevada, Los Alamos Scientific Laboratory Report LA-7480-MS, 1979.

7. Vine, E. N., Aguilar, R. D. and others, Sorption Desorption Studies on Tuff II. A continuation of studies with samples from Jackass Flats, Nevada, and initial studies with samples from Yucca Mountain, Nevada, Los Alamos Scientific Laboratory Report LA-8110-MS, 1980.

8. Erdal, B. R., Daniels, W. R. and Wolfsberg, K., eds., Research and Development related to Nevada Nuclear Waste Storage Investigations, January 1 - March 31, 1981, Los Alamos Scientific Laboratory Report LA-8847-PR, 1981.

9. Wolfsberg, K., Aguilar, R. D. and others, Sorption-Desorption Studies on Tuff III. A continuation of studies with samples from Jackass Flats and Yucca Mountain, Nevada, Los Alamos National Laboratory Report LA-8747-MS, 1981.

10. Erdal, B. R., Daniels, W. R., Vaniman, D. T. and Wolfsberg, K., Research and Development related to the Nevada Nuclear Waste Storage Investigations, April 1 - June 30, 1981, Los Alamos National Laboratory Report LA-8959-PR, 1981.

11. Guzowski, R. V., Nimick, F. B. and Muller, A. B., Repository Site Definition in Basalt: Pasco Basin, Washington, Sandia National Laboratories Report, SAND81-2088, NUREG/CR-2352, 1982.

12. Wolfsberg, K., Daniels, W .R., Erdal, B. R. and Vaniman, D. T., Research and Development Related to the Nevada Nuclear Waste Storage Investigations, April 1 - June 30, 1982, Los Alamos National Laboratory Report LA-9484-PR, 1982.

13. Letter From F. Nimick, Sandia National Laboratories, to L. Rohrbach, NRC, Subject: Preliminary calculations of solubilities of radionuclides in basalt groundwaters, dated April 27, 1982. Available in NRC PDR for inspection and copying for a fee.

14. Rai, D and Serne, R. J., Solid Phases and Solution Species of Different Elements in Geologic Environments, Battelle, Pacific Northwest Laboratories Report PNL-2651, 1978.

15. Wood, B. J. and Rai, Dhanpat, Nuclear Waste Disposal: Actinide Migration from Geologic Repositories, Battelle, Pacific Northwest Laboratories Report PNL-SA-9549, 1981.

16 Muller, A. B., Finley, N. C. and Pearson, F. J., Geochemical Parameters used in the Bedded Salt Reference Repository Risk Assessments Methodology, Sandia National Laboratories Report, SAND81-0557, NUREG/CR-1996, 1981.

17. Campbell, J. E., Longsine, D. E. and Cranwell, R. M., Risk Methodology for Geologic Disposal of Radioactive Waste: The NWFT/DVM Computer Code Users Manual, Sandia National Laboratories Report SAND81-0886, November 1981.

18. Iman, R. L., Davenport, J. M. and Zeigler, D. M., Latin Hypercube Sampling (Program Users Guide), Sandia National Laboratories Report SAND79-1475, January, 1980.

19. Environmental Protection Agency. "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Working Draft #19 40CFR191. Available in NRC PDR for inspection and from the EPA.

20. Cranwell, R. M., and others, Risk Methodology for Geologic Disposal of Radioactive Waste: Final Report, Sandia National Laboratories Report SAND81-2573, NUREG/CR-2452, December 1982.

21. Rush, F. E., Regional Ground-Water Systems in the Nevada Test Site area, Nye, Lincoln, and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources - Reconnaissance Series Report 54, 1970.

22. Reade, M. T. and McKay, E. D. Geology and Hydrology of Yucca Mountain and Vicinity, Nevada Test Site, CGS/8116R028, C.G.S., Inc., Urbana, Illinois 61801, 1982.

23. Pepping, R. E., Chu, M. S. and Siegel, M. D., A Simplified Analysis of a Hypothetical High-Level Waste Repository in a Basalt Formation, Sandia National Laboratories Report, SAND82-1557, NUREG/CR-3235, v. 2, 1982.

24. Freeze, R. A. and Cherry, J. A., Groundwater, Prentice-Hall Inc., Englewood Cliffs, N.J., 1979.

25. Guzowski, R. V., Nimick, F. B., Siegel, M. D. and Finley, N. C., Repository Site Definition in Tuff: Yucca Mountain, Nevada, Sandia National Laboratories Report SAND82-2105, NUREG/CR-2937, to be published.

26. Merkin, J. H., Free Convection Boundary Layers on Axi-Symmetric and Two-Dimensional Bodies of Arbitrary Shape in a Saturated Porous Medium, Int. J. Heat Mass Transfer, v. 22, pp. 1461-1462, 1979.

27. Interim Reference Repository Conditions for Spent Fuel and Commercial High Level Nuclear Waste Repositories in Tuff, Battelle Project Management Division (ONWI) NWTS-12, September 1981.

28. White, A. F., Claassen, H. C. and Benson, L. V., The Effect of Dissolution of Volcanic Glass on the Water Chemistry in a Tuffaceous Aquifer, Rainier Mesa, Nevada, Geological Survey Water-Supply Paper 1535-Q, 1980.

29. Winograd, I. J. and Robertson, F. N., Deep Oxygenated Ground Water Anomaly or Common Occurrence?, Science, v. 216, pp. 1227-1230, 1982.

30. Allard, B., Solubilities of Actinides in Neutral or Basic Solutions, in Proceedings of the Actinides 1981 Conference: Oxford, Pergamon Press, 1982.

31. Letter from J. Serne, Battelle Pacific Northwest Laboratories, to A. Muller, Sandia National Laboratories, Subject: Sorption Data for Radionuclides in Basalt Ground-Water Systems, dated May 13, 1981. Available in NRC PDR for inspection and copying for a fee.

32. Baes, C. F. and Mesmer, R. E. The Hydrolysis of Cations, Wiley Interscience, John Wiley and Sons, New York, N. Y., 1976.

33. Daniels, W. R., Erdal, B. R., Vaniman, D. T., Wolfsberg, K., Research and Development Related to the Nevada Nuclear Waste Storage Investigations, January 1 - March 31, 1982, Los Alamos National Laboratory Report LA 9327, 1982.

34. Erickson, K. L., Preliminary Rate Expressions for Analysis of Radionuclide Migration Resulting from Fluid Flow through Jointed Media, Scientific Basis for Nuclear Waste Management, Volume 2: New York, Plenum Press, p. [illegible], [illegible]

35. Erickson, K. L., Fundamental Approach to the Analysis of Radionuclide Transport Resulting from Fluid Flow Through Jointed Media, Sandia National Laboratories Report SAND80-0457, 1981.

36. Erickson, K. L., Approximations for Adapting Porous Media Radionuclides Transport Models to Analysis of Transport in Jointed Porous Rock, Scientific Basis for Nuclear Waste Management, Volume 6: in press.

37. Crank, J., The Mathematics of Diffusion (2nd ed.). Oxford, Clarendon Press, pp. 49-53, 1975.

38. Rosen, J. B., Kinetics of a Fixed Bed System for Solid Diffusion into Spherical Particles: Jour. Chem. Phys., v. 20, no. 3, pp. 387-393, 1952.

39. Rosen, J. B., General Numerical Solution for Solid Diffusion in Fixed Beds: Ind. Eng. Chem., v. 46, pp. 1590, 1954.

Volume 4

A Simplified Analysis of a Hypothetical Repository in a Bedded Salt Formation

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Vols. 5 and 6

Technical Assistance for Regulatory Development: Review and Evaluation of the Draft EPA Standard 40CFR191 for Disposal of High-Level Waste

- Health Effects Associated with Unit Radionuclide Releases to the Environment
- Calculation of Health Effects per Curie Release for Comparison with the EPA Standard

Prepared by Fuel Cycle Risk Analysis Division

Sandia National Laboratories

April 1983

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Simple models are presented for the estimation of individual and population health effects for long-term radionuclide releases to the surface environment. In volume 5, models based on the use of asymptotic solutions to mixed cell models in conjunction with appropriate usage rates, dose factors, risk factors, and population estimates are demonstrated. These simple models may be useful in evaluating topics such as the potential importance of individual radionuclides, different release patterns or exposure pathways, and the relationship between individual and population exposures. Illustrative model calculations are compared with the calculated population exposures on which the Draft (#19) EPA Standard 40CFR191 is based. In Volume 6, simple models are employed to provide insights into the degree of conservatism in the health effects per curie value presented by the draft standard. No attempt is made to encompass all uncertainty in the input parameters use in the calculations, and some of the modeling assumptions used in this analysis are different from those of the EPA. Three sets of calculations of health effects (cancer deaths) per curie release are presented and discussed in terms of their potential implications upon the curie release limits of the EPA draft standard.

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Volume 5	Health Effects Associated with Unit Radionuclide Releases to the Environment J. C. Helton
Volume 6	Calculation of Health Effects Per Curie Release for Comparison with the EPA Standard G. E. Runkle

Volume 5

Health Effects Associated with Unit Radionuclide Releases to the Environment

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TECHNICAL ASSISTANCE FOR REGULATORY DEVELOPMENT: REVIEW AND EVALUATION OF THE DRAFT EPA STANDARD 40CFR191 FOR DISPOSAL OF HIGH-LEVEL WASTE

VOL. 5

HEALTH EFFECTS ASSOCIATED WITH UNIT RADIONUCLIDE RELEASES TO THE ENVIRONMENT

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ABSTRACT

Simple models are presented for the estimation of individual and population health effects (i.e., latent cancer fatalities) for long-term radionuclide releases to the surface environment. These models were suggested by techniques employed by the Environmental Protection Agency in the development of a proposed standard for the disposal of high-level radioactive waste. The modeling approach is based on the use of asymptotic solutions to mixed-cell models in conjunction with appropriate usage rates, dose factors, risk factors, and population estimates. Although the models are simple, it is felt that they can be used in preliminary investigations of topics in high-level waste disposal such as potential importance of individual radionuclides, relative importance of different release patterns or exposure pathways, and relationships between individual and population exposures. The use of the models is illustrated by calculating the population health effects along various exposure pathways for the radionuclides considered in the proposed Environmental Protection Agency Standard. The results of these calculations are compared with the calculated population exposures on which the proposed Environmental Protection Agency Standard is based.

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1. Overview

1.1 Preliminary Comments

The Environmental Protection Agency has recently performed an analysis of the population health effects associated with a release to the surface environment of selected radionuclides contained in high-level waste (Sm81). Table 1-1 contains a synopsis of the population health effects calculated in the Environmental Protection Agency analysis due to a one curie release of each of the indicated radionuclides over an extended period of time. In turn, the values contained in this table were used in the derivation of the Environmental Protection Agency's draft standard for the geologic disposal of high-level radioactive waste (En80). Specifically, it was decided to allow 1000 health effects (i.e., latent cancer fatalities) over a 10,000 year period per 100,000 metric tons of heavy metal (MTHM) used as reactor fuel. For each radionuclide, the allowable release limit per 1000 MTHM over a 10,000 year period was obtained by dividing 10 health effects by the health effects per curie for a release to surface water given in Table 1-1. The proposed standard and the results of the indicated calculation are given in Table 1-2.

Releases to surface water are probably the most likely, tended to dominate health effects in the Environmental Protection Agency calculations shown in Table 1-1, and were used in the derivation of the proposed standard given in Table 1-2. For these reasons, it was decided to examine the calculations related to the surface-water exposure pathway. Specifically, it was decided to examine the Environmental Protection Agency calculations by developing simple models of the same type that they used and then using these models to predict individual and population exposures and health effects. In this development, the dose and risk factors presented in Runkle et al. (Ru81) are used.

1.2 Computational Approach

The computational results presented are obtained with the use of simple linear models to represent radionuclide movement. Specifically, the models considered are of the form

$$dX/dt = R - AX \,, \tag{1.1}$$

Table 1-1. Health Effects per Curie Released for Different Release Modes*

Nuclide	Releases to a River	Releases to an Ocean	Releases to Land Surface	Releases to the Air
C- 14	4.58 E- 2	1.12 E- 7	2.58 E- 5	2.04 E- 4
Ni- 59				
Sr- 90	1.21 E- 1	1.91 E- 6	9.75 E- 4	1.63 E- 2
Zr- 93				
Tc- 99	2.85 E- 4	1.04 E- 6	6.03 E- 8	3.67 E- 5
Sn-126	1.20 E- 1	7.86 E- 6	4.13 E- 2	1.12 E- 1
I-129	1.08 E- 2	9.62 E- 5	2.31 E- 5	1.38 E- 3
Cs-135	3.81 E- 3	1.58 E- 5	4.01 E- 4	7.36 E- 4
Cs-137	1.98 E- 2	1.60 E- 5	5.62 E- 4	6.91 E- 3
Sm-151				
Ra-226				
U-234				
Np-237	5.96 E- 1	2.44 E- 3	3.22 E- 3	8.03 E- 2
Pu-238	2.29 E- 2	2.38 E- 5	3.21 E- 3	1.47 E- 2
Pu-239	6.92 E- 2	1.31 E- 4	5.55 E- 2	5.18 E- 2
Pu-240	6.53 E- 2	1.15 E- 4	4.94 E- 2	4.76 E- 2
Am-241	7.19 E- 1	1.19 E- 2	8.98 E- 2	1.59 E- 1
Pu-242	6.76 E- 2	1.30 E- 4	5.63 E- 2	5.13 E- 2
Am-243	2.68 E 0	8.81 E- 2	1.03 E 0	1.14 E 0

*This table is a reprint of Table D-1 of (Sm81).

Table 1-2. Cumulative Releases to the Accessible Environment for 10,000 Years After Disposal Proposed by the Environmental Protection Agency

Radionuclide	Half-Life[a] (years)	Proposed Release Limit[b] (curies per 1000 MTHM)	Release Limit From Table 1-1[c] (curies per 1000 MTHM)
Americium-241	458.	10	13.9*
Americium-243	7370..	4	3.73
Carbon-14	5730	200	218.3
Cesium-135	3.E6	2000	2624.7
Cesium-137	30.2	500	505.0
Iodine-129	1.7E7	900	925.9
Neptunium-237	2.14E6	20	16.8
Plutonium-238	86.	400	436.7
Plutonium-239	2.44E4	100	144.5
Plutonium-240	6580.	100	153.1
Plutonium-242	3.79E5	100	147.9
Radium-226	1600.	3	
Strontium-90	28.1	80	82.6
Technetium-99	2.12E5	2000	35,087.7
Tin-126	1.E5	80	83.3
Any other alpha-emitting radionuclide		10	
Any other radionuclide which does not emit alpha particles		500	

a From (We74)
b From (EP80)
c Derived from "Releases to a River" in Table 1-1.

where X is the amount of radionuclide in some region of interest (units: Ci), R is the rate of radionuclide input to this region (units: Ci/yr) and A is a rate constant for movement out of that region (units: yr^{-1}). The solution of the preceding equation is given by

$$X(t) = e^{-At}X_0 + (R/A)(1. - e^{-At}), \qquad (1.2)$$

where $X(0) = X_0$. Further, when A is positive as is the case for situations considered in this presentation, the asymptotic or steady state solution to (1.1) is given by

$$SX = R/A \, . \qquad (1.3)$$

It is this latter solution which will be used in the development of dose and risk results to be presented.

The equation appearing in (1.1) is used to represent three different situations. The first situation is a radionuclide release to a surface-water body. Here, for each radionuclide considered,

$$R = TD(I)/T \quad \text{and} \quad A = F/VW \, , \qquad (1.4)$$

where TD(I) equals total release for radionuclide I (units: Ci) over a time period of length T (units: yrs), F equals the flow rate out of the water body under consideration (units: L/yr), and VW equals the volume of the water body (units: L). For completeness, the rate constant A appearing in (1.4) should also contain a term representing radioactive decay. However, as this term would be very small relative to F/VW for the radionuclides commonly considered in the geologic disposal of high-level waste, it is omitted. Radionuclide releases over relatively long time periods will be considered. In particular, dose factors which provide a 70. year dose commitment from a 70. year chronic exposure will be used. Therefore, T must be significantly greater than 70. years. The coefficient A is derived from the assumption that the surface-water body can be treated as a uniformly mixed cell such that a radionuclide can leave the cell only by outward movement of water. Additional discussion of R and A can be obtained in Chapter 3.

The second situation is a radionuclide release to soil. Here, for each radionuclide considered, R is defined as in (1.4) and A is defined by

$$A = \frac{S(I)*ER}{DP*(1. - PO)*DE} + \frac{(1. - S(I))*RO}{DP*PO*SA*1000.} + \frac{ALOG(2.)}{HLIFE(I)} , \quad (1.5)$$

where S(I) represents radionuclide partitioning between the liquid and solid phases of the soil and is defined in Table 1-5 (units: unitless), ER represents erosion rate per unit area (units: kg/m^2 per yr), DP represents depth of soil (units: m), PO represents porosity of soil (units: unitless), DE represents mean particle density of soil material (units: kg/m^3), RO represents runoff rate per unit area (units: L/m^2 per yr), SA represents percent saturation of pore space in soil (units: unitless), ALOG(2.) is the natural logarithm of 2. and HLIFE(I) is the half-life of radionuclide I (units: yr). Due to the slower processes associated with radionuclide movement in soil, radioactive decay is incorporated into the expression appearing in (1.5). The coefficient A is derived from the assumptions that the soil can be treated as a uniformly mixed cell with a water phase and a solid phase such that (1) a radionuclide is partitioned between the water and solid phases on the basis of a distribution coefficient and (2) a radionuclide can leave the cell only by radioactive decay or movements of water and solids. Additional discussion of A can be obtained in Chapter 4.

The third situation is radionuclide deposition on crops due to sprinkler irrigation. In this case,

$$R = FRET*TD(I)*FRIV/T \quad (1.6)$$

and

$$A = ALOG(2.)/WHPHL , \quad (1.7)$$

where TD(I), T and ALOG(2.) are already defined, FRET is the fraction of deposited radionuclides in sprinkler irrigation initially retained on plants (units: unitless), FRIV is the fraction of the river receiving the radionuclide release used for sprinkler irrigation (units: unitless) and WHRHL is the weathering half life for radionuclides deposited by sprinkler irrigation (units: yrs). The variables R and A are derived from the assumption that the radionuclides retained on plants due to sprinkler irrigation can be treated as being in a uniformly-mixed cell such that radionuclides can enter this cell only by deposition on plants and can leave the cell only by weathering. Due to the generally short weathering half lives which are considered, radioactive decay is omitted in the definition of A. Additional discussion on the derivation of R and A is provided in Chapter 5.

For each of the situations indicated in the three preceding paragraphs, radionuclide movement can be represented by a differential equation of the form given in (1.1). As indicated in (1.3), each of these equations will have an asymptotic solution of the form R/A which represents the amount of radionuclide in the system at steady state. From this solution, steady state concentrations can be obtained by dividing by the appropriate volume or mass. For radionuclide I and release to surface water, the steady state solution is

$$R/A = (TD(I)/T)/(F/VW) = TD(I)*VW/(F*T) \qquad (1.8)$$

and so division by VW yields a steady-state concentration of

$$TD(I)/(F*T) \qquad (1.9)$$

Similar calculations will yield steady-state concentrations for release to soil and deposition on plants due to sprinkler irrigation.

Once the concentrations indicated in the preceding paragraph are known, they can be used to calculate individual exposure rates. In turn, multiplication of these exposure rates by appropriate dose factors will yield individual dose rates. Then, multiplication by risk factors will yield individual cancer risk. Finally, multiplication of individual dose and risk by population size will yield population dose and population risk. Tables 1-4, 1-5 and 1-6 contain selected formulas for individual dose (units: rem/ind) and associated population size (units: ind). Table 1-3 contains definitions for variables used in Tables 1-4, 1-5 and 1-6. Detailed derivations for all relations are given later in the presentation. However, all were derived as already indicated. That is, an asymptotic concentration was obtained in each substrate of interest. Next, these concentrations were used in conjunction with individual usage rates and dose factors to obtain individual dose. Then, multiplication by the appropriate risk factor yields individual risk, and multiplication by the indicated population size yields population dose and risk. Due to the assumed linearity of many of the relations, multiplication by population size often results in considerable simplification of the algebraic expressions for population dose and risk. The appearance of the factor 70. in many of the expressions results from the fact that dose factors for a 70. year dose commitment from a 70. year chronic exposure are being used for ingestion and inhalation. Multiplication of a one year chronic (i.e., assumed to be the same over an entire lifetime) exposure rate by these factors yields the indicated dose commitment.

1.3 Computational Results

This section presents population health effects obtained with the relations given in Tables 1-4, 1-5 and 1-6. These results are presented in Tables 1-7, 1-8 and 1-9 and were calculated for a total discharge of 1. curie per radionuclide (i.e., TD(I) = 1.). The dose factors used in these calculations are given in Tables 2.1, 2.2 and 2.3 of Runkle et al. (Ru81). The cancers and associated risk factors used are listed in Table 1-10. For each exposure mode, the indicated population health effect is the sum of the health effects for the individual cancers. All water treatment factors are assumed to be 1. (i.e., WT(I) = 1.), and concentration ratios (i.e., CRDM(I), CRDMT(I), CRSF(I), CRWF(I)) are taken from Tables A-8 and C-5 of Nuclear Regulatory Commission Guide 1.109 (Nu76). The distribution coefficients employed for surface water and soil are the same as those given in the Environmental Protection Agency analysis for sediment (Sm81, Table 5-5); however, all distribution coefficients indicated as being zero in the preceding table were assigned the value of 1. for our analysis. The Environmental Protection Agency may have used different distribution coefficients for soil calculations but their documentation does not make this clear

Table 1-3. Variables Appearing in Tables 1-4, 1-5 and 1-6

Variable	Definition
AIRCON	Concentration of suspended solids in air (units: kg/m^3)
ALOG(2.)	Natural logarithm of 2.
AR	Area of soil (units: m^2)
CMLK	Individual milk consumption (units: L/yr)
CMT	Individual meat consumption (units: kg/yr)
CPLT	Individual plant consumption (units: kg/yr)
CRDM(I)	Concentration ratio for radionuclide I from diet to milk (units: Ci/L per Ci/day)
CRDMT(I)	Concentration ratio for radionuclide I from diet to meat (units: Ci/kg per Ci/day)
CRSP(I)	Concentration ratio for radionuclide I from soil to plant (units: unitless)
CRWF(I)	Concentration ratio for radionuclide I from water to fish (units: Ci/kg per Ci/L)
DCOEF(I)	Distribution coefficient for radionuclide I (units: Ci/kg per Ci/L)
DE	Mean particle density of soil material (units: kg/m^3)
DENSITY	Mean particle density for external exposure calculations (units: kg/m^3)
DEPTH	Depth to which radionuclides are assumed to be concentrated on surface for external exposure calculations (units: m)
DFEXT(I,1,J)	Dose factor for ground exposure to organ J from radionuclide I (units: rem/hr per Ci/m^2)
DFEXT(I,2,J)	Same as DFEXT(I,1,J) but for water immersion (units: rem/hr per Ci/m^3)

Table 1-3. (continued)

Variable	Definition
DFEXT(I,3,J)	Same as DFEXT(I,1,J) but for air immersion (units: rem/hr per Ci/m^3)
DFING(I,J)	Dose factor for exposure to organ J from ingestion of radionuclide I (units: rem per Ci/yr)
DFINH(I,J)	Same as DFING(I,J) but for inhalation
DFSH	Constant relating fish production to river flow (units: kg/yr per L/yr)
DMLK	Individuals supported by milk production (units: ind/m^2)
DMT	Individuals supported by meat production (units: ind/m^2)
D[illegible]	Depth of soil (units: m)
DPLT	Individuals supported by plant production (units: ind/m^2)
DPOP	Constant relating population size to river flow (units: ind per L/yr)
DSL	Population density for inhalation and external exposure calculations (units: ind/m^2)
ER	Erosion rate (units: kg/m^{-2} per yr)
F	River flow rate (units: [illegible]/yr)
FMLK	Fraction of land used for milk production (units: unitless)
FMT	Fraction of land used for meat production (units: unitless)
FPLT	Fraction of land used to grow plants for human consumption (units: unitless)

Table 1-3. (continued)

Variable	Definition
FRET	Fraction of radionuclides in sprinkler irrigation initially retained on plants (units: unitless)
FRIV	Fraction of river used for sprinkler irrigation (units: unitless)
HLIFE(I)	Half-life for radionuclide I (units: yr)
PDEN	Plant density (units: kg/m^2)
PMLK	Plant consumption by dairy cattle (units: kg/day)
PMT	Plant consumption by beef cattle (units: kg/day)
PO	Porosity of soil (units: unitless)
POROSIT	Porosity for external exposure calculations (units: unitless)
REXARSD	Exposure to suspended sediment (units: hr/yr)
REXARSL	Exposure to suspended soil (units: hr/yr)
REXTSD	Exposure to sediment (units: hr/yr)
REXTSL	Exposure to soil (units: hr/yr)
REXTWAT	Exposure water (units: hr/yr)
RINGWAT	Water ingestion rate (units: L/yr)
RINHAIR	Inhalation rate (units: m^3/yr)
RO	Runoff rate (units: L/m^2 per yr)
SA	Percent saturation of pore space in soil (units: unitless)
T	Length of radionuclide discharge (units: yr)
TD(I)	Total discharge of radionuclide I (units: Ci)

Table 1-3. (continued)

Variable	Definition
TMINSD	Fraction of year that individual is exposed to suspended sediment (units: unitless)
TMINSL	Fraction of year that individual is exposed to suspended soil (units: unitless)
WHRHL	Weathering half life for radionuclides deposited by sprinkler irrigation (units: yr)
WMLK	Water consumption by dairy cattle (units: L/day)
WMT	Water consumption by beef cattle (units: L/day)
WT(I)	Water treatment factor for radionuclide I (units: unitless)
70.	Average life expectancy (units: yr)

Table 1-4. Exposure to Organ Associated With Cancer J Due to Radionuclide I for Releases to Surface Water

Exposure From Water Consumption

Individual : RINGWAT*TD(I)*WT(I)*DFING(I,J)/(F*T)
(rem/ind)

Pop. Size : DPOP*F*T/70.
(ind)

Exposure From Fish Consumption

Individual : TD(I)*CRWF(I)*DFSH*DFING(I,J)/(DPOP*F*T)
(rem/ind)

Pop. Size : DPOP*F*T/70.
(ind)

Exposure From Inhalation of Suspended Sediment

Individual : DCCEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD*DFINH(I,J)/(F*T)
(rem/ind)

Pop. Size : DPOP*F*T/70.
(ind)

Exposure From Water Immersion

Individual : TD(I)*REXTWAT*DF(I,2,J)*7.E4/(F*T)
(rem/ind)

Pop. Size : DPOP*F*T/70.
(ind)

Exposure From Shoreline Sediment

Individual : DCCEF(I)*TD(I)*DEPTH*DENSITY*(1.-POROSIT)*REXTSD
(rem/ind) *DFEXT(I,1,J)*70./(F*T)

Pop. Size : DPOP*F*T/70.
(ind)

Exposure From Suspended Sediment

Individual : DCCEF(I)*TD(I)*AIRCON*REXARSD*DFEXT(I,3,J)*70./(F*T)
(rem/ind)

Pop. Size : DPOP*F*T/70.
(ind)

Table 1-5. Exposure to Organ Associated With Cancer J Due to Radionuclide I for Releases to Soil

Expressions Introduced to Simplify Notation

S(I) = DCOEF(I)*(1. - PO)*DE/(DCOEF(I)*(1. - PO)*DE + PO*1000.)

(units: unitless)

A(I) = S(I)*ER/(DP*(1. - PO)*DE) + (1. - S(I))*RO/(DP*PO*1000.)

+ ALOG(2.)/HLIFE(I) (units: yr^{-1})

FAC(I) = 1./(A(I)*DP*(1. - PO)*DE) (units: m^2 yr/kg)

Exposure From Plant Consumption

Individual : CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)/(T*AR)
(rem/ind)

Pop. Size AR*FPLT*DPLT*T/70.
(ind)

Exposure From Milk Consumption

Individual : TD(I)*FAC(I)*CRSP(I)*FMLK*CROM(I)*CMLK*DFING(I,J)/(T*AR)
(rem/ind)

Pop. Size : AR*FMLK*DMLK*T/70.
(ind)

Exposure From Meat Consumption

Individual : TD(I)*FAC(I)*CRSP(I)*FMT*CROMT(I)*CMT*DFING(I,J)/(T*AR)
(rem/ind)

Pop. Size : AR*FMT*DMT*T/70.
(ind.)

Table 1-5. (continued)

Exposure From Inhalation of Suspended Soil

Individual (rem/ind) : TD(I)*FAC(I)(AIRCON*RINHAIR*TMINSL*DFINH(I,J)/(T*AR)

Pop. Size (ind) : AR*DSL*T/70.

Exposure From Soil

Individual (rem/ind) : TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSITY)*REXTSL

*DFEXT(I,1,J)*70./(T*AR)

Pop. Size (ind) : AR*DSL*T/70.

Exposure From Suspended Soil

Individual (rem/ind) : TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)*70./(T*AR)

Pop. Size (ind.) : AR*DSL*T/70.

Table 1-6. Exposure to Organ Associated With Cancer J Due to Radionuclide I for Releases to Surface Water With Subsequent Use of Surface Water for Livestock and Sprinkler Irrigation

Exposure From Plant Consumption

Individual (rem/ind) : FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)/(T*AR*PDEN*ALOG(2.))

Pop. Size (ind) : AR*FPLT*DPLT*T/70.

Exposure From Milk Consumption

Individual[a] (rem/ind) : FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK*DFING(I,J) /(T*AR*PDEN*ALOG(2.))

Individual[b] (rem/ind) : TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)/(F*T)

Pop. Size (ind.) : AR*FMLK*DMLK*T/70.

Exposure From Meat Consumption

Individual[a] (rem/ind) : FRET*TD(I)*FRIV*WHRHL*PMT*CRDMT(I)*CMT*DFING(I,J) /(T*AR*PDEN*ALOG(2.))

Individual[b] (rem/ind) : TD(I)*WMT*CRDMT(I)*CMT*DFING(I,J)/(F*T)

Pop. Size (ind) : AR*FMT*DMT*T/70.

[a]Exposure from radionuclides deposited by sprinkler irrigation on plants which are subsequently used as animal feed.

[b]Exposure from radionuclides in water used for livestock.

Table 1-7. Population Health Effects for 1. Curie Radionuclide Releases to Surface Water

NUCLIDE	WRHETOT[a]	FHHETOT[b]	INSDTOT[c]	EXWRTOT[d]	EXSDTOT[e]	EXARSDT[f]
C14	2.08E-05	2.58E-04	9.95E-16	0.	0.	1.98E-20
NI59	5.75E-05	1.55E-05	5.34E-14	0.	0.	0.
SR90	3.91E-02	3.17E-03	2.15E-11	2.18E-10	0.	6.78E-19
ZR93	5.89E-06	5.25E-08	7.24E-11	1.61E-11	3.42E-08	4.71E-17
TC99	2.00E-06	8.10E-08	2.22E-14	5.24E-11	0.	8.19E-20
SN126	4.68E-04	3.79E-03	3.55E-13	7.26E-09	1.27E-07	1.86E-14
I129	8.87E-05	3.60E-06	4.35E-15	6.86E-09	6.35E-09	2.54E-17
CS135	1.60E-04	8.65E-04	4.89E-13	2.66E-11	0.	7.91E-19
CS137	9.72E-04	5.255-03	2.95E-12	4.03E-07	1.19E-06	1.33E-14
SM151	1.26E-05	8.53E-07	1.90E-11	1.05E-10	2.03E-07	1.14E-12
RA226	2.34E+00	3.17E-01	2.07E-09	1.31E-06	1.81E-06	2.13E-14
U234	4.39E-03	2.37E-05	5.36E-09	4.76E-10	3.10E-08	2.19E-16
NP237	5.04E-03	1.36E-04	7.90E-10	1.45E-07	1.98E-09	2.05E-16
PU238	1.73E-04	1.64E-06	7.69E-08	6.05E-11	3.67E-08	1.92E-16
PU239	2.87E-03	2.72E-05	3.04E-06	4.84E-11	2.23E-08	1.58E-16
PU240	2.87E-03	2.72E-05	3.04E-06	5.65E-11	3.67E-08	1.84E-16
AM241	3.21E-03	2.17E-04	5.14E-07	1.57E-08	2.54E-06	2.54E-14
PU242	2.68E-03	2.53E-05	2.83E-06	4.44E-11	3.11E-08	1.44E-16
AM243	3.22E-03	2.18E-04	5.11E-07	1.25E-07	1.84E-05	1.98E-13

[a]WRHETOT – Total health effects from drinking water

[b]FHHETOT – Total health effects from eating fish

[c]INSDTOT – Total health effects from inhalation of sediment

[d]EXWRTOT – Total health effects from water imersion

[e]EXSDTOT – Total health effects from external exposure to sediment

[f]EXARSDT – Total health effects from external exposure to suspended sediment

Table 1-8. Population Health Effects for 1. Curie Radionuclide Release to Soil

NUCLIDE	PLHETOT[a]	MKHETOT[b]	MTHETOT[c]	INSLTOT[d]	EXSLTOT[e]	EXARSLT[f]
C14	2.05E-04	5.35E-05	1.67E-05	4.89E-13	0.	9.74E-18
NI59	1.36E-05	1.97E-06	1.89E-07	2.27E-11	0.	0.
SR90	2.16E-03	3.75E-05	3.40E-06	9.56E-09	0.	3.02E-16
ZR93	1.29E-06	1.40E-10	1.15E-07	1.27E-08	6.02E-06	8.31E-15
TC99	8.97E-07	4.87E-07	9.42E-07	1.09E-11	0.	4.03E-17
SN126	2.10E-06	1.14E-07	4.41E-07	1.74E-10	6.26E-05	9.18E-12
I129	3.19E-06	4.15E-07	2.43E-08	2.14E-12	3.13E-06	1.25E-14
CS135	4.86E-05	1.27E-05	5.10E-07	2.03E-10	0.	3.29E-16
CS137	2.48E-04	6.47E-05	2.61E-06	1.03E-09	4.15E-04	4.65E-12
SM151	6.80E-06	7.38E-10	8.92E-08	3.72E-09	4.00E-05	2.25E-10
RA226	1.12E-02	1.94E-03	9.99E-04	8.71E-07	7.63E-04	9.00E-12
U234	4.17E-03	4.52E-05	3.72E-06	1.86E-06	1.08E-05	7.61E-14
NP237	2.26E-05	2.46E-09	1.19E-08	3.88E-07	9.74E-06	1.01E-13
PU238	1.47E-05	6.37E-10	5.39E-10	3.56E-06	1.70E-06	8.91E-15
PU239	9.15E-04	3.97E-08	3.36E-08	5.30E-04	3.89E-06	2.76E-14
PU240	8.91E-04	3.87E-08	3.28E-08	5.15E-04	6.24E-06	3.12E-14
AM241	5.30E-04	5.75E-08	2.78E-07	9.28E-05	4.60E-04	4.60E-12
PU242	8.60E-04	3.73E-08	3.16E-08	4.97E-04	5.47E-06	2.54E-14
AM243	7.13E-04	7.74E-08	3.74E-07	1.23E-04	4.45E-03	4.79E-11

[a]PLHETOT — Total health effects from plant ingestion due to radionuclide uptake by plants from soil

[b]MKHETOT — Total health effects from milk ingestion due to radionuclide uptake by plants from soil

[c]MTHETOT — Total health effects from meat ingestion due to radionuclide uptake by plants from soil

[d]INSLTOT — Total health effects from inhalation of suspended soil

[e]EXSLTOT — Total health effects from external exposure to soil

[f]EXARSLT — Total health effects from external exposure to suspended soil

Table 1-9. Population Health Effects for 1. Curie Radionuclide Release to Surface Water With Subsequent Use of Surface Water for Livestock and Sprinkler Irrigation

NUCLIDE	IPLRHET[a]	PLHETOT[b]	IRPLHET[c]
C14	1.12E-04	2.05E-04	3.17E-04
NI59	3.10E-04	1.36E-05	3.23E-04
SR90	2.10E-01	2.16E-03	2.13E-01
ZR93	3.17E-05	1.29E-06	3.30E-05
TC99	1.08E-05	8.97E-07	1.17E-05
SN126	2.52E-03	2.10E-06	2.52E-03
I129	4.78E-04	3.19E-06	4.81E-04
CS135	8.62E-04	4.86E-05	9.11E-04
CS137	5.24E-03	2.48E-04	5.48E-03
SM151	6.80E-05	6.80E-06	7.48E-05
RA226	1.26E+01	1.12E-02	1.26E+01
U234	2.36E-02	4.17E-03	2.78E-02
NP237	2.71E-02	2.26E-05	2.72E-02
PU238	9.34E-04	1.47E-05	9.48E-04
PU239	1.55E-02	9.15E-04	1.64E-02
PU240	1.55E-02	8.91E-04	1.64E-02
AM241	1.73E-02	5.30E-04	1.78E-02
PU242	1.44E-02	8.60E-04	1.53E-02
AM243	1.74E-02	7.13E-04	1.81E-02

[a]IPLRHET — Total health effects from plant ingestion due to foliar deposition

[b]PLHETOT — Total health effects from plant ingestion due to radionuclide uptake by plants from soil

[c]IRPLHET — IPLRHET + PLHETOT

Table 1-9. (continued)

NUCLIDE	IMKRHET[d]	IMKWHET[e]	MKHETOT[f]	IRMKHET[g]
C14	2.92E-05	1.69E-05	5.35E-05	9.95E-05
NI59	4.51E-05	2.60E-05	1.97E-06	7.30E-05
SR90	3.66E-03	2.11E-03	3.75E-05	5.81E-03
ZR93	3.44E-09	1.99E-09	1.40E-10	5.57E-09
TC99	5.84E-06	3.37E-06	4.87E-07	9.70E-06
SN126	1.37E-04	7.91E-05	1.14E-07	2.16E-04
I129	6.23E-05	3.60E-05	4.15E-07	9.86E-05
CS135	2.25E-04	1.30E-04	1.27E-05	3.67E-04
CS137	1.36E-03	7.88E-04	6.47E-05	2.22E-03
SM151	7.36E-09	4.27E-03	7.38E-10	1.24E-08
RA226	2.19E+00	1.27E-00	1.94E-03	3.46E+00
U234	2.57E-04	1.48E-04	4.52E-05	4.50E-04
NP237	2.94E-06	1.70E-06	2.46E-05	4.65E-06
PU238	4.05E-08	2.34E-08	6.37E-10	6.46E-08
PU239	6.73E-07	3.88E-07	3.97E-08	1.10E-06
PU240	6.72E-07	3.88E-07	3.87E-08	1.10E-06
AM241	1.88E-06	1.08E-06	5.75E-08	3.02E-06
PU242	6.26E-07	3.625-07	3.73E-08	1.02E-06
AM243	1.88E-06	1.09E-08	7.74E-08	3/05E-06

[d]IMKRHET – Total health effects from foliar deposition and subsequent plant use in milk production

[e]IMKWHET – Total health effects from water used for milk cattle

[f]MKHETOT – Total health effects from milk ingestion due to radionuclide uptake by plants from soil

[g]IRMKHET – IMKRHET + IMKWHET + MKHETOT

Table 1-9. (Continued)

NUCLIDE	IMTRHET[h]	IMTWHET[i]	MTHETOT[j]	IRMTHET[k]
C14	9.11E-06	4.39E-06	1.67E-05	3.02E-05
NI59	4.31E-06	2.07E-06	1.89E-07	6.57E-06
SR90	3.32E-04	1.60E-04	3.40E-06	4.94E-04
ZR93	2.83E-06	1.36E-06	1.15E-07	4.31E-06
TC99	1.13E-05	5.44E-06	9.42E-07	1.77E-05
SN126	5.30E-04	2.55E-04	4.41E-07	7.85E-04
I129	3.64E-06	1.75E-06	2.43E-08	5.41E-06
CS135	9.05E-06	4.36E-06	5.10E-07	1.39E-05
CS137	5.50E-05	2.65E-05	2.61E-06	8.41E-05
SM151	8.93E-07	4.30E-07	8.92E-08	1.41E-06
RA226	1.13E+00	5.43E-01	9.99E-04	1.67E+00
U234	2.11E-05	1.02E-05	3.72E-06	3.50E-05
NP237	1.42E-05	6.86E-06	1.19E-08	2.11E-05
PU238	3.43E-08	1.65E-08	5.39E-10	5.14E-08
PU239	5.69E-07	2.74E-07	3.36E-08	8.77E-07
PU240	5.69E-07	2.74E-07	3.29E-08	8.75E-07
AM241	9.07E-06	4.37E-06	2.78E-07	1.37E-05
PU242	5.30E-07	2.55E-07	3.16E-08	8.16E-07
AM243	9.12E-06	4.39E-06	3.74E-07	1.39E-05

[h]IMTRHET – To health effects from foliar deposition and subsequent plant use in meat production

[i]IMTWHET – ~~Total health effects~~ from water used for meat production

[j]MTHETOT – Total health effects from meat ingestion due to radionuclide uptake by plants from soil

[k]IRMTHET – IMTRHET + IMTWHET + MTHETOT

Table 1-10. Organs and Risk Factors Considered

Organ/Cancer	Risk Factor EPA[a] (cancer/ind-rem)	Risk Factor Sandia[b] (cancer/ind-rem)
Bone	1.00E-5	9.75E-6
Red Marrow/ Leukemia	4.00E-5	2.85E-5[c]
Lung	4.00E-5	2.5E-5
Liver	1.00E-5	
GI-LLI	2.00E-5	
Stomach		1.15E-5[d]
Pancreas		3.85E-6[d]
Other GI		3.85E-6[d]
Thyroid	1.0[illegible]E-6	
Kidney	1.00E-5	
Breast		2.88E-5[e]
Other	7.00E-5	3.60E-5[e]

[a]From Table 4.3-1 of (Sm81)

[b]From Table 3.4 of (Ru81)

[c]Dose factor for bone used

[d]Dose factor for GI-LLI used

[e]Dose factor for total body used

(see Sm81, p. 93). The values used for all other variables are indicated in Table 1-11.

To generate the values for INMWHET and INTWHET in Table 1-9, it was necessary to know the area AR under consideration. This was obtained by assuming that an irrigation rate IRAT of 300 L/m^2 per yr was used. Then, AR can be expressed in terms of IRAT, F and FRIV.

1.4 Comparison With Environmental Protection Agency Results

The Environmental Protection Agency results for a release to surface water are presented in Table 1-12. As already noted, it is the numbers appearing in the column labeled "TOTAL" of this table that were used in obtaining the Environmental Protection Agency draft standard for radionuclide releases in the context of geologic disposal for high-level waste; these numbers were obtained by summing the numbers in the other columns and represent total population health effects. The population health effects in columns labeled "p = 1" through "p = 8" are now compared with related results in Tables 1-7, 1-8 and 1-9.

The results for drinking water ingestion appearing in column p = 1 of Table 1-12 and column WRHETOT of Table 1-7 were calculated with models that are essentially identical. This similarity tends to be obscured by the differences in notation and derivation technique used in this report and in (Sm81). Therefore, the computational approach used in the two developments will be compared. Much of the apparent difference arises from the nature of the dose factors used. In this regard, the reader is reminded that the dose factors in (Sm81) for ingestion and inhalation yield a 50. year dose commitment from a 1. year exposure. In contrast, in our analysis the dose factors for ingestion and inhalation yield a 70. year dose commitment from a 70. year chronic exposure. For the former dose factors, multiplication of a 1. year ingestion or inhalation rate by the dose factor provides the 50. year commitment from the 1. year of exposure; for the latter dose factors, multiplication of the average annual ingestion or inhalation rate by the dose factor provides the dose commitment over 70. years which results from 70. years of exposure.

Table 1-11. Variables Used in Calculation of Results Presented in Tables 1-7, 1-8 and 1-9

Variable	Definition	Variable	Definition
AIRCON	3.5E-9 kg/m^3 (Bon73, Table 1.4-5)	PDEN	2. kg/m^2 (Nu76, p. 1.109-55)
CMLK	110. L/yr (Nu76, Table D-1)	PMLK	50. kg/day (Nu76, Table A-10)
CMT	95. kg/yr (Nu76, Table D-1)	PMT	50. kg/day (Nu76, Table A-10)
CPLT	190. kg/yr (Nu76, Table D-1)	PO	.5 (To70, Table 4-25)
DE	2800. kg/m^3 (Cu73, Table 34-20)	POROSIT	.5 (To70, Table 4-25)
DENSITY	2800. kg/m^3 (Cu73, Table 34-20)	REXARSD	8.3 hr/yr (Nu76, Table D-1)
DEPTH	.025 m	REXARSL	8760. hr/yr (Nu76, Table D-1)
DFSH	3.3E-7 kg/L (Sm81, p. 87)	REXTSD	8.3 hr/yr (Nu76, Table D-1)
DMLK	1.5E-3 ind/m^2 (Sm81, p. 91)	REXTSL	8760 hr/yr (Nu76, Table D-1)
DMT	2.1E-4 ind/m^2 (Sm81, p. 91)	REXTWAT	8.3 hr/yr (Nu76, Table D-1)
DP	.15m (Sm81, p. 85)	RINGWAT	370. L/yr (Nu76, Table D-1)
DPLT	1.0E-3 ind/m^2 (Sm81, p. 91)	RINHAIR	7300 m^3/yr (Nu76, Table D-1)
DPOP	3.3E-7 ind-yr/L (Sm81, p. 86)	RO	510 L/m^2-yr (To70, Table 2-22)
DSL	6.67E-5 ind/m^2 (Sm81, p. 91)	SA	.5 (To70, Figure 4-2)
ER	.3[illegible] kg-yr/m^2 (To70, Table 2-33)	THINSD	9.5E-4 (Nu76, Table D-1)
FMLK	.25 (Sm81, p. 89)	THINSL	1. (Nu76, Table D-1)
FMT	.25 (Sm81, p. 89)	WHRHL	.038 yr (Boo81)
FPLT	.5 (Sm81, p. 89)	WMLK	60 L/day (Nu76, Table A-10)
FRET	.25 (Boo81)	WMT	50 L/day (Nu76, Table A-10)
FRIV	1.		

Table 1-12. Health Effects per Curie Released for Releases to a River[a]

Nuclide	TOTAL	Drinking Water Ingestion (p = 1)	Freshwater Fish Ingestion (p = 2)	Above Surface Crops Ingestion (p = 3)	Milk Ingestion (p = 4)	Beef Ingestion (p = 5)	Inhalation of Resuspended Material (p = 6)	External Dose - Ground Contam. (p = 7)	External Dose - Air Submersion (p = 8)
C- 14	4.58 E- 2	7.40 E- 5	5.59 E- 4	2.99 E- 2	1.11 E- 2	4.10 E- 3	1.46 E-12	0.0	0.0
Ni- 59									
Sr- 90	1.21 E- 1	8.03 E- 3	6.66 E- 5	1.05 E- 1	7.79 E- 3	1.04 E- 4	7.87 E- 7	0.0	0.0
Zr- 93									
Tc- 99	2.85 E- 4	2.42 E- 5	6.02 E- 7	1.92 E- 4	6.25 E- 5	5.82 E- 6	4.92 E-10	0.0	0.0
Sn-126	1.20 E- 1	1.41 E- 3	7.01 E- 3	6.66 E- 3	2.95 E- 4	2.09 E- 3	3.71 E- 6	1.02 E- 1	5.61 E- 9
I-129	1.08 E- 2	1.63 E- 3	4.05 E- 5	6.43 E- 3	2.44 E- 3	1.84 E- 4	1.22 E- 8	9.19 E- 5	1.54 E-12
Cs-135	3.81 E- 3	2.55 E- 4	1.69 E- 4	2.13 E- 3	9.99 E- 4	2.65 E- 4	1.12 E- 7	0.0	0.0
Cs-137	1.98 E- 2	2.01 E- 3	1.33 E- 3	7.83 E- 3	2.08 E- 3	5.55 E- 4	7.51 E- 8	5.96 E- 3	3.35 E-10
Sm-151									
Ra-226									
U-234									
Np-237	5.96 E- 1	1.30 E- 1	2.15 E- 3	4.60 E- 1	9.21 E- 5	3.90 E- 4	1.03 E- 1	4.55 E- 1	[illegible]
Pu-238	2.29 E- 2	3.92 E- 3	2.28 E- 3	1.42 E- 2	3.03 E- 8	1.16 E- 9	2.40 E- 3	5.16 E- 5	2.63 E-13
Pu-239	6.92 E- 2	4.32 E- 3	2.50 E- 3	2.51 E- 2	5.39 E- 8	2.06 E- 9	3.69 E- 2	3.24 E- 4	1.71 E-12
Pu-240	6.53 E- 2	4.32 E- 3	2.51 E- 3	2.37 E- 2	5.16 E- 8	1.97 E- 9	3.41 E- 2	5.86 E- 4	3.00 E-12
Am-241	7.19 E- 1	1.37 E- 1	5.47 E- 3	5.61 E- 1	8.32 E- 4	3.91 E- 6	1.14 E- 2	8.61 E- 3	1.64 E-10
Pu-242	6.76 E- 2	4.10 E- 3	2.38 E- 3	2.43 E- 2	4.44 E- 6	4.29 E- 8	3.62 E- 2	6.07 E- 4	3.10 E-12
Am-243	2.68 E 0	3.35 E- 1	1.40 E- 2	2.13 E 0	3.28 E- 3	1.55 E- 5	8.93 E- 2	1.13 E- 1	4.61 E- 9

[a]This table is a reprint of Table D-2 of (Sm81).

From (3.1.2-6) in (Sm81), the population exposure from a release to a river is given by

$$S_{nop} = P_R I_W D_{nop} Q_{np}/R, \qquad (1.8)$$

where S_{nop} represents population exposure to organ o from radionuclide n for path p (in this case, p = 1), P_R represents the size of the population exposed each year to drinking water, I_W represents individual water consumption per year, D_{nop} represents the dose factor to organ o from radionuclide n for path p, Q_{np} represents the total release of radionuclide n for path p, and R represents annual river discharge. From the relations in Table 1-4, the same population exposure is given by

$$\mathrm{RINGWAT*TD(I)*WT(I)*DFING(I,J)*DPOP/70.} \qquad (1.9)$$

The expressions for population exposure in (1.8) and (1.9) are essentially the same as the following correspondences exist:

P_R/R = DPOP = 3.3E-7 ind-yr/L in both analyses

$$I_W = \mathrm{RINGWAT} = \begin{cases} 603 \text{ L/yr in EPA analysis} \\ 370 \text{ L/yr in present analysis} \end{cases}$$

Q_{np} = TD(I) = 1. Ci in both analyses

WT(I) = 1. in both analyses.

The difference between the expressions D_{nop} and DFING(I,J)/70. arises from the nature of the dose factors: this is best seen by first calculating an individual dose commitment and then converting to a population dose commitment.

From (3.1.2-1) in (Sm81), the 50. year dose commitment to an individual from the radionuclides in water ingested during 1. year is given by

$$DI'_{nop} = Q'_{np} I_W D_{nop}/R. \qquad (1.10)$$

For the preceding relation, DI_{nop} and Q_{np} are being considered functions of time $DI_{nop}(t)$ and $Q_{np}(t)$ such that $DI_{nop}(t)$ is the total dose commitment to an individual from birth to time t and $Q_{np}(t)$ is the total radionuclide release from time 0 to time t. Then, $DI'_{nop}(t)$ and $Q'_{np}(t)$ represent the derivatives of these functions with respect to time and thus correspond to annual individual dose commitment rate at time t and annual discharge rate at time t. Multiplication of the expression in (1.10) by population size P_R yields the population dose commitment rate

$$S'_{nop} = DI'_{nop} P_R = Q'_{np} I_W D_{nop} P_R/R. \qquad (1.11)$$

Now, integration can be used to recover S_{nop} for a time period of length T in the following manner:

$$\begin{aligned} S_{nop}(T) &= \int_0^T S'_{nop}(t)dt \\ &= \int_0^T Q'_{np}(t) I_W D_{nop} P_R/R dt \qquad (1.12) \\ &= Q_{np}(T) I_W D_{nop} P_R/R. \end{aligned}$$

which yields the relation in (1.8).

In comparison, Table 1-4 provides the following expression for a 70. year dose commitment to an individual from a chronic 70. year exposure:

RINGWAT*TD(I)*WT(I)*DFING(I,J)/(F*T). (1.13)

The expression for total population size is derived from the assumptions that the size of the population exposed to drinking water each year is DPOP*F, that the time period considered is of length T, and that the average life expectancy is 70. years. Thus, if T is significantly larger than 70., then the total number of individuals exposed is given by

$$DPOP*F*T/70. \tag{1.14}$$

Now, multiplication of the expressions in (1.13) and (1.14) yields the relation in (1.9).

The use of derivatives and integrals in (1.10), (1.11), and (1.12) tends to obscure the relation between the expressions in (1.8) and (1.9). Therefore, the expression in (1.10) for individual dose commitment will be reconsidered with an average annual discharge rate rather than a time varying discharge rate obtained by differentiating $C_{np}(t)$. Specifically, with the assumption that a total discharge of size Q_{np} takes place over a time period of length T, the expression for 50. year dose commitment to an individual from 1. year of exposure in (1.10) becomes

$$Q_{np}I_W D_{nop}/(R*T). \tag{1.15}$$

and so the dose commitment to an individual from 50. years of exposure can be estimated as

$$Q_{np}I_W D_{nop}*50./(R*T). \tag{1.16}$$

The expression for lifetime dose commitment in (1.16) from the Environmental Protection Agency analysis is comparable to the similar expression in (1.13) for lifetime dose commitment. For both expressions, multiplication by total population size for the time period considered will yield population dose. The population for (1.16) is

$$P_R*T/50. = DPOP*F*T/50. \tag{1.17}$$

while the population for (1.13) is given in (1.14). Now, multiplication of the expressions in (1.16) and (1.17) will yield (1.8). Similarly, multiplication of the expressions in (1.13) and (1.14) will yield (1.9).

Overall, the results appearing for drinking water ingestion in Tables 1-12 and 1-7 are quite similar. In most cases, the difference was less than one order of magnitude; however, in a few cases the difference was greater. As both approaches used the same technique to calculate surface water concentration, the differences are due to the water ingestion rates assumed, the cancers considered and the dose and risk factors used. The organs and risk factors used for ingestion and inhalation calculations are given in Table 1-10. Further, the differences in the dose factors considered has already been discussed.

The results for freshwater fish ingestion appearing in column p = 2 of Table 1-13 and column FHHETOT of Table 1-7 were calculated with models that are essentially identical. Again, the results are similar; in most cases, the results are within an order of magnitude. However, in some cases, the difference is closer to two orders of magnitude. As for water ingestion, differences are introduced by the cancers, dose factors and risk factors used. Although most of the concentration ratios from water to fish used in the two analyses are similar, some variation is also introduced here (see Table 5-2 of (Sm81) and Table A-8 of (Nu76)).

The results for plant ingestion appearing in column p = 3 of Table 1-12 and column IRPLHET of Table 1-9 are calculated with similar models. Both models have a submodel for radionuclide build-up on plants due to sprinkler irrigation and a submodel for radionuclide build-up in soil. For IRPLHET, the population health effects associated with these two submodels are given in the columns labeled IPLRHET and PLHETOT, respectively, in Table 1-9; no such distinction is made in the results presented in (Sm81). For both analyses, a radionuclide release is assumed to take place to soil through sprinkler irrigation with 50 percent of the soil being used to grow plant material for direct human consumption. In the Environmental Protection Agency study (Sm81), it is assumed that a .5 curie release to the soil for each radionuclide takes place; for the calculations that generated Table 1-9, a 1. curie release is assumed to take place. Therefore, as the models are linear with respect to radionuclide input, the appropriate comparison between the ingestion rates should be made with the indicated values for IRPLHET divided by 2. Both models use the same exponential model for radionuclide build-up on plants due to sprinkler irrigation (i.e., the submodel used in determining IPLRHET); however, some of the parameters used within the model were different (e.g., .20 for fraction of radionuclides initially retained in the Environmental Protection Agency analysis and .25 in our analysis). Both models also use similar exponential models to represent radionuclide build-up in the soil (i.e., the submodel used in determining PLHETOT). In the Environmental Protection Agency analysis, radionuclide removal is by water flow and radioactive decay. Our analysis includes those two removal mechanisms and also solid-material outflow. However, the models may differ in some details (e.g., the exact manner in which the rate constants for radionuclide outflow in water were determined) and in the actual parameters used in the analyses (e.g., water outflow rates, distribution coefficients). However, the final calculated health effects are generally within an order of magnitude of each other. The differences are probably due to the different cancers, dose factors and risk factors considered and to the different values used for the same or similar parameters. Also, the inclusion of soil removal (i.e., erosion) in the calculation of PLHETOT may have an effect.

The results for milk ingestion appearing in column p = 4 of Table 1-12 can be compared with the sum of the values appearing in columns IMKRHET and MKHETOT of Table 1-9. In both analyses, it is assumed that 25 percent of the avail· le land is used to grow plant material for use in mil, production. The values for IMKRHET result from the radionuclides retained on plants due to sprinkler irrigation and the values for MKHETOT result from the radionuclides in plants due to uptake from soil. As for direct plant ingestion, the results in Table 1-12 are the sum of these two paths. Also, as a 1. curie release was considered in the generation of the results contained in Table 1-9, the proper comparison is between the values in Table 1-12 and one-half of the sum of IMKRHET and MKHETOT. As radionuclide concentration in plants for animal feed was determined in the same manner as radionuclide concentration in plants for human consumpt.on, the discussion in the preceding paragraph is also relevant to the present comparison. There is a considerable amount of difference between the milk ingestion results in the Environmental Protection Agency analysis and in our analysis. Although the results are similar for some radionuclides, for other radionuclides a difference of up to three orders of magnitude exists. These differences are probably caused by factors of the type already indicated. However, to identify the major causes of these differences, it would be necessary to compare calculations for the same radionuclides on a parameter-by-parameter basis. The health effects that result from radionuclides in livestock water for dairy cattle are indicated in column IMKWHET of Table 1-9. This path is not included in the calculation of the results presented in Table 1.12.

The results for beef ingestion appearing in column p = 5 of Table 1-12 can be compared with the sum of values appearing in columns IMTRHET and MTH2TOT of Table 1-9. As the calculations for beef ingestion are the same as those for milk ingestion except for the use of appropriate concentration ratios and ingestion rates, the discussion for milk ingestion also pertains to beef ingestion. Overall, the results for beef ingestion for the two analyses are more similar than those for milk ingestion. For most radionuclides, the results are within one order of magnitude. However, in some cases, this difference goes up to approximately two orders of magnitude. The health effects that result from radionuclides in livestock water for beef cattle are indicated in column IMTWHET of Table 1-9. As for milk consumption, this path is not included in the calculation of the results presented in Table 1-12.

Results in the Environmental Protection Agency analysis for health effects due to inhalation of suspended material, external exposure due to ground contamination and external exposure due to suspended material in air are presented in columns p = 6, p = 7, and p = 8, respectively, of Table 1-12. Similar results for our analysis are presented in columns INSLTOT, EXSLTOT, and EXARSLT, respectively, of Table 1-8. As our analysis was for a total release of 1. curie, the values in Table 1-12 should be compared with one-half the corresponding values in Table 1-8. Generally, the results in our analysis are one to two orders of magnitude below corresponding results in Table 1-12. In the Environmental Protection Agency analysis, it is assumed that all radionuclides in the soil are concenttrated on the surface for the calculation of the exposure modes now under consideration (see Equations (3.1.5-9) and (3.1.5-10) in (Sm81)). This alone is sufficient to cause discernable differences between the results.

To determine inhalation exposure, the Environmental Protection Agency obtained suspended radionuclide concentration through multiplication of surface radionuclide concentration (units: Ci/m^2) by a resuspension factor of 10^{-9} m^{-1} (Sm81, p. 92). In contrast, we obtained suspended radionuclide concentration by multiplication of soil radionuclide concentration (units: Ci/m^3) by an assumed concentration of suspended material in air of 3.5E-9 kg/m^3. For an assumed amount X of a particular radionuclide in a soil region of area AR, the Environmental Protection Agency approach yields a suspended concentration of

$$(X/AR)*10^{-9} = X*10^{-9}/AR\ Ci/m^3 \qquad (1.18)$$

while our approach yields a suspended radionuclide concentration of

$$(X/(AR*.15*2800.*.5))*3.5E\text{-}9$$

$$= (X/AR)*1.7E\text{-}11\ Ci/m^3. \qquad (1.19)$$

Thus, this difference alone will cause the results from Tables 1-12 and 1-8 for inhalation of radionuclides and external exposure to suspended radionuclides to differ by a factor of approximately 59. Similarly, for ground exposure, we assume that only the radionuclides in the top 2.5 cm of the soil are available for external exposure. Thus, as our soil was assumed to be 15. cm deep and the Environmental Protection Agency analysis assumed that all radionuclides in soil were on the surface, this difference alone will cause the results from Table 1-12 and 1-8 for ground exposure to differ by a factor of 6. Other differences are due to the cancers, dose factors and risk factors considered and to the individual parameters used in determining the amount of each radionuclide in soil.

In summary, the population health effects in our analysis were generally within one to two orders of magnitude of the results obtained in the Environmental Protection Agency analysis. However, in some cases, the differences were closer to three orders of magnitude. As the two analyses used similar models, these differences are due primarily to the cancers, dose factors, and risk factors used and to the parameters actually used within the models. If desired, the exact cause of the differences can be determined for individual radionuclides and specific exposure pathways from a parameter by parameter comparison of the two calculations.

1.5 Discussion

Overall, it is felt that the computational relationships indicated in Tables 1-4, 1-5 and 1-6 will yield conservative results. For example, no radionuclide removal by sedimentation is considered in the results related to surface-water concentration in Table 1-4. However, the individual using these relationships has a great deal of control on the conservatism of the final calculated results through the selection of ingestion rates, concentration ratios, risk factors, constants used in the definition of population size, and other parameters.

The relationships presented in Tables 1-4, 1-5 and 1-6 provide a convenient way to observe the differences between exposures to individuals and populations. In particular, the exposure to individuals can vary dramatically while population exposure remains unchanged. This results from the assumed linearity of the processes considered. Thus, while length of release and size of river receiving the release will affect individual exposure, these properties will not affect population exposure obtained with the models in use.

Computational relationships of the form given in Tables 1-4, 1-5 and 1-6 provide a way of comparing hazards from different substances. They could be used to compare risks between artificially and naturally occurring radioactivity. Also, there is nothing in the models which is inherently tied to radioactive materials. Therefore, provided appropriate dose and risk factors were defined, they could be used to calculate the consequences associated with nonradioactive pollutants. In turn, such values could be used in the comparison of the risks associated with waste disposal and the risks associated with other activities. In making such comparisons, it is essential that the compared risks be calculated in the same manner and with the same degree of conservatism. Otherwise, the comparisons are meaningless. Hopefully, with relatively simple models such as those in Tables 1-4, 1-5 and 1-6, it would be possible to treat all the substances considered in the same manner.

The computational relationships in Tables 1-4, 1-5 and 1-6 provide a way to screen for the most appropriate radionuclides to consider in the regulation of geologic disposal of high-level waste. The consequences associated with a unit release of each radionuclide of possible interest can be calculated. These consequences can then be weighted by the inventory of the radionuclide present. Once this has been done for all radionuclides, consideration of the relative size of the weighted consequences provides one way to select the radionuclides for regulatory consideration.

Unfortunately, many of the variables used in Tables 1-4, 1-5 and 1-6 will be imprecisely known in any analysis. The relative simplicity of the relationships in these tables permits an easy inspection of the effects of uncertainty in individual variables. Quite often, this effect is linear. For example, a doubling of the water ingestion rate will double the associated consequences. Discernment of the effects of variation in several (possibly correlated) variables is more difficult. However, techniques exist which can be used in such analyses (Im76).

Tables 1-7, 1-8 and 1-9 present the population health effects for the various pathways considered in Tables 1-4, 1-5 and 1-6 with a release of 1. Ci. The individual parameters used in the associated calculations are indicated in Section 1.3. It is often possible to investigate the effects of other parameters without reproducing an entire calculation. For example, the health effects for a water ingestion rate of 603. L/yr (Sm81, p. 86) rather than 370. L/yr can be obtained by multiplying the results in column WRHETOT of Table 1-7 by 603./370. The combined effects of various release modes can be obtained by taking appropriate linear combinations of values in Tables 1-7, 1-8 and 1-9. For example, the population health effects for each radionuclide due to water and plant ingestion resulting from a release to a river with 10 percent of the river used for flood irrigation are given by

$$1.*\mathrm{WRHETOT} + .1*\mathrm{FLHETOT}. \qquad (1.20)$$

Such relationships can be used to investigate different sites and different assumptions about a specific site.

This discussion ends with a caveat. The models presented are very simple and probably tend to overestimate health effects. They will certainly do so if one is sufficiently aggressive in seeking out conservative values for the individual parameters in the models. Therefore, care must be exercised in the interpretation and presentation of model predictions. In particular, care must be taken in comparing results obtained with these models with results obtained with other methods. However, there is also an advantage to this simplicity. It permits consideration of different hazards at an equivalent level of complexity.

2. Mixed-Cell Models

The exposure calculations presented in later chapters are based on radionuclide concentrations obtained by using one compartment mixed-cell models. For releases to surface water, no radionuclide partitioning within the cell is considered. However, for releases to soil, such partitioning is considered. To facilitate presentation of the later exposure calculations, derivations are presented in this chapter for the differential equations which underlie the models in use. This presentation is adapted from Sections B-2 and B-3 of Helton and Finley (He82).

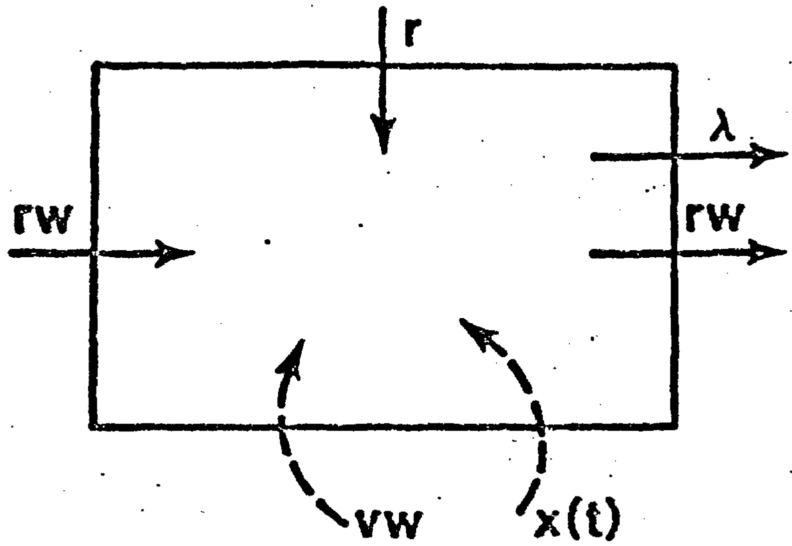
The differential equation for a single uniformly-mixed cell without radionuclide partitioning between a liquid and a solid phase is presented first. The situation under consideration is indicated in Figure 2-1. The cell is assumed to have a constant volume VW (units: L). Further, it is assumed that water enters and leaves the cell at a rate RW (units: L/yr) and that a radionuclide with decay constant λ (units: yr^{-1}) enters the cell at a rate R (units: Ci/yr). It is desired to determine the amount X(t) (units: Ci) of the radionuclide present in the cell at time t (units: yrs). The basic assumption used in deriving X(t) is that the cell is uniformly-mixed; mathematically, this means that the radionuclide concentration C(t) (units: Ci/L) at any time t is given by

$$C(t) = X(t)/VW. \qquad (2.1)$$

A differential equation representing the rate of change of X(t) is now derived. Then, X(t) can be obtained by solving this equation. The derivative dX(t)/dt (units: Ci/yr) is defined by the limit

$$\lim_{\Delta t \to 0} \frac{X(t + \Delta t) - X(t)}{\Delta t} \qquad (2.2)$$

and represents the rate at which X(t) is changing. In turn, this rate is equal to the difference between the rate R_1 (units: Ci/yr) at which the radionuclide is entering the cell and the rate R_2 (units: Ci/yr) at which the radionuclide is leaving the cell. The rate



R: rate at which radionuclide enters cell (units: Ci/yr)

RW: rate at which water enters and leaves cell (units: L/yr)

λ: decay constant for radionuclide (units: yr^{-1})

VW: volume of water in cell (units: L)

X(t): amount of radionuclide in cell at time t (units: Ci)

Figure 2-1. Flows Associated With a Single Uniformly-Mixed Cell With no Radionuclide Partitioning Between a Liquid and a Solid Phase.

R_1 is given by R. The rate R_2 is the sum of two components: a rate due to physical flow out of the cell, and a rate due to radioactive decay. The rate due to physical flow is equal to the product of the radionuclide concentration $X(t)/VW$ in the cell and the rate of water flow RW out of the cell; the rate due to decay is equal to the product of the decay constant λ and the amount $X(t)$ of radionuclide present. Thus,

$$R_1 = R \text{ and } R_2 = [(RW/VW) + \lambda]\, X(t), \tag{2.3}$$

and hence, the desired equation is given by

$$\begin{aligned} dX(t)/dt &= R_1 - R_2 \\ &= R - [(RW/VW) + \lambda]\, X(t). \end{aligned} \tag{2.4}$$

Also associated with the preceding equation is an initial value condition $X(0) = X_0$, which represents the amount of radionuclide present at time $t = 0$.

Thus, determination of $X(t)$ reduces to the solution of an initial value problem of the form

$$dX(t)/dt = R - AX(t),\ X(0) = X_0, \tag{2.5}$$

where

$$A = (RW/VW) + \lambda\ . \tag{2.6}$$

Such problems are relatively easy to solve and applicable solution techniques include separation of variables, introduction of integration factors, and application of Laplace transforms. The preceding techniques are discussed in introductory texts on differential equations and lead to the following unique solution for the initial value problem in (2.5):

$$X(t) = e^{-At} X_0 + (R/A)(1 - e^{-At}). \tag{2.7}$$

If the initial value condition is $X(0) = 0$, then the preceding solution becomes

$$X(t) = (R/A)(1 - e^{-At}). \qquad (2.8)$$

Further, regardless of the initial value condition, the steady state or asymptotic solution SX to which any solution of (2.5) converges is given by

$$SX = \lim_{t \to \infty} X(t)$$

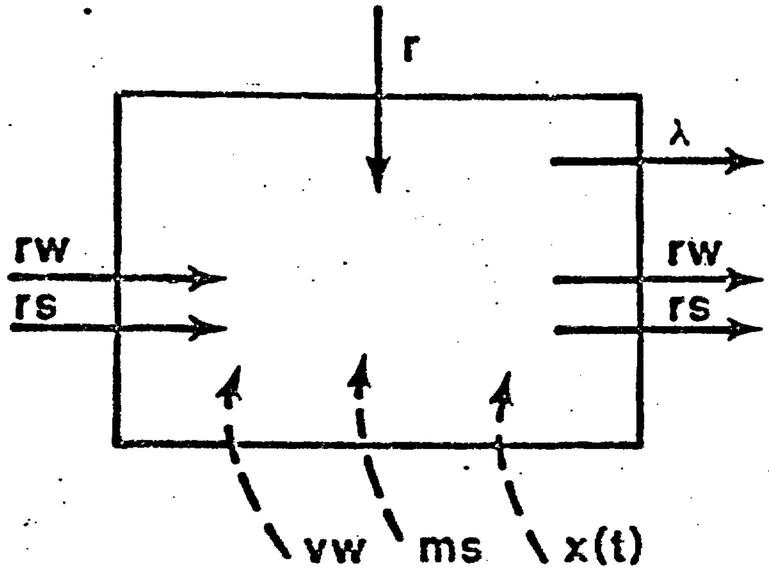
$$= \lim_{t \to \infty} [e^{-At} X_0 + (R/A)(1 - e^{-At})]$$

$$= R/A, \qquad (2.9)$$

provided $A > 0$.

The differential equation for a single uniformly-mixed cell with radionuclide partitioning between a liquid and a solid phase is presented next. The situation under consideration is indicated in Figure 2-2. The cell is assumed to have a constant volume VW (units: L) and to contain a constant mass MS of solid material (units: kg). Further, it is assumed that water enters and leaves the cell at a rate RW (units: L/yr), that solid material enters and leaves the cell at a rate RS (units: kg/yr), and that a radionuclide with decay constant λ (units: yr^{-1}) enters the cell at a rate R (units: Ci/yr). The partitioning of the radionuclide between the liquid and solid phases of the system is assumed to be described by the ratio

$$FL = \frac{\text{conc. of radionuclide sorbed to solids}}{\text{conc. of radionuclide dissolved in water}} = \text{[illegible]}, \qquad (2.10)$$



R: rate at which radionuclide enters cell (units: Ci/yr)

RW: rate at which water enters and leaves cell (units: L/yr)

RS: rate at which solid material enters and leaves cell (units: kg/yr)

λ: decay constant for radionuclide (units: yr^{-1})

VW: volume of water in cell (units: L)

MS: mass of solids in cell (units: kg)

X(t): amount of radionuclide in cell at time t (units: Ci)

Figure 2-2. Flows Associated With a Single Uniformly-Mixed Cell With Radionuclide Partitioning between a Liquid and a Solid Phase.

where AS (units: Ci) is the amount of radionuclide in the system sorbed to solids and AW (units: Ci) is the amount of radionuclide in the system dissolved in water. The ratio in (2.10) is known as a KD-value or a distribution coefficient.

It is desired to determine the amount X(t) (units: Ci) of the radionuclide present in the cell at time t (units: yr). Three basic assumptions underlie the derivation of X(t). First, it is assumed that the radionuclide is uniformly distributed through the cell and is partitioned between the liquid and solid phases on the basis of its distribution coefficient. A derivation for this partitioning is presented in the next paragraph. Second, it is assumed that the flow of water and solid material out of the cell is the only mechanism involved in the physical transport of the radionuclide. Third, it is assumed that all radionuclides associated with a phase, liquid or solid, remain with that phase in movements out of the cell. In essence, the cell is treated as a uniformly mixed "vessel" in which the radionuclides are partitioned between the liquid and solid phases on the basis of the distribution coefficient and such that radionuclides can be carried out of this "vessel" and out of the system only by movements of water or solid material.

A derivation for the partitioning of a radionuclide between the liquid and solid phases of a system is now presented. The following notation is used in the derivation:

X = amount of radionuclide in system (units: Ci),

XS = amount of radionuclide in system sorbed to solids (units: Ci),

XW = amount of radionuclide in system dissolved in water (units: Ci),

MS = mass of solid in system (units: kg),

VW = volume of water in system (units: L).

Assume X, MS, VW, and KD are known for the system under consideration. Now, XS and XW are determined. Since

$$KD = (XS/MS)(XW/VW)^{-1} \text{ and } X = XS + XW, \qquad (2.11)$$

we have that

$$(KD)(MS) = (XS)(VW)(XW)^{-1} \text{ and } XW = X - XS. \qquad (2.12)$$

Thus,

$$(KD)(MS) = (XS)(VW)(X - XS)^{-1}. \qquad (2.13)$$

Further, multiplication by (X - XS) gives

$$(KD)(MS)(X) - (KD)(MS)(XS) = (XS)(VW) \qquad (2.14)$$

or

$$(KD)(MS)(X) = [(KD)(MS) + VW]\, XS, \qquad (2.15)$$

and hence

$$XS = \left[\frac{(KD)(MS)}{(KD)(MS) + VW}\right] X. \qquad (2.16)$$

Further, since XW = X - XS,

$$XW = \left[1. - \frac{(KD)(MS)}{(KD)(MS) + VW}\right] X. \qquad (2.17)$$

The relations in (2.16) and (2.17) represent the desired partitioning.

A differential equation representing the rate of change of X(t) is now derived. Then, X(t) can be obtained by solving this equation. The following derivation is similar to that previously presented for a uniformly-mixed cell without partitioning. As for that case, dX(t)/dt is equal to the difference between the rate R_1 at which the radionuclide is entering the cell and the rate R_2 at which the radionuclide is leaving the cell. The rate R_1 is given by R. The rate R_2 is the sum of three components: a rate due to physical flow out of the cell with solid material, a rate due to physical flow out of the cell with water, and a rate due to radioactive decay. The two rates due to physical flow are equal to the products of the concentrations XS(t)/MS and XW(t)/VW with the flow rates RS and RW, where XS(t) represents the amount of radionuclide in the cell sorbed to solid material and XW(t) represents the amount of radionuclide in the cell dissolved in water. The functions XS(t) and XW(t) can be obtained from (2.16) and (2.17). The rate due to decay is equal to the product of the decay constant and the amount X(t) of radionuclide present. Thus,

$$R_1 = R \qquad (2.18)$$

and

$$R_2 = [XS(t)/MS][RS] + [XW(t)/VW]\,[RW] + \lambda\, X(t)$$

$$= \left[\frac{(KD)(MS)}{(KD)(MS) + VW}\right]\left[X(t)\right]\left[\frac{RS}{MS}\right]$$

$$+ \left[1. - \frac{(KD)(MS)}{(KD)(MS) + VW}\right]\left[X(t)\right]\left[\frac{RW}{VW}\right] + \lambda\, X(t)$$

[From (2.16) and (2.17)]

$$= \left[\frac{S(RS)}{MS} + \frac{(1. - S)(RW)}{VW} + \lambda\right] X(t) \qquad (2.19)$$

where

$$S = \frac{(KD)(MS)}{(KD)(MS) + VW} . \tag{2.20}$$

Hence, the desired equation is given by

$$dX(t)/dt = R_1 - R_2$$

$$= R - \left[\frac{S(RS)}{MS} + \frac{(1. - S)(RW)}{VW} + \lambda\right] X(t). \tag{2.21}$$

Also associated with the preceding equation is an initial value condition $X(0) = X_0$.

Thus, determination of $X(t)$ reduces to the solution of an initial value problem of the form

$$dX(t)/dt = R - AX(t),\ X(0) = X_0, \tag{2.22}$$

where

$$A = \frac{S(RS)}{MS} + \frac{(1. - S)(RW)}{VW} + \lambda \tag{2.23}$$

with S defined as in (2.20). Various forms of the solution to the preceding initial value problem are given in (2.7), (2.8), and (2.9).

3. Release to Surface Water

3.1 Preliminary Comments

Population exposures and resultant health effects are now calculated for radionuclide release to a surface-water body. In particular, WRDS(I,J),WRHE(I,J) and WRHETOT(I) are determined for exposure from water consumption, where

WRDS(I,J) = population dose (units: rems) to organ associated with cancer J from radionuclide I,

WRHE(I,J) = number of occurrences of cancer J in population due to radionuclide I,

WRHETOT(I) = total number of cancers in population due to radionuclide I.

Similarly, FHDS(I,J), FHHE(I,J) and FHHETOT(I) are determined for fish ingestion; INSDDS(I,J), INSDHE(I,J) and INSDTOT(I) are determined for inhalation of suspended sediment; EXWRDS(I,J), EXWRHE(I,J) and EXWRTOT(I) are determined for water immersion; EXSDDS(I,J), EXSDHE(I,J) and EXSDTOT(I) are determined for external exposure from shoreline sediments; and EXARSDD(I,J), EXARSDH(I,J) and EXARSDT(I) are determined for external exposure from suspended sediments.

The quantities indicated in the preceding paragraph are obtained in the following manner. First, individual radionuclide exposure rates are determined. Then, these exposure rates are used in conjunction with appropriate dose and risk factors to yield individual dose and risk for selected organs and cancers. Next, these individual doses and risks are multiplied by population size to obtain population dose and risk for selected organs and cancers. Further, as many algebraic simplifications as possible are carried out; due to the nature of the models used, this results in relatively simple expressions for population dose and risk which are independent of the population size, river size, and time period considered. Finally, population risk from the various cancers is summed to give an overall population risk estimate.

It is assumed that the surface-water body under consideration can be represented as a single uniformly-mixed cell as described by the differential equation appearing in (2.5). For radionuclide I, it is assumed that a release of size TD(I) (units: Ci) takes place into the surface water over a time period of length T (units: yrs). Further, for use in (2.5), it is assumed that the annual discharge (units: Ci/yr) for radionuclide I is given by TD(I)/T. Thus, for each radionuclide, the asymptotic concentration (units: Ci/L) in the surface water is given by

$$CW(I) = TD(I)/F*T , \tag{3.1}$$

where F denotes the annual flow (units: L/yr) of the river which constitutes the surface water body under consideration.

As in the EPA analysis (Sm81), it is assumed that population size and fish production are linear, homogeneous functions of river flow F. That is, it is assumed that

$$POP = DPOP*F \tag{3.2}$$

and

$$FSH = DFSH*F , \tag{3.3}$$

where

POP = population (units: ind*) supported by river

DPOP = constant (units: ind per L/yr)

FSH = fish production (units: kg/yr) supported by river

DFSH = constant (units: kg/yr per L/yr).

Further, with an assumed life expectancy of 70. yr, the total population TP (units: ind) supported by the river over a time period of length T is

---

*individuals

$$TP = DPOP*F*T/70. \tag{3.4}$$

3.2 Exposure From Water Consumption

The population exposures and resultant health effects are now calculated for water ingestion. It follows from (3.1) that the amount of radionuclide I ingested by an individual (units: Ci/yr) is given by

$$CW(I)*RINGWAT*WT(I) = RINGWAT*TD(I)*WT(I)/F*T , \tag{3.5}$$

where

RINGWAT = individual water ingestion rate (units: L/yr)

WT(I) = water treatment removal factor for radionuclide I (units: unitless).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

$$RINGWAT*TD(I)*WT(I)*DFING(I,J)/F*T \tag{3.6}$$

and

$$RINGWAT*TD(I)*WT(I)*DFING(I,J)*RISK(J)/F*T , \tag{3.7}$$

respectively.

Population exposure and risk now follow from the expressions in (3.6) and (3.7). Specifically, with use of the relation in (3.4),

$$\begin{aligned} WRDS(I,J) &= [RINGWAT*TD(I)*WT(I)*DFING(I,J)/F*T] \\ &\quad *[DPOP*F*T/70.] \\ &= RINGWAT*TD(I)*WT(I)*DFING(I,J)*DPOP/70. \end{aligned} \tag{3.8}$$

and

$$WRHE(I,J) = [RINGWAT*TD(I)*WT(I)*DFING(I,J)*RISK(J)/F*T]$$

$$*[DPOP*F*T/70.]$$

$$= RINGWAT*TD(I)*WT(I)*DFING(I,J)*RISK(J)$$

$$*DPOP/70. \qquad (3.9)$$

Thus, the total cancers from radionuclide I are given by

$$WRHETOT(I) = \Sigma_J WRHE(I,J) . \qquad (3.10).$$

3.3 Exposure from Fish Consumption

The population exposures and resultant health effects are now calculated for fish ingestion. It follows from (3.2) and (3.3) that average individual fish consumption is

$$(DFSH*F)/(DPOP*F) = DFSH/DPOP . \qquad (3.11)$$

Thus, it follows from (3.1) that the amount of radionuclide I ingested by an individual from fish consumption (units: Ci/yr) is given by

$$CW(I)*CRWF(I)*(DFSH/DPOP)$$

$$= TD(I)*CRWF(I)*DFSH/(DPOP*F*T) . \qquad (3.12)$$

where

CRWF(I) = concentration ratio for radionuclide I from water to fish (units: Ci/kg per Ci/L).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

(TD(I)*CRWF(I)*DFSH*DFING(I,J))/(DPOP*F*T)   (3.13)

and

(TD(I)*CRWF(I)*DFSH*DFING(I,J)*RISK(J))

/(DPOP*F*T) ,   (3.14)

respectively.

Population exposure and risk now follow from the expressions in (3.13) and (3.14). Specifically, with use of the relation in (3.4),

FHDS(I,J) = |[TD(I)*CRWF(I)*DFSH*DFING(I,J)]

/[DPOP*F*T]| * |DPOP*F*T/70.|

= TD(I)*CRWF(I)*DFSH*DFING(I,J)/70   (3.15)

and

FHHE(I,J) = |[TD(I)*CRWF(I)*DFSH*DFING(I,J)*RISK(J)]

/[DPOP*F*T]| * |DPOP*F*T/70.|

= TD(I)*CRWF(I)*DFSH*DFING(I,J)*RISK(J)/70.

(3.16)

Thus, the total cancers from radionuclide I are given by

$$FHHETOT(I) = \Sigma_J \; FHHE(I,J) \; . \qquad (3.17)$$

3.4 Exposure From Inhalation of Suspended Sediment

The population exposures and resultant health effects are now calculated for inhalation of suspended sediment. For this calculation and for subsequent exposure calculations involving sediment, it is assumed that sediment concentration CSED(I) (units: Ci/kg) of the I^{th} radionuclide is given by

$$CSED(I) = DCOEF(I)*CW(I)$$

$$= DCOEF(I)*TD(I)/F*T \; , \qquad (3.18)$$

[From (3.1)]

where

DCOEF(I) = distribution coefficient for radionuclide I (units: Ci/kg per Ci/L).

Hence, the amount of radionuclide I inhaled by an individual (units: Ci/yr) is given by

CSED(I)*AIRCON*RINHAIR*TMINSD

= DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD/F*T , (3.19)

where

AIRCON = concentration of suspended sediment in the air (units: kg/m^3),

RINHAIR = rate of inhalation (units: m^3/yr),

TMINSD = fraction of year that individual is exposed to suspended sediment (units: unitless).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

[DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD*DFINH(I,J)]/[F*T]

. (3.20)

and

[DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD*DFINH(I,J)

*RISK(J)]/[F*T] , (3.21)

respectively.

Population exposure and risk now follow from the expressions in (3.20) and (3.21). Specifically, with the use of the relation in (3.4),

INSDDS(I,J) = {[DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD

*DFINH(I,J)]/[F*T]} * {DPOP*F*T/70.}

= [DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD

*DFINH(I,J)*DPOP]/70. (3.22)

and

INSDHE(I,J) = {[DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD

*DFINH(I,J)*RISK(J)]/[F*T]} * {DPOP*F*T/70.}

= [DCOEF(I)*TD(I)*AIRCON*RINHAIR*TMINSD

*DFINH(I,J)*RISK(J)*DPOP]/70. (3.23)

Thus, the total cancers from radionuclide I are given by

$$INSDTOT(I) = \Sigma_J \; INSDHE(I,J) \quad . \tag{3.24}$$

3.5 Exposure From Water Immersion

The population exposures and resultant health effects are now calculated for water immersion. The external exposure (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

$$CW(I)*REXTWAT*DFEXT(I,2,J)*70.*1000.$$

$$= TD(I)*REXTWAT*DFEXT(I,2,J)*7.E4/F*T \tag{3.25}$$

[From (3.1)]

and

$$TD(I)*REXTWAT*DFEXT(I,2,J)*7.E4*RISK(J)/F*T \quad , \tag{3.26}$$

where

REXTWAT = exposure rate to contaminated water (units: hr/yr),

70. = average life expectancy (units: yr/ind)

1000. = liters per cubic meter (units: L/m^3).

The factors 70. yr/ind and 1000. L/m^3 appear in (3.25) to produce necessary unit conversions.

Population exposure and risk now follow from the expressions in (3.25) and (3.26). Specifically, with use of the relation in (3.4),

EXWRDS(I,J) = [TD(I)*REXTWAT*DFEXT(I,2,J)*7.E4/F*T]

*[DPOP*F*T/70.]

= TD(I)*REXTWAT*DFEXT(I,2,J)*DPOP*1.E3 (3.27)

and

EXWRHE(I,J) = [TD(I)*REXTWAT*DFEXT(I,2,J)*7.E4*RISK(J)

/F*T]*[DPOP*F*T/70.]

= TD(I)*REXTWAT*DFEXT(I,2,J)*RISK(J)

*DPOP*1.E3. (3.28)

Thus, the total cancers from radionuclide I are given by

$$EXWRTOT(I) = \sum_J EXWRHE(I,J) \; . \qquad (3.29)$$

3.6 <u>Exposure From Shoreline Sediment</u>

The population exposures and resultant health effects are now calculated for external exposure to shoreline sediment. For these calculations, it is first necessary to determine a surface radionuclide concentration. To do this, it is assumed that all radionuclides down to a certain depth in the sediment are concentrated on the sediment surface. Then, the surface concentration CSURF(I) (units: Ci/m^2) for radionuclide I is given by

CSURF(I) = CSED(I)*DEPTH*DENSITY*(1. - [illegible])

= DCSED(I)*TD(I)*DEPTH*DENSITY*(1. - [illegible]

/F*T , [illegible]

[From (3.[illegible])]

where

DEPTH = depth to which radionuclides are assumed to be concentrated on surface (units: m),

DENSITY = mean particle density of sediment (units: kg/m^3),

POROSIT = porosity of sediments (units: unitless).

Hence, the external exposure (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

CSURF(I)*REXTSD*DFEXT(I,1,J)*70.

= [DCOEF(I)*TD(I)*DEPTH*DENSITY*(1. - POROSIT)/F*T]

*[REXTSD*DFEXT(I,1,J)*70.]   (3.31)

[From (3.30)]

and

[DCOEF(I)*TD(I)*DEPTH*DENSITY*(1. - POROSIT)/F*T]

*[REXTSD*DFEXT(I,1,J)*70.]*RISK(J) .   (3.32)

respectively, where

REXTSD = exposure rate to sediment (units: hr/yr),

70. = average life expectancy (units: yr/ind).

Population exposure and risk now follow from the expressions in (3.31) and (3.32). Specifically, with use of the relation in (3.4),

$$EXSDDS(I,J) = [DCOEF(I)*TD(I)*DEPTH*DENSITY *(1. - POROSIT)/F*T]*[REXTSD*DFEXT(I,1,J) *70.]*[DPOP*F*T/70.]$$

$$= DCOEF(I)*TD(I)*DEPTH*DENSITY *(1. - POROSIT)*REXTSD*DFEXT(I,1,J)*DPOP \tag{3.33}$$

and

$$EXSDHE(I,J) = [DCOEF(I)*TD(I)*DEPTH*DENSITY *(1. - POROSIT)/F*T]*[REXTSD*DFEXT(I,1,J) *70.]*RISK(J)*[DPOP*F*T/70.]$$

$$= DCOEF(I)*TD(I)*DEPTH*DENSITY*(1. - POROSIT) *REXTSD*DFEXT(I,1,J)*RISK(J)*DPOP \; . \tag{3.34}$$

Thus, the total cancers from radionuclide I are given by

$$EXSDHET(I) = \sum_J EXSDHE(I,J) \; . \tag{3.35}$$

3.7 Exposure From Suspended Sediment

The population exposures and resultant health effects are now calculated for external exposure from suspended sediment. The external exposure (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

CSED(I)*AIRCON*REXARSD*DFEXT(I,3,J)*70.

= [DCOEF(I)*TD(I)*AIRCON*REXARSD*DFEXT(I,3,J)*70.]

/[F*T] (3.36)

[From (3.18)]

and

[DCOEF(I)*TD(I)*AIRCON*REXARSD*DFEXT(I,3,J)*70.*RISK(J)]

/[F*T] , (3.37)

respectively, where

REXARSD = exposure rate to suspended sediment (units: hr/yr),

70. = average life expectancy (units: yr [illegible]).

Population exposure and risk now follow from the expressions in (3.36) and (3.37). Specifically, with use of the relation in (3.4),

EXARSDD(I,J) = {[DCOEF(I)*TD(I)*AIRCON*REXARSD

*DFEXT(I,3,J)*70.]/[F*T]} * {[illegible]*F*T/70.}

= D[illegible]*TD(I)*AI[illegible]

DFEXT(I,3,J)[illegible] (3.38)

and

$$
\begin{aligned}
\text{EXARSDH(I,J)} &= \Big\{[\text{DCOEF(I)*TD(I)*AIRCON*REXARSD} \\
&\quad \text{*DFEXT(I,3,J)*70.*RISK(J)]} \\
&\quad \text{/[F*T]}\Big\} \cdot \Big\{\text{DPOP*F*T/70.}\Big\} \\
&= \text{DCOEF(I)*TD(I)*AIRCON*REXARSD} \\
&\quad \text{*DFEXT(I,3,J)*DPOP*RISK(J)} \; . \qquad (3.39)
\end{aligned}
$$

Thus, the total cancers from radionuclide I are given by

$$
\text{EXARSDT(I)} = \textstyle\sum_J \text{EXARSDH(I,J)} \; . \qquad (3.40)
$$

4. Release to Soil

4.1 Preliminary Comments

Population exposures and resultant health effects are now calculated for radionuclide release to soil. In particular, PLDS(I,J), PLHE(I,J) and PLHETOT(I) are determined for exposure from plant consumption, where

PLDS(I,J) = population dose (units: rems) to organ associated with cancer J from radionuclide I,

PLHE(I,J) = number of occurrences of cancer J in population due to radionuclide I,

PLHETOT(I) = total number of cancers in population due to radionuclide I.

Similarly, MKDS(I,J), MKHE(I,J) and MKHETOT(I) are determined for milk consumption; MTDS(I,J), MTHE(I,J) and MTHETOT(I) are determined for meat consumption; INSLDS(I,J), INSLHE(I,J) and INSLTOT(I) are determined for inhalation of suspended soil; EXSLDS(I,J), EXSLHE(I,J) and EXSLTOT(I) are determined for external exposure from soil; and EXARSLD(I,J), EXARSLH(I,J) and EXARSLT(I) are determined for external exposure from suspended soil. The preceding quantities are determined in a manner similar to that used in Chapter 3.

It is assumed that the region under consideration can be represented as a single uniformly-mixed cell as described by the differential equation appearing in (2.21). A specific form of this equation is now derived for use in this chapter. The following symbols are introduced for use in this derivation:

X(I) = amount of radionuclide I in soil (units: Ci).

XS(I) = amount of radionuclide I in soil sorbed to solid material (units: Ci).

XW(I) = amount of radionuclide I in soil dissolved in water (units: Ci).

DF = depth of soil (units: m).

AF = area of soil (units: m²).

ER = erosion rate per unit area (units: kg/m^2 per yr),

RO = runoff rate per unit area (units: L/m^2 per yr),

DCOEF(I) = distribution coefficient for radionuclide I (units: Ci/kg per Ci/L),

MS = mass of solid material in soil (units: kg),

VW = volume of water in soil (units: L),

PO = porosity of soil (units: unitless),

DE = mean particle density of soil material (units: kg/m^3),

SA = percent saturation of pore space in soil (units: unitless).

Radionuclide partitioning is considered first. The solid mass MS and the water volume VW in the soil are given by

$$MS = AR*DP*(1. - PO)*DE \tag{4.1}$$

and

$$VW = AR*DP*PO*SA*1000 \; . \tag{4.2}$$

Thus, the factor S(I) used in the determination of radionuclide partitioning between the liquid and solid phases of a system is given by

$$S(I) = \frac{DCOEF(I)*MS}{DCOEF(I)*MS + VW} \qquad \text{[From (2.20)]}$$

$$= \frac{DCOEF(I)*AR*DP*(1. - PO)*DE}{DCOEF(I)*AR*DP*(1. - PO)*DE + AR*DP*PO*SA*1000}$$

$$= \frac{DCOEF(I)*(1. - PO)*DE}{DCOEF(I)*(1. - PO)*DE + PO*SA*1000} \tag{4.3}$$

Hence, it follows from (2.16) and (2.17) that the partitioning of radionuclide I between the liquid and solid phases of the system is given by

$$XS(I) = S(I)*X(I) \quad \text{and} \quad XW(I) = [1. - S(I)]*X(I) \,. \qquad (4.4)$$

The desired equation can now be constructed. In particular, it follows from (2.21) that

$$dX(I)/dt = R(I) - [XS(I)/MS]*AR*ER$$

$$- [XW(I)/VW]*AR*RO - \lambda*X(I)$$

$$= R(I) - \left\{\frac{S(I)*X(I)}{AR*DP*(1. - PO)*DE}\right\}*AR*ER$$

$$- \left\{\frac{[1. - S(I)]*X(I)}{AR*DP*PO*SA*1000}\right\}*AR*RO - \lambda*X(I)$$

[From (4.1), (4.2), (4.4)]

$$= R(I) - A(I)*X(I) \qquad (4.5)$$

where

$$A(I) = \frac{S(I)*ER}{DP*(1. - PO)*DE} + \frac{[1. - S(I)]*RO}{DP*PO*SA*1000} + \lambda \,. \qquad (4.6)$$

For radionuclide I, the decay constant λ is given by

$$\lambda = ALOG(2.)/HLIFE(I) \,, \qquad (4.7)$$

where

HLIFE(I) = half-life of radionuclide I (units: yr).

As indicated in (2.9), the asymptotic solution to the equation in (4.5) is given by

$$R/A(I) = TD(I)/T*A(I) \ , \tag{4.8}$$

where the second part of the preceding equality follows from the assumption that the annual-discharge (units: Ci/yr) for radionuclide I is given by TD(I)/T. Thus, for each radionuclide, the asymptotic concentration (units: Ci/kg) in the soil is given by

$$CSL(I) = [TD(I)/T*A(I)]/MS$$

$$= [TD(I)]/[T*A(I)*AR*DP*(1. - PO)*DE]$$

[From (4.1)]

$$= TD(I)*FAC(I)/T*AR \ , \tag{4.9}$$

where the factor FAC(I) is introduced for notational convenience and is defined by

$$FAC(I) = [A(I)*DP*(1. - PO)*DE]^{-1} \ . \tag{4.10}$$

It is noted that FAC(I) contains no term which depends on the area AR of the soil region under consideration or the length T of the time period under consideration.

In similarity to the Environmental Protection Agency analysis, the following parameters are assumed to be known for the region under consideration:

FPLT = fraction of land used to grow plants for human consumption (units: unitless),

FMLK = fraction of land used for milk production (units: unitless),

FMT = fraction of land used for meat production (units: unitless),

DPLT = number of people supported per m^2 by plant production (units: ind/m^2),

DMLK = number of people supported per m^2 by milk production (units: ind/m^2),

DMT = number of people supported per m^2 by meat production (units: ind/m^2)

DSL = population density for inhalation and external exposure calculations (units: ind/m^2).

The preceding variables lead to the following populations for use in later exposure calculations:

$$TPPLT = AR*FPLT*DPLT*T/70. \tag{4.11}$$

$$TPMLK = AR*FMLK*DMLK*T/70. \tag{4.12}$$

$$TPMT = AR*FMT*DMT*T/70. \tag{4.13}$$

$$TPSL = AR*DSL*T/70. \tag{4.14}$$

where

TPPLT = total population exposed to plant ingestion (units: ind),

TPMLK = total population exposed to milk consumption (units: ind),

TPMT = total population exposed to meat consumption (units: ind),

TPSL = total population for inhalation and external exposure calculations (units: ind),

70. = average life expectancy (units: yr).

4.2 Exposure From Plant Consumption

The population exposures and resultant health effects are now calculated for plant ingestion. It follows from (4.9) that the amount of radionuclide I ingested by an individual (units: Ci/yr) is given by

CPLT*CSL(I)*CRSP(I)

= CPLT*TD(I)*FAC(I)*CRSP(I)/T*AR , (4.15)

where

CPLT = individual plant consumption (units: kg/yr),

CRSP(I) = concentration ratio from soil to plant for radionuclide I (units: Ci/kg per Ci/kg).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)/T*AR (4.16)

and

CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)*RISK(J)/T*AR , (4.17)

respectively.

Population exposure and risk now follow from the expressions in (4.16) and (4.17). Specifically, with use of the relation in (4.11),

PLDS(I,J) = [CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)/T*AR]

*[AR*FPLT*DPLT*T/70.]

= CPLT*TD(I)*FAC(I)*CRSP(I)DFING(I,J)*FPLT

*DPLT/70. (4.18)

and

```
PLHE(I,J) = [CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)

          *RISK(J)/T*AR]*[AR*FPLT*DPLT*T/70.]

          = [CPLT*TD(I)*FAC(I)*CRSP(I)*DFING(I,J)

          *RISK(J)*FPLT*DPLT]/70.                    (4.19)
```

Thus, the total cancers from radionuclide I are given by

$$PLHETOT(I) = \Sigma_J \; PLHE(I,J) . \qquad (4.20)$$

4.3 Exposure From Milk Consumption

The population exposures and resultant health effects are now calculated for milk ingestion. It follows from (4.9) that the amount of radionuclide I ingested by an individual (units: Ci/yr) is given by

```
CSL(I)*CRSP(I)*PMLK*CRDM(I)*CMLK
                                                     (4.21)
   = TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK/T*AR ,
```

where

PMLK = plant consumption by dairy cattle (units: kg/day),

CRDM(I) = concentration ratio from diet to milk for radionuclide I (units: Ci/L per Ci/day),

CMLK = individual milk consumption (units: L/yr).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK*DFING(I,J)/T*AR

(4.22)

and

[TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK*DFING(I,J)

*RISK(J)]/[T*AR] , (4.23)

respectively.

Population exposure and risk now follow from the expressions in (4.22) and (4.23). Specifically, with use of the relation in (4.12),

MKDS(I,J) = {[TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK

*DFING(I,J)]/[T*AR]}*{AR*PMLK*DMLK*T/70.}

= [TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK

*DFING(I,J)*PMLK*DMLK]/70. (4.24)

and

MKHE(I,J) = {[TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK

*DFING(I,J)*RISK(J)]/[T*AR]}*{AR*PMLK*DMLK

*T/70.}

= [TD(I)*FAC(I)*CRSP(I)*PMLK*CRDM(I)*CMLK

*DFING(I,J)*RISK(J)*PMLK*DMLK]/70. (4.25)

Thus, the total cancers from radionuclide I are given by

$$MKHETOT(I) = \sum_J MKHE(I,J) \quad (4.26)$$

4.4 Exposure From Meat Consumption

The population exposures and resultant health effects for meat consumption are determined the same as those for milk consumption with the exceptions that PMT, CRDMT(I), CMT, FMT and DMT are used instead of PMLK, CRDM(I), CMLK, FMLK and DMLK, respectively, where

PMT = plant consumption by beef cattle (units: kg/day),

CRDMT(I) = concentration ratio from diet to meat for radionuclide I (units: Ci/kg per Ci/day),

CMT = individual meat consumption (units: kg/yr)

and the remaining two variables are defined after (4.14). Thus,

$$MTDS(I,J) = [TD(I)*FAC(I)*CRSP(I)*PMT*CRDMT(I)*CMT *DFING(I,J)*FMT*DMT]/70. , \quad (4.27)$$

$$MTHE(I,J) = [TD(I)*FAC(I)*CRSP(I)*PMT*CRDMT(I)*CMT *DFING(I,J)*RISK(J)*FMT*DMT]/70. \quad (4.28)$$

and

$$MTHETOT(I) = \sum_J MTHE(I,J) . \quad (4.29)$$

4.5 Exposure From Inhalation of Suspended Soil

The population exposures and resultant health effects for inhalation of suspended soil are determined in the same manner as those for inhalation of suspended sediment with the exceptions that CSL(I), TPSL and TMINSL are used instead of CSED(I), TP and TMINSD, respectively, where

TMINSL = fraction of year that individual is exposed to suspended soil (units: unitless).

Specifically, the amount of radionuclide inhaled by an individual (units: Ci/yr) is given by

```
CSL(I)*AIRCON*RINHAIR*TMINSL
                                                    (4.30)
   = TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL/T*AR .
```

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

```
TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL*DFINH(I,J)/T*AR . (4.31)
```

and

```
[TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL*DFINH(I,J)*RISK(J)]

/[T*AR] ,                                            (4.32)
```

respectively.

Population exposure and risk now follow from the expressions in (4.31) and (4.32). Specifically, with use of the relation in (4.14),

```
INSLDS(I,J) = {[TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL

              *DFINH(I,J)]/[T*AR]} * {AR*DSL*T/70.}

            = TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL

              *DFINH(I,J)*DSL/70.                    (4.33)
```

and

INSLHE(I,J) = {[TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL

*DFINH(I,J)*RISK(J)]/[T*AR]} * {AR*DSL*T/70}.

= [TD(I)*FAC(I)*AIRCON*RINHAIR*TMINSL

*DFINH(I,J)*RISK(J)*DSL]/70. (4.34)

Thus, the total cancers from radionuclide I are given by

$$\text{INSLTOT(I)} = \sum_J \text{INSLHE(I,J)} \;. \qquad (4.35)$$

4.6 Exposure From Soil

The population exposures and resultant health effects for external exposure from soil are determined in the same manner as those for external exposure from sediment with the exceptions that CSL(I), TPSL and REXTSL are used instead of CSED(I), TP and REXTSED, respectively, where

REXTSL = exposure rate to soil (units: hr/yr).

First, as was done in (3.30), it is necessary to convert the soil concentration CSL(I) (units: Ci/kg) to a surface concentration CSURF(I) (units: Ci/m^2), where

CSURF(I) = CSL(I)*DEPTH*DENSITY*(1. - POROSIT)

= TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)/T*AR

(4.36)

Hence, the external exposure (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

CSURF(I)*REXTSL*DFEXT(I,1,J)*70.

= [TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)/T*AR]

*[REXTSL*DFEXT(I,1,J)*70.] (4.37)

and

[TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)/T*AR]

*[REXTSL*DFEXT(I,1,J)*70.]*RISK(J) , (4.38)

respectively.

Population exposure and risk now follow from the expressions in (4.37) and (4.38). Specifically, with use of the relation in (4.14),

EXSLDS(I,J) = [TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)

/T*AR]*[REXTSL*DFEXT(I,1,J)*70.]

*[AR*ISL*T/70.]

= TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)

*REXTSL*DFEXT(I,1,J)*ISL (4.39)

and

EXSLHE(I,J) = [TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)

/T*AR]*[REXTSL*DFEXT(I,1,J)*70.]*RISK(J)

*[AR*DSL*T/70.]

= TD(I)*FAC(I)*DEPTH*DENSITY*(1. - POROSIT)

*REXTSL*DFEXT(I,1,J)*RISK(J)*DSL . (4.40)

Thus, the total cancers from radionuclide I are given by

$$EXSLTOT(I) = \Sigma_J EXSLHE(I,J). \quad (4.41)$$

4.7 Exposure From Suspended Soil

The population exposures and resultant health effects for external exposure from suspended soil are determined in the same manner as those for external exposure from suspended sediment with the exceptions that CSL(I), and REXARSL are used instead of CSED(I) and REXARSD, respectively, where

REXARSL = exposure rate to suspended soil (units: hr/yr).

The external exposure (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

CSL(I)*AIRCON*REXARSL*DFEXT(I,3,J)*70.

= [TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)*70.]

/[T*AP] (4.42

and

[TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)*70.*RISK(J)]

/[T*AR] , (4.43)

respectively.

Population exposure and risk now follow from the expressions in (4.42) and (4.43). Specifically, with use of the relation in (4.14),

EXARSLD(I,J) = {[TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)

*70.]/[T*AR]}*{AR*DSL*T/70.}

= TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)*DSL

(4.44)

and

EXARSLH(I,J) = {[TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)

*70.*RISK(J)]/[T*AR]}*{AR*DSL*T/70.}

= TD(I)*FAC(I)*AIRCON*REXARSL*DFEXT(I,3,J)

*RISK(J)*DSL . (4.45)

Thus, the total cancers from radionuclide I are given by

EXARSLT(I) = Σ_J EXARSLH(I,J) . (4.46)

5. Irrigation After Release to Surface Water

5.1 Preliminary Comments

Population exposures and resultant health effects are now calculated for irrigation after a radionuclide release to a surface-water body. Similar calculations are considered in Chapter 4. However, there the only uptake mode considered is direct uptake from soil to plant. In this chapter the additional uptake modes resulting from radionuclides retained on plants due to sprinkler irrigation and from radionuclides in drinking water for milk and beef cattle are considered. In particular, IPLRDS(I,J), IPLRHE(I,J) and IPLRHET(I) are determined for exposure resulting from human ingestion of plants containing radionuclides deposited by sprinkler irrigation, where

IPLRDS(I,J) = population dose (units: rems) to organ associated with cancer J due to radionuclide I,

IPLRHE(I,J) = number of occurrences of cancer J in population due to radionuclide I,

IPLRHET(I) = total number of cancers in population due to radionuclide I.

Further, IMKRDS(I,J), IMKRHE(I,J) and IMKRHET(I) are determined for that part of the dose from milk ingestion which results from milk cattle ingesting radionuclides deposited on feed due to sprinkler irrigation, where

IMKRDS(I,J) = population dose (units: rems) to organ associated with cancer J due to radionuclide I,

IMKRHE(I,J) = number of occurrences of cancer J in population due to radionuclide I,

IMKRHET(I) = total number of cancers in population due to radionuclide I.

Similarly, IMKWDS(I,J), IMKWHE(I,J) and IMKWHET(I) are determined for that part of the dose from milk ingestion which results from milk cattle ingesting radionuclides in their drinking water. In like manner, IMTRDS(I,J), IMTRHE(I,J), IMTRHET(I), IMTWDS(I,J), IMTWHE(I,J) and IMTWHET(I) are determined for human ingestion of beef.

The preceding quantities are determined in a manner similar to that used in Chapter 4.

As already indicated, this section considers foliar deposition due to sprinkler irrigation. The concentration of radionuclide retained on, or in a plant, as the result of sprinkler irrigation is determined by solving a differential equation which represents the change in this concentration as the difference between the rate at which the radionuclide is contaminating the plant and the rate at which the radionuclide is being removed by weathering. This equation is

$$dC(t)/dt = D(t) - \lambda_w(t) \tag{5.1}$$

where

$C(t)$ = concentration of radionuclide on plant material (in Ci/kg),

$D(t)$ = rate of radionuclide deposition (in Ci/kg/yr), and

λ_w = rate constant for removal by weathering (in yr^{-1}).

With the initial condition $C(0) = 0$ and the assumption that $D(t)$ has a constant value D, the preceding equation has the solution

$$C(t) = (D/\lambda_w)\ (1 - e^{-t}), \tag{5.2}$$

which provides the concentration due to foliar deposition.

The weathering half-life is often taken to be 14 days. This yields a value for λ_w of 18.1 yr^{-1}. It is pointed out that $1 - e^{-\lambda_w t}$ approaches 1 rapidly. With t = 0.17 yr, the value is 0.95, and with t = 0.25 yr, the value is 0.99. Thus, the length of time for irrigation is probably not critical. The deposition rate D is given by

$$D = FRET*CWAT*IRAT/PLEN\ , \tag{5.3}$$

where

FRET = fraction of deposited radionuclides retained on crops, often taken to be 0.25 (dimensionless),

CWAT = concentration of radionuclide in irrigation water (in Ci/L),

IRAT = irrigation rate (in $L/m^2/yr$), and

PDEN = standing crop (in kg/m^2).

The values indicated for λ_w and FRET are widely used and appear to come from a study by Milbourn and Taylor [Mi65].

The manner in which the relations in (5.2) and (5.3) will be used is now indicated. First, for simplicity, the asymptotic value for C(t) will be used. That is, the concentration C (units: Ci/kg) due to foliar deposition as a result of sprinkler irrigation is taken as

$$C = D/\lambda_w = FRET*CWAT*IRAT/\lambda_w*PDEN \quad . \qquad (5.4)$$

Values for the variables in (5.4) are now obtained for radionuclide I in the context of the situation under consideration. From (3.1),

$$CWAT(I) = TD(I)/F*T \quad . \qquad (5.5)$$

Further,

$$IRAT = FRIV*F/AR \quad , \qquad (5.6)$$

where

FRIV = fraction of river used for sprinkler irrigation (units: unitless).

Also,

$$\lambda_w = ALOG(2.)/WHPHL \quad , \qquad (5.7)$$

where

WHRHL = weathering half-life for radionuclides deposited by sprinkler irrigation (units: yrs).

Thus, the concentration C(I) (units: Ci/kg) of radionuclide I on plants due to sprinkler irrigation is given by

$$C(I) = [FRET*TD(I)*FRIV*WHRHL] /[T*AR*PDEN*ALOG(2.)] \qquad (5.8)$$

5.2 Exposure From Plant Consumption

The population exposures and resultant health effects are now determined for human ingestion of plants containing radionuclides deposited by sprinkler irrigation. It follows from (5.8) that the amount of radionuclide I ingested by an individual (units: Ci/yr) is given by

$$C(I)*CPLT = [FRET*TD(I)*FRIV*WHRHL*CPLT] /[T*AR*PDEN*ALOG(2.)] . \qquad (5.9)$$

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

$$[FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)] /[T*AR*PDEN*ALOG(2.)] \qquad (5.10)$$

and

$$[FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)*RISK(J)] /[T*AR*PDEN*ALOG(2.)] , \qquad (5.11)$$

respectively.

Population exposure and risk now follow from the expressions in (5.10) and (5.11). Specifically, with use of the relation in (4.11) for total population available for plant consumption,

$$IPLRDS(I,J) = \{[FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)]$$

$$/[T*AR*PDEN*ALOG(2.)]\} * \{AR*FPLT*DPLT*T/70.\}$$

$$= [FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)$$

$$*FPLT*DPLT]/[PDEN*ALOG(2.)*70.] \qquad (5.12)$$

and

$$IPLRHE(I,J) = \{[FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)$$

$$*RISK(J)]/[T*AR*PDEN*ALOG(2.)]\}$$

$$*\{AR*FPLT*DPLT*T/70.\}$$

$$= [FRET*TD(I)*FRIV*WHRHL*CPLT*DFING(I,J)$$

$$*RISK(J)*FPLT*DPLT]/[PDEN*ALOG(2.)*70.]$$

$$(5.13)$$

Thus, the total cancers from radionuclide I are given by

$$IPLRHET(I) = \sum_J IPLRHE(I,J) \ . \qquad (5.14)$$

5.3 Exposure From Milk Consumption

The population exposures and resultant health effects are now determined for milk ingestion. Two sets of determinations are made. The first is for that part of exposure and health effects which results from foliar deposition of radionuclides due to sprinkler irrigation. The second is for that part of exposure and health effects which results from radionuclides in water given to livestock.

It follows from (5.8) that the amount of radionuclide I ingested by an individual (units: Ci/yr) due to foliar deposition and subsequent plant use in milk production is given by

C(I)*PMLK*CRDM(I)*CMLK

= {[FRET*TD(I)*FRIV*WHRHL]/[T*AR*PDEN*ALOG(2.)]}

* {PMLK*CRDM(I)*CMLK}

= [FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK]

/[T*AR*PDEN*ALOG(2.)] . (5.15)

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

[FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK

*DFING(I,J)]/[T*AR*PDEN*ALOG(2.)] (5.16)

and

[FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK

*DFING(I,J)*RISK(J)]/[T*AR*PDEN*ALOG(2.)] , (5.17)

respectively.

Population exposure and risk now follow from the expressions in (5.16) and (5.17). Specifically, with use of the relation in (4.12) for total population available for milk consumption,

$$
\begin{aligned}
IMKRDS(I,J) = {} & \{[FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I) \\
& *CMLK*DFING(I,J)]/[T*AR*PDEN*ALOG(2.)]\} \\
& *\{AR*FMLK*DMLK*T/70\}. \\
= {} & [FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK \\
& *DFING(I,J)*FMLK*DMLK]/[PDEN*ALOG(2.)*70.]
\end{aligned}
\tag{5.18}
$$

and

$$
\begin{aligned}
IMKRHE(I,J) = {} & \{[FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I) \\
& *CMLK*DFING(I,J)*RISK(J)]/[T*AR*PDEN \\
& *ALOG(2.)]\}*\{AR*FMLK*DMLK*T/70\}. \\
= {} & [FRET*TD(I)*FRIV*WHRHL*PMLK*CRDM(I)*CMLK \\
& *DFING(I,J)*RISK(J)*FMLK*DMLK] \\
& /[PDEN*ALOG(2.)*70.]\ .
\end{aligned}
\tag{5.19}
$$

Thus, the total cancers from radionuclide I are given by

$$
IMKRHET(I) = \sum_J IMKRHE(I,J)\ . \tag{5.20}
$$

It follows from (3.1) that the amount of radionuclide I ingested by an individual (units: Ci/yr) due to water used for milk cattle is given by

$$
CW(I)*WMLK*CRDM(I)*CMLK = TD(I)*WMLK*CRDM(I)*CMLK/F*T, \tag{5.21}
$$

where

WMLK = water consumption by dairy cattle (units: L/day).

Thus, the dose (units: rem/ind) to the organ associated with cancer J due to radionuclide I and the resultant cancer risk (units: cancer/ind) are given by

$$TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)/F*T \qquad (5.22)$$

and

$$TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*RISK(J)/F*T , \qquad (5.23)$$

respectively.

Population exposure and risk now follow from the expressions in (5.22) and (5.23). Specifically, with use of the relation in (4.12) for total population available for milk consumption,

$$\begin{aligned} IMKWDS(I,J) &= [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)/F*T] \\ &\quad *[AR*FMLK*DMLK*T/70.] \\ &= [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*AR \\ &\quad *FMLK*DMLK]/[F*70.] \qquad (5.24) \end{aligned}$$

and

$$\begin{aligned} IMKWHE(I,J) &= [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*RISK(J) \\ &\quad /F*T]*[AR*FMLK*DMLK*T/70.] \\ &= [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*RISK(J) \\ &\quad *AR*FMLK*DMLK]/[F*70.] . \qquad (5.25) \end{aligned}$$

Thus, the total cancers from radionuclide I are given by

$$IMKWHET(I,J) = \sum_J IMKWHE(I,J) \ . \qquad (5.26)$$

Unlike all earlier calculations for population effects, the variables F and AR did not drop out of the expressions in (5.24) and (5.25). However, if one assumes that the irrigation rate IRAT (units: L/m^2 per yr) is known, it is possible to remove F and AR. Specifically,

$$F*FRIV = AR*IRAT \qquad (5.27)$$

and so

$$AR/F = FRIV/IRAT \ . \qquad (5.28)$$

Now, with use of the relation in (5.28), the equalities in (5.24) and (5.25) can be rewritten as

$$IMKWDS(I,J) = [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*FRIV$$

$$*FMLK*DMLK]/[IRAT*70.] \qquad (5.29)$$

and

$$IMKWHE(I,J) = [TD(I)*WMLK*CRDM(I)*CMLK*DFING(I,J)*RISK(J)$$

$$*FRIV*FMLK*DMLK]/[IRAT*70.] \ . \qquad (5.30)$$

5.4 Exposure From Meat Consumption

The population exposures and resultant health effects for meat consumption are determined in the same manner as those for milk consumption with the exceptions that PMT, CRDMT(I), CMT, FMT, DMT and WMT are used instead of PMLK, CRDM(I), CMLK, FMLK, DMLK and WMLK, respectively.

Thus,

```
IMTRDS(I,J) = [FRET*TD(I)*FRIV*WHRHL*PMT*CRDMT(I)*CMT
              *DFING(I,J)*FMT*DMT]/[PDEN*ALOG(2.)*70.] ,
                                                        (5.31)

IMTRHE(I,J) = [FRET*TD(I)*FRIV*WHRHL*PMT*CRDMT(I)*CMT
              *DFING(I,J)*RISK(J)*FMT*DMT]
              /[PDEN*ALOG(2.)*70.]                      (5.32)

IMTWDS(I,J) = [TD(I)*WMT*CRDMT(I)*CMT*DFING(I,J)*AR
              *FMT*DMT]/[F*70.]
            = [TD(I)*WMT*CRDMT(I)*CMT*DFING(I,J)*FRIV
              *FMT*DMT]/[IRAT*70.]                      (5.33)
```

and

```
IMTWHE(I,J) = [TD(I)*WMT*CRDMT(I)*CMT*DFING(I,J)*RISK(J)
              *AR*FMT*DMT]/[F*70.]
            = [TD(I)*WMT*CRDMT(I)*CMT*DFING(I,J)*RISK(J)
              *FRIV*FMT*DMT/[IRAT*70.] .                (5.34)
```

The total cancers from radionuclide I are given by

$$IMTRHET = \sum_J IMTRHE(I,J) \tag{5.35}$$

and

$$IMTWHET = \sum_J IMTWHE(I,J). \tag{5.36}$$

References

Bon73 Bond, R. G. and C. P. Straud (Eds.), 1973, Handbook of Environmental Control, Vol. 1, CRC Press, Cleveland, OH.

Boo81 Boone, F. W., Y. C. Ng, and J. M. Palms, 1981 "Terrestrial Pathways of Radionuclide Particulates," Health Physics 41, 735-747.

Cu73 Cummins, A. B. and I. A. Given (Eds.), 1973, SME Mining Engineering Handbook, Society of Mining Engineers, Littleton, CO.

En80 Environmental Protection Agency, 1980, Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, 40CFR191 (Working Draft No. 16, October 21, 1980).

Im78 Iman, R. L., J. C. Helton, and J. E. Campbell, 1978, Risk Methodology for Geologic Disposal of Radioactive Waste: Sensitivity Analysis Techniques, SAND78-0912, Sandia Labaoratories, Albuquerque, NM.

He82 Helton, J. C. and N. C. Finley, 1982, PATHI Self-Teaching Curriculim: Example Problems for Pathways-To-Man Model, SAND81-2377, Sandia National Laboratories, Albuquerque, NM.

Mi65 Milbourn, G. M. and R. Taylor, 1965, "The Contamination of Grasslands With Radioactive Strontium: I, Initial Retention and Loss," Radiation Botany 5, 337-347.

Nu76 Nuclear Regulatory Commission, 1976, Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10CFR Part 50, Appendix I, Regulatory Guide 1.109, U.S. Nuclear Regulatory Commission, Washington, DC.

Ru81 Runkle, G. E., R. M. Cranwell, and J. D. Johnson, 1981, Risk Methodology for Geologic Disposal of Radioactive Waste: Dosimetry and Health Effects, SAND80-1372, Sandia National Laboratories, Albuquerque, NM.

Sm81 Smith, J. M., T. W. Fowler, and A. S. Goldin, 1981, Environmental Pathway Models for Estimating Population Health Effects From Disposal of High-Level Radioactive Waste in Geologic Repositories, EPA520/5-80-002 (Draft June 8, 1981), Environmental Protection Agency, Washington, DC.

To70 Todd, D. K. (Ed.), 1970, The Water Encyclopedia, Water Information Center, Huntington, NY.

We74 Weast, W. E., 1974, Handbook of Chemistry and Physics (55th edition), CRC Press, Cleveland, OH.

Volume 6

Calculation of Health Effects per Curie Release for Comparison with the EPA Standard

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TECHNICAL ASSISTANCE FOR REGULATORY DEVELOPMENT: REVIEW AND EVALUATION OF THE DRAFT EPA STANDARD 40CFR191 FOR DISPOSAL OF HIGH-LEVEL WASTE

VOL. 6

CALCULATION OF HEALTH EFFECTS PER CURIE RELEASE FOR COMPARISON WITH THE EPA STANDARD

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ABSTRACT

The Environmental Protection Agency (EPA) is developing a standard for geologic disposal of high-level radioactive wastes (40CFR191) based on radioactive releases (expressed in curies) that may result in 1,000 health effects (i.e., latent cancer fatalities) over a 10,000 year period. Health effects calculations were used by EPA to establish the curie release limits. The Fuel Cycle Risk Analysis Division of Sandia National Laboratories was requested by the Nuclear Regulatory Commission (NRC) High-Level Waste Licensing Management Branch to perform calculations, using the methodology developed under the Risk Assessment Methodology Program, to compare with the results from the EPA analysis. The intent was to provide some insights into the degree of conservatism in the health effects per curie values presented by the EPA standard. No attempt was made to encompass all the uncertainty in the input parameters used in the calculations and some of the modeling assumptions used in this analysis are different from those of the EPA. Three sets of calculations of health effects (cancer deaths) per curie release were performed in this analysis. The calculational methods, the results of the analysis, and the potential implication of these results upon the curie release limits of the EPA are discussed in this report.

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1.0 Introduction

The Environmental Protection Agency (EPA) is developing a standard for geologic disposal of high-level radioactive wastes that would limit the curie releases to the accessible environment of the various radionuclides found in high-level waste. The EPA guidance establishes that the releases of radionuclides to the accessible environment from the wastes from 100,000 Metric Ton of Heavy Metal (MTHM) should not result in excess of 1,000 health effects (i.e., latent cancer fatalities) over a 10,000 year period. The process by which EPA established the release limits consisted of two steps. In the first step, the projected releases of radioactivity from a generic geologic repository in various geologic media (bedded salt, domed salt, granite, basalt and shale) were calculated and in the second step, the potential excess cancer deaths from the releases were estimated. A set of calculated health effects per curie released into the environment for all the radionuclides considered in the EPA analysis was established to estimate the potential health hazard. The EPA analyses of the various media were used to select the limit of 1,000 health effects over 10,000 years for a 100,000 MTHM repository. The 1,000 health effects criteria was then used to establish the release limits for individual radionuclides. The Nuclear Regulatory Commission (NRC) requested the Fuel Cycle Risk Analysis Division of Sandia National Laboratories (SNL) to perform an evaluation using the methodology developed under the Risk Assessment Methodology Program (FIN:A-1192) to calculate the health effects that may result from the release of one curie of each of various radionuclides to the biosphere. The intent of this two week effort was to provide some insights into the degree of conservatism in the health effects per curie values calculated by the EPA. The intent was not to present values to replace the EPA curie values, but rather to perform calculations similar to the EPA analysis that would provide some perspective on the EPA release limits. No attempt was made to bound all of the uncertainty in the input parameters in the pathway modeling effort, to encompass all the possibilities of release or to address the uncertainties in the dose conversion factors and health effects estimates. The calculations presented in this report were designed to flag potential problems with the EPA release limits that may warrant further analysis.

Three sets of calculations were performed in this work. The first set of calculations (EPA/SANDIA Analysis) used the Pathways Model developed at Sandia (Helton and Kaestner, 1981) and the input parameters (e.g., distribution coefficients (Kd), concentration ratios, dose conversion factors, risk estimates, etc.) and the health effects calculational methods from the EPA. A second set of calculations (SANDIA Analysis) was made using the Pathways Model (Helton and Kaestner, 1981) and the

Dosimetry and Health Effects Model (Runkle, et al., 1981). In these calculations the input parameters to the Pathways Model were selected from those used in demonstrating the Risk Assessment Methodology (described in Cranwell, et al., 1982). The referernce site used in this demonstration was based on a hypothetical site and generic parameters representing several sites throughout the United States. The EPA point value for the distribution coefficients (Kd) for the various radionuclides were used in the analysis. The third set of calculations (SAMPLED SANDIA Analysis) were performed using a statistical technique to sample an assigned range of values for some of the input parameters to the Pathways Model. A distribution was assigned to each range of values. This approach can be used to represent some of the uncertainty in the calculated results due to input data uncertainties. Many other uncertainties have not been addressed in this analysis and include uncertainties in the concentration ratios, the dose conversion factors, and the risk estimators of health effects, to name only a few.

There are several differences in the modeling approaches used in this analysis that may affect the results and are therefore detailed below. First, for calculating the health effects per curie release for the water based pathway, the EPA input a unit curie source over 10,000 years (i.e., 10^{-4} Ci/yr) into the surface (river) water to calculate the drinking water and fish intakes. For the land based pathways (which include ingestion of crops, beef and milk), EPA input a 0.5 curie source into the soil compartment over 10,000 years (i.e., 5×10^{-5} Ci/yr) to estimate the soil concentrations, and further assumed that 50% of the contaminated land was used for crop production for direct human consumption, 25% for milk production and 25% for beef production.

In the analyses (EPA/SANDIA, SANDIA, SAMPLED SANDIA) presented in this report, a unit curie source was input to the liquid phase of the surface water over 10,000 years (i.e., 10^{-4} Ci/yr) and the interchange between the surface water and the soil compartments of the Pathways Model determined the soil concentration. The calculations performed by the Pathways Model resulted in an input of 2.3E-3 Ci to the soil over the 10,000 year period. In addition, the fractional partitioning of land use (assumed by EPA) was not incorporated in this analysis.

Second, the EPA analysis considered a population detriment that was based on a linear relationship of population to the flow rate in a river for the water based pathways and was linearly proportional to the area of land for the land based pathways. In the approach used by EPA, it is important to note that the area (A) canceled out of the equation for the land based ingestion calculation, which eliminated the linear relationship between area and population.

The Risk Assessment Methodology used for this analysis was based on the risk to an average individual and was converted to a population risk by relating the river flow rate to the population density (persons/ℓ) assumed by EPA to estimate the population for the water based pathways. For the land based pathways the density (persons/m^2) defined by EPA was multiplied by the area considered in the reference site analysis (Cranwell et al., 1982). The land area was defined as 40 km x 2 km on both sides of a river (160 km^2), that was assumed to fall within the flood plain of the river and to provide food (crops, beef and milk) for the population. With this approach, the population is a linear function of the assumed area and doubling the area will result in a doubling of the population.

The three calculational methods for the EPA/SANDIA, SANDIA and SAMPLED SANDIA Analyses are detailed in Chapters 2-4, respectively. Chapter 5 is a summary of the results calculated in this analysis.

2.0 Description of the EPA/SANDIA Analysis

The EPA/SANDIA Analysis used the Environmental Pathways Model developed at Sandia (Helton and Kaestner, 1981) and the input parameters used by EPA in their analysis. The input parameters included concentration ratios, human and animal consumption rates, dose conversion factors and risk estimates. These calculations were designed to estimate the health effects per curie release by employing the Risk Assessment Methodology developed at SNL and the EPA input parameters.

The Pathways Model (Helton and Kaestner, 1981) was used to estimate the radionuclide concentrations in the surface water and soil compartments following a 10^{-4} curie/year release into the surface water for a 10,000 year period. For the simplified analysis presented in this report, a system consisting of two compartments, soil and surface water, was used. For this situation, the mathematical formulation for each radionuclide considered is a system of two differential equations of the following form:

$$\begin{aligned} dx_1/dt &= h_1 - (\lambda + k_{21})\, x_1 + k_{12}\, x_2 \\ dx_2/dt &= h_2 + k_{21}\, x_1 - (\lambda + k_{02} + k_{12})\, x_2 \end{aligned} \qquad (1)$$

where x_i is the amount (units: Ci) of radionuclide in compartment i (1 - soil, 2 - surface water), h_i is the rate of radionuclide input (units: Ci/yr) to compartment i, and λ is the decay constant (units: yr^{-1}) for the radionuclide under consideration. The k_{ij} is the rate constant for movement from compartment j to compartment i, where i = 0 denotes a flow from compartment j to an area outside the modeled system. Each coefficient, k_{ij}, is of the following form:

$$k_{ij} = \frac{(1 - S_j)RW_{ij}}{VW_j} + \frac{S_j\,RS_{ij}}{MS_j} . \tag{2}$$

where VW_j denotes the volume of water in compartment j (units: ℓ), MS_j denotes the mass of solids in compartment j (units: kg), RW_{ij} denotes the rate at which water flows from compartment j to compartment i (units: ℓ/yr), and RS_{ij} denotes the rate at which solid material flows from compartment j to compartment i (units: kg/yr). Further, the unitless quantity S_j represents the effects of radionuclides partitioning in compartment j and is defined by

$$S_j = \frac{Kd_j MS_j}{Kd_j MS_j + VW_j} . \tag{3}$$

where Kd_j is the distribution coefficient in compartment j for the radionuclide under consideration (units: ℓ/kg). The nonzero values for the VW_j, MS_j, RW_{ij} and RS_{ij} for the site described in this section are given in Table 2.1.

The system of equations in (1) can be reformulated in matrix notation as

$$dx/dt = h + Kx, \tag{4}$$

where

$$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} , \; h = \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} \text{ and } K = \begin{bmatrix} -(\lambda + k_{21}) & k_{12} \\ k_{21} & -(\lambda + k_{02} + k_{12}) \end{bmatrix} \tag{5}$$

For this analysis h_1 was assumed to be 10^{-4} curies/yr and h_2 was assumed to be 0. As the system under consideration is completely open, the equations represented in (1) and (2) have a unique asymptotic solution, sx, where

$$sx = -K^{-1}\,h. \tag{6}$$

For the analysis presented in this report, the asymptotic solutions indicated in (6) were used instead of time-dependent solutions. Variables B_1 to B_4 were used to introduce variance in the exchange rate between subzones and may be sampled from a user-specified range. For this analyris, a mid-point value (see Table 2.1) was assumed.

Table 2.1

Environmental Transport Input Parameters
(Helton and Kaestner, 1981)

__Surface Water:__

VW_2 = Volume of Water	2.2×10^{10} ℓ
MS_2 = Mass of Solid	$6.8 \times 10^{5} \left(\frac{R_4}{R_1}\right)$ kg
RS_{12} = Rate of mass outflow to soil subzone	1.1×10^{11} (R_3) kg/y
RW_{02} = Rate of water outflow to surface water in next zone	1.9×10^{13} (R_1) ℓ/y
RS_{02} = Rate of solid outflow to surface in next zone	5.9×10^{8} (R_4) kg/y
RW_{12} = Rate of water outflow to soil subzone	4.0×10^{10} (R_2) ℓ/y

__Soil:__

VW_1 = Volume of water	2.0×10^{10} ℓ
MS_1 = Mass of solid	1.1×10^{11} kg
RW_{21} = Rate of water outflow to surface water	4.0×10^{10} (R_2) ℓ/y
RS_{21} = Rate of mass outflow to surface water	0.0 (kg/y)

__Assumed Values:__

$$\left.\begin{array}{l} R_1 = 1.0 \\ R_2 = 1.0 \\ R_3 = 10^{-3} \\ R_4 = 9.0 \end{array}\right\}$$

Variables to introduce variation in the subzones indicated above. Variations were not considered in the EPA/SANDIA or the SANDIA analyses, therefore these variables were assigned the point values given in this table.

Also for this analysis, the radionuclides were assumed to be released to the liquid phase of the surface water. Further, no adsorption onto the solid particulate phase of the surface water was considered. This would represent a situation where there are no Kd effects in the water. In an alternative scenario that considers river flooding, particulates are carried onto the surrounding land mass and contribute a large radionuclide burden to the soil. This analysis placed the radionuclide solely in the liquid phase of the surface water, as assumed by the EPA. However, the distribution coefficient, Kd, was taken into account in the radionuclide concentration in the soil subzone. The point values for the Kd values for the radionuclides that were used in this analysis and also by the EPA are given in Table 2.2. The EPA data (unless otherwise specified) were obtained from personal communication with J. M. Smith, EPA, Montgomery, Alabama. Since the initial work in 1981, these EPA parameters and the environmental calculations have been published in Smith, et al., 1982.

In the analysis presented in this section, a unit curie source was input to the liquid phase of the water over 10,000 years and the interchanges between the surface water and the soil compartments of the Pathways Model determined the soil concentration. The results of the Pathways analysis are given in Table 2.3 for the surface water and soil compartments. These radionuclide concentrations were used to calculate the health effects (cancer deaths) per curie release. The calculations of the cumulative health effects over time, T, may be summarized by the following general equation

$$RSK_{ij} = Q_{ij} * (\sum_k DF_{ijk} * HE_{jk}) * POP_j * T \qquad (7)$$

where

RSK_{ij} = health effects (cancer deaths) per curie release of radionuclide i via pathway j (ingestion, inhalation or external)

Q_{ij} = quantity intake per year (via ingestion or inhalation) or exposure (external) to radionuclide i via pathway j (Ci/y)

DF_{ijk} = dose conversion factor to calculate the dose commitment to organ k from radionuclide i via pathway j (rem/Ci)

Table 2.2

Distribution Coefficients (Kd)
Assumed by EPA

Radionuclide	Kd Value (cm^3/gm)
Am241	2000
Am243	2000
Cs135	200
Cs137	200
I129	0
Np239	15
Pu239	2000
Pu240	2000
Pu242	2000
Sr90	20
Tc99	0
Sn126	250

Table 2.3

Radionuclide Concentrations in the Surface Water and Soil From the Pathways Analysis

Radionuclide	Surface Water (Ci/ℓ)	Soil (Ci/kg)
Am241	5.26E-18	1.13E-15
Am243	5.26E-18	7.02E-15
Cs135	5.26E-18	1.05E-15
Cs137	5.26E-18	7.66E-17
I129	5.26E-18	9.57E-19
NP237	5.26E-18	7.99E-17
PU239	5.26E-18	9.10E-15
PU240	5.26E-18	6.54E-15
PU242	5.26E-18	1.04E-14
SR90	5.26E-18	4.56E-17
TC99	5.26E-18	9.57E-19
SN126	5.26E-18	1.31E-15

HE_{jk} = health effects conversion factor to estimate the potential fatal cancers from the dose commitment to organ k via pathway j $\left(\frac{\text{health effects}}{\text{rem}}\right)$

POP_j = population exposed to the dose commitment from pathway j (persons)

T = time interval of the calculation. For this analysis (and EPA) the time interval was assumed to be 10,000 years.

The three pathways included in this analysis were the ingestion (includes several subpathways), inhalation and external exposure. The calculations of health effects per curie release for each of these pathways are detailed in subsections 2.1, 2.2 and 2.3, respectively.

2.1 Ingestion

The ingestion pathway consists of intake of radionuclides from various subpathways including drinking water, fish, plants, milk and meat. The calculations for these subpathways used the following components: (1) dose factors and health estimates (2) population at risk and (3) quantity intake. Each component is discussed below with reference to the various subpathways.

2.1.1 Dose Factors and Health Effects Estimates

The dose conversion factors and the health effects estimates per rem of exposure were taken from Table 2.4. For each radionuclide, the product of the ingestion dose commitment factors and health effects conversion factors were summed over all organs. The summation was used to calculate the health effects from all of the subpathways. The dose conversion factors used by EPA represent a 50-year dose commitment (rem) to an individual which results from the initial intake of one curie of the radionuclide.

2.1.2 Population at Risk

EPA used the flow rate of the world's rivers and the world population to estimate the population that can be supported by a given river flow rate. This ratio, of the flow rate to the world population, was applied to the flow rate of the river considered in this analysis (1.9E13ℓ/yr) to define the population for the drinking water. A resulting population of 6.3E6 persons was used for the EPA/SANDIA calculations. EPA also related the world's average fish consumption rate (10^{10} kg/yr) to the world's river flow rate (3E16 ℓ/yr) to estimate the

Table 2.4

HEALTH EFFECTS CONVERSION FACTORS, HEALTH EFFECTS/MAN REM
(FATAL CANCERS FOR ALL ORGANS EXCEPT OVARIES AND TESTES. GENETIC EFFECTS TO FIRST GENERATION FOR OVARIES AND TESTES)

BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
1.000E-05	4.000E-05	4.000E-05	1.000E-05	2.000E-05	1.000E-06	1.000E-05	7.000E-05	2.000E-05	2.000E-05

NUCLIDE DEPENDENT INPUT DATA

NUCLIDE PATHWAY DOSE COMMITMENT FACTORS
(INHALATION AND INGESTION=REM/CI INTAKE AIR SUBMERSION=REM/Y PER CI/M**3 GROUND CONTAMINATION=REM/Y PER CI/M**2)

ORGAN

NUCLIDE	PATHWAY	BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
C-14	INHAL1	8.460E+00	2.420E+01	6.180E+00	8.880E+00	7.220E+00	6.480E+00	7.920E+00	1.410E+01	5.290E+00	5.420E+00
	INHAL2	8.460E+00	2.420E+01	6.180E+00	8.880E+00	7.220E+00	6.480E+00	7.920E+00	1.410E+01	5.290E+00	5.420E+00
	INGEST	1.170E+03	3.380E+03	8.490E+02	1.230E+03	1.460E+03	8.890E+02	1.060E+03	1.920E+03	7.360E+02	7.230E+02
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	INHAL1	1.290E+04	2.150E+03	6.470E+03	4.980E+03	7.120E+02	2.150E+03	2.150E+03	2.150E+03	2.150E+03	2.150E+03
	INHAL2	1.290E+04	2.150E+03	6.470E+03	4.980E+03	3.560E+02	2.150E+03	2.150E+03	2.150E+03	2.150E+03	2.150E+03
	INGEST	9.670E+03	1.610E+03	1.610E+03	3.320E+03	9.700E+02	1.610E+03	1.610E+03	1.610E+03	1.610E+03	1.610E+03
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	INHAL1	3.210E+05	1.210E+05	6.540E+06	1.930E+04	9.310E+05	3.740E+03	3.740E+03	1.510E+05	3.740E+03	3.730E+03
	INHAL2	3.000E+06	1.100E+06	4.920E+04	1.490E+04	5.500E+04	1.540E+04	1.540E+04	2.410E+05	1.540E+04	1.540E+04
	INGEST	1.200E+06	4.300E+05	1.570E+02	5.710E+03	1.980E+05	5.990E+03	5.990E+03	9.500E+04	5.990E+03	5.990E+03
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR-93	INHAL1	1.470E+03	1.750E+03	5.850E+04	2.930E+03	7.160E+03	1.600E+03	1.360E+03	2.500E+03	1.040E+03	1.470E+02
	INHAL2	4.120E+03	2.440E+03	3.080E+04	2.110E+03	6.950E+03	1.320E+03	1.320E+03	2.130E+03	1.460E+03	4.950E+02
	INGEST	1.970E+02	3.340E+02	3.900E+01	1.430E+02	1.750E+04	1.690E+01	1.990E+02	2.470E+02	1.360E+03	1.340E+02
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04	1.780E+04
TC-99	INHAL1	2.420E+02	2.150E+02	5.220E+04	4.210E+02	1.650E+03	9.460E+03	3.070E+02	8.870E+02	2.120E+02	2.[illegible]20E+02
	INHAL2	2.420E+02	2.150E+02	5.220E+[illegible]4	4.210E+02	1.660E+03	9.460E+03	[illegible]70E+02	8.870E+02	2.120E+02	2.120E+02
	INGEST	3.610E+02	3.220E+02	0.0	6.280E+02	3.200E+03	1.410E+04	4.580E+02	2.140E+02	3.170E+02	3.170E+02
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Taken from Smith, et al., 1982

Table 2.4 (continued)

		ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SN-126	INHAL1	1.580E+03	1.580E+05	1.270E+06	4.190E+03	7.600E+04	1.230E+03	6.160E+03	6.160E+03	6.160E+03	6.160E+03
	INHAL2	1.580E+05	1.580E+05	1.270E+06	4.190E+03	7.600E+04	1.230E+03	6.160E+03	6.160E+03	6.160E+03	6.160E+03
	INGEST	8.570E+04	8.570E+04	3.110E+03	1.690E+03	1.180E+05	4.990E+02	2.810E+03	2.820E+03	2.820E+03	2.620E+03
	EXT AIR	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07
	EXT GND	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05
I-129	INHAL1	5.790E+02	6.050E+02	7.880E+02	4.660E+02	4.280E+01	5.000E+06	4.490E+02	2.050E+03	3.760E+02	3.570E+02
	INHAL2	5.790E+02	6.050E+02	7.880E+02	4.660E+02	4.280E+01	5.000E+06	4.490E+02	2.050E+03	3.760E+02	3.570E+02
	INGEST	9.020E+02	9.420E+02	1.790E+02	7.240E+02	6.700E+01	7.800E+06	7.020E+02	3.180E+03	5.920E+02	5.590E+02
	EXT AIR	1.450E+05	1.310E+05	4.850E+04	3.600E+04	1.150E+04	1.010E+05	5.380E+04	9.540E+04	3.400E+04	1.310E+05
	EXT GND	8.730E+03	7.870E+03	2.910E+03	2.160E+03	6.900E+02	6.040E+03	3.230E+03	5.730E+03	2.040E+03	7.830E+03
CS-135	INHAL1	7.470E+03	7.470E+03	6.400E+02	7.470E+03	8.510E+01	7.480E+03	7.470E+03	4.400E+03	7.470E+03	7.470E+03
	INHAL2	7.470E+03	7.470E+03	6.400E+02	7.470E+03	8.510E+01	7.400E+03	7.470E+03	4.400E+03	7.470E+03	7.470E+03
	INGEST	1.120E+04	1.120E+04	0.0	1.120E+04	5.350E+02	1.130E+04	1.120E+04	6.610E+03	1.120E+04	1.120E+04
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-137	INHAL1	4.540E+04	4.910E+04	1.620E+04	5.230E+04	1.600E+04	4.470E+04	5.130E+04	3.260E+04	5.000E+04	4.440E+04
	INHAL2	4.540E+04	4.910E+04	1.620E+04	5.230E+04	1.600E+04	4.470E+04	5.130E+04	3.260E+04	5.000E+04	4.440E+04
	INGEST	6.820E+04	7.380E+04	1.950E+04	7.870E+04	2.550E+04	6.720E+04	7.730E+04	4.910E+04	7.540E+04	6.680E+04
	EXT AIR	4.660E+06	4.450E+06	3.600E+06	3.180E+06	2.750E+06	4.020E+06	3.380E+06	3.810E+06	1.390E+06	4.240E+06
	EXT GND	8.290E+04	7.920E+04	6.400E+04	5.650E+04	4.900E+04	7.150E+04	6.030E+04	6.790E+04	2.490E+04	7.550E+04
SM-151	INHAL1	5.100E+02	2.090E+02	6.780E+04	1.900E+03	3.040E+03	1.520E+01	5.540E+02	1.090E+03	1.470E+01	1.070E+01
	INHAL2	4.910E+03	1.940E+03	1.590E+04	1.830E+04	2.810E+03	1.040E+02	5.380E+03	1.190E+03	1.050E+02	1.030E+02
	INGEST	4.510E+00	3.200E+00	1.050E-01	1.730E+01	5.850E+03	1.030E-01	5.520E+00	2.340E+01	5.660E+00	5.360E-01
	EXT AIR	2.440E+01	2.130E+01	4.240E+00	2.350E+00	2.920E+00	9.060E+00	7.020E+00	3.070E+01	3.920E+00	3.850E+01
	EXT GND	4.590E+00	4.000E+00	7.960E-01	4.410E-01	5.480E-01	1.700E+00	1.320E+00	5.780E+00	7.360E-01	7.300E+00
RA-226	INHAL1	1.100E+07	9.800E+05	2.810E+07	3.400E+05	1.000E+05	3.400E+05	3.490E+05	4.600E+06	3.400E+05	3.400E+05
	INHAL2	1.100E+07	9.800E+05	2.810E+07	3.400E+05	1.000E+05	3.400E+05	3.490E+05	4.600E+06	3.400E+05	3.400E+05
	INGEST	6.320E+07	2.140E+06	2.710E+02	1.870E+06	8.160E+05	8.010E+05	5.750E+06	7.790E+06	8.060E+05	8.010E+05
	EXT AIR	1.500E+07	1.390E+07	1.270E+07	1.120E+07	1.030E+07	1.280E+07	1.060E+07	1.180E+07	9.900E+06	1.130E+07
	EXT GND	2.520E+05	2.340E+05	2.070E+05	1.850E+05	1.690E+05	2.120E+05	1.750E+05	2.210E+05	1.630E+05	1.890E+05
U-234	INHAL1	2.000E+07	8.100E+05	2.730E+09	5.900E+05	5.480E+04	5.900E+05	8.700E+05	9.800E+06	5.900E+05	5.900E+05
	INHAL2	5.900E+07	2.400E+06	2.800E+07	1.700E+06	4.790E+04	1.700E+06	2.500E+06	5.500E+06	1.700E+06	1.700E+06
	INGEST	2.000E+07	8.000E+05	8.230E+02	5.800E+05	8.860E+04	5.800E+05	8.500E+05	1.700E+06	5.800E+05	5.800E+05
	EXT AIR	2.940E+03	2.640E+03	1.030E+03	7.640E+02	6.560E+02	1.[illegible]E+03	8.130E+02	2.490E+03	6.640E+02	2.090E+0[illegible]
	EXT GND	5.630E+02	5.050E+02	1.970E+02	1.450E+02	1.640E+02	2.460E+02	1.560E+02	4.780E+02	1.270E+02	4.000E+02
NP-237	INHAL1	9.0[illegible]E+08	3.010E+08	2.900E+08	4.020E+08	1.380E+05	3.0[illegible]E+06	5.200E+07	8.500E+07	1.800E+06	5.800E+06
	INHAL2	2.240E+09	7.470E+08	3.000E+07	9.910E+08	1.260E+05	7.400E+06	1.280E+08	1.900E+08	4.600E+06	1.400E+07
	INGEST	1.900E+07	6.200E+06	8.870E+02	8.200E+06	1.450E+05	6.080E+04	1.100E+06	1.600E+06	3.900E+04	1.200E+05
	EXT AIR	3.270E+06	3.030E+06	1.790E+06	1.560E+06	1.130E+06	2.150E+06	1.500E+06	2.050E+06	1.020E+06	2.410E+06
	EXT GND	7.250E+04	6.720E+04	3.970E+04	3.460E+04	2.500E+04	4.470E+04	3.340E+04	4.570E+04	2.270E+04	5.350E+04

Table 2.4 (continued)

		ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-238	INHAL1	7.910E+08	2.640E+08	3.090E+08	3.550E+08	6.200E+04	2.600E+06	4.600E+07	7.600E+07	1.600E+06	5.000E+06
	INHAL2	2.030E+09	6.770E+08	3.200E+07	9.070E+08	5.510E+04	6.600E+06	1.170E+08	1.730E+08	4.100E+06	1.300E+07
	INGEST	5.000E+05	1.700E+05	7.890E-02	2.200E+05	1.100E+05	1.640E+03	2.910E+04	4.320E+04	1.030E+03	3.200E+03
	EXT AIR	1.260E+03	1.090E+03	3.020E+02	1.330E+02	4.450E+02	2.460E+02	1.770E+02	1.660E+03	1.860E+02	1.320E+03
	EXT GND	2.470E+02	2.140E+02	5.920E+01	2.600E+01	8.710E+01	4.810E+01	3.460E+01	3.250E+02	3.640E+01	2.680E+02
PU-239	INHAL1	9.120E+08	3.040E+08	2.940E+08	4.040E+08	5.780E+04	3.000E+06	5.200E+07	8.600E+07	1.800E+06	5.800E+06
	INHAL2	2.280E+09	7.610E+08	3.000E+07	1.000E+09	5.130E+04	7.400E+06	1.300E+08	1.920E+08	4.600E+06	1.500E+07
	INGEST	5.700E+05	1.900E+05	6.090E-02	2.500E+05	9.850E+04	1.850E+03	3.220E+04	4.820E+04	1.150E+03	3.600E+03
	EXT AIR	6.410E+02	5.610E+02	1.710E+02	9.380E+01	1.900E+02	1.890E+02	1.230E+02	7.220E+02	1.170E+02	6.110E+02
	EXT GND	1.220E+02	1.070E+02	3.240E+01	1.780E+01	3.600E+01	3.590E+01	2.330E+01	1.370E+02	2.210E+01	1.160E+02
PU-240	INHAL1	9.130E+08	3.040E+08	2.950E+08	4.050E+08	5.820E+04	3.000E+06	5.200E+07	8.600E+07	1.800E+05	5.800E+06
	INHAL2	2.280E+09	7.600E+08	3.100E+07	1.010E+09	5.170E+04	7.400E+06	1.300E+08	1.940E+08	4.600E+06	1.500E+07
	INGEST	5.700E+05	1.900E+05	8.320E-02	2.500E+05	9.930E+04	1.840E+03	3.220E+04	4.830E+04	1.150E+03	3.690E+03
	EXT AIR	1.160E+03	1.000E+03	2.890E+02	1.400E+02	3.950E+02	2.530E+02	1.780E+02	1.460E+03	1.600E+02	1.170E+03
	EXT GND	2.250E+02	[illegible].960E+02	5.640E+01	2.720E+01	7.790E+01	4.930E+01	3.470E+01	2.850E+02	3.520E+01	2.280E+02
AM-241	INHAL1	9.430E+08	3.140E+08	3.130E+08	4.190E+08	6.520E+04	3.100E+06	5.400E+07	8.900E+07	1.900E+06	6.000E+06
	INHAL2	2.350E+09	7.830E+08	3.200E+07	1.040E+09	6.110E+04	7.700E+06	1.340E+08	1.990E+08	4.800E+06	1.500E+07
	INGEST	1.900E+07	6.400E+06	1.270E+02	8.500E+06	1.100E+05	6.320E+04	1.100E+06	1.600E+06	3.940E+04	1.200E+05
	EXT AIR	2.720E+05	2.480E+05	1.010E+05	8.300E+04	5.680E+04	1.330E+05	8.800E+04	1.440E+05	8.510E+04	1.260E+05
	EXT GND	[illegible].420E+04	1.300E+04	5.300E+03	4.330E+03	2.960E+03	7.210E+03	4.590E+03	7.500E+03	4.440E+03	6.570E+03
PU-242	INHAL1	8.690E+08	2.870E+08	2.800E+08	3.850E+08	5.510E+04	2.800E+06	5.000E+07	8.200E+07	1.800E+06	5.500E+06
	INHAL2	2.170E+09	7.220E+08	2.900E+07	9.560E+08	4.900E+04	7.100E+06	1.230E+08	1.840E+08	4.400E+06	1.400E+07
	INGEST	5.400E+05	1.800E+05	1.600E-01	2.400E+05	9.400E+04	1.760E+03	3.060E+04	4.600E+04	1.090E+03	3.420E+03
	EXT AIR	1.040E+03	8.930E+02	2.360E+02	9.370E+01	3.650E+02	1.770E+02	1.320E+02	1.390E+03	1.51[illegible]E+02	1.100E+03
	EXT GND	2.030E+02	1.750E+02	4.630E+01	1.840E+01	7.160E+01	3.470E+01	2.590E+01	2.720E+02	2.9[illegible]E+01	2.170E+02
AM-243	INHAL1	9.430E+08	1.560E+09	3.030E+08	4.210E+08	3.220E+05	3.100E+06	5.400E+07	8.900E+07	1.900E+06	6.000E+06
	INHAL2	2.340E+09	3.870E+09	3.100E+07	1.040E+09	1.500E+05	7.700E+06	1.3[illegible]E+08	1.990E+08	4.800E+06	1.500E+07
	INGEST	1.900E+07	3.200E+07	9.640E+02	8.500E+06	1.490E+05	6.340E+04	1.100E+06	1.600E+06	4.070E+04	1.200E+05
	EXT AIR	2.170E+06	2.010E+06	1.060E+06	9.140E+05	6.490E+05	1.330E+06	8.970E+05	1.290E+06	6.760E+05	1.410E+06
	EXT GND	5.290E+04	4.800E+04	2.630E+04	2.260E+04	1.610E+04	3.260E+04	2.210E+04	3.150E+04	1.650E+04	3.480E+04

population intake of fish (3.3E-7 kg per person/ℓ). The EPA estimate of 3.3E-7 kg per person/ℓ is the same as assuming a 1 kg/yr fish intake. Therefore, for the EPA/SANDIA calculations a 1 kg/yr consumption of fish and the same population used for the drinking water calculations (6.3E6 persons) were assumed.

The population for the land-based ingestion intakes was calculated by multiplying the density (persons/m^2) provided by EPA for the three subpathways by the area considered in the hypothetical reference site analysis (160 km^2) (Cranwell, et al., 1982). The populations used in these subpathway calculations were

CROP

$$160\ km^2 * 1.0E\text{-}3 \frac{person}{m^2} = 1.6E5\ persons$$

MILK

$$160\ km^2 * 1.5E\text{-}3 \frac{person}{m^2} = 2.4E5\ persons$$

BEEF

$$160\ km^2 * 2.1E\text{-}4 \frac{person}{m^2} = 3.4E4\ persons\ .$$

2.1.3 Quantity Intake of Radionuclides

The quantity intake of a radionuclide is dependent upon the concentration of the radionuclide in the food source and the rate of intake or consumption. The EPA/SANDIA calculations utilized the equations for each subpathway available in the Pathways Model and substituted the appropriate EPA parameter values. In some cases, the modeling approaches differed between EPA and the Pathways Model, and in these cases, the input parameters were selected from those used in the reference site analysis (Cranwell, et al., 1982). The EPA point values used in the analysis are given with each equation and are summarized in Tables 2.5 and 2.6. The radionuclide dependent concentration ratios were taken from a computer output provided by J. M. Smith, EPA, and are given in Table 2.7 (recently published in Smith, et al., 1982). The equations for the various ingestion subpathways are defined in Sections 2.1.3.1 to 2.1.3.5.

Table 2.5

Ingestion, Inhalation and External Exposure Rates Assumed by EPA

Ingestion Rates	
Water Consumption by Humans	6.03E02 ℓ/yr
Plant Consumption by Humans	1.94E02 kg/yr
Milk Consumption by Humans	1.12E02 ℓ/yr
Beef Consumption by Humans	8.5E01 kg/yr
Fish Consumption by Humans	1.0E00 kg/yr
Inhalation Rate	
Average Air Consumption by Humans	8.40E03 m^3/y
Annual External Exposure	
Submersion in Air	1/3 year
Groundshine from Soil*	1/3 year

*An effective depth of 0.15m was assumed for soil by EPA.

Table 2.6

Crop and Animal Parameters
Assumed by EPA

<u>Animal Consumption Rates</u>	
Plant Consumption by Dairy Cows	5.0E01 kg/day
Plant Consumption by Beef Cows	5.0E01 kg/day
<u>Sprinkler Irrigation for Crops</u>	
Irrigation Rate	3.0E02 $\ell/m^2/y$*
Retention Fraction	2.5E-01*
Standing Crop	7.16E-01 kg/m^2
Rate Constant for Weathering (λ_ω)	1.8E01y^{-1} (13.75 day half-life)
Irrigation Time (τ)	1.7E-1 y
$e^{-\lambda\omega\tau}$	4.65E-2
<u>Sprinkler Irrigation for Pasture</u>	
Irrigation Rate	3.0E02 $\ell/m^2/y$*
Retention Fraction	2.5E-01*
Standing Crop	2.8E-01 kg/m^2
Rate Constant for Weathering (λ_ω)	1.8E01 y^{-1} (13.75 day half-life)
Irrigation Time (τ)	1.7E-1 y
$e^{-\lambda\omega\tau}$	4.65E-2

*These parameters were not defined in the EPA Analysis: therefore the values used in reference site analysis to demonstrate the SNL Risk Assessment Methodology were substituted for the calculation.

Table 2.7

Concentration Ratios Assumed by EPA

	FISH/WATER (Ci/kg per Ci/l)	CROP/SOIL (dimensionless)	PASTURE (FEED)/SOIL (dimensionless)	MILK/FEED $\left(\frac{day \cdot kg}{kg \cdot l}\right)$	BEEF/FEED $\left(\frac{day \cdot kg}{kg \cdot kg}\right)$
Am241	2.5E1	0.11E-2	0.74E-2	0.36E-4	0.16E-5
Am243	2.5E1	0.22E-3	0.15E-2	0.36E-4	0.16E-5
CS135	4.0E2	0.10E-5	0.17E-4	0.56E-2	0.14E-1
CS137	4.0E2	0.85E-2	0.14E0	0.56E-2	0.14E-1
I129	1.5E1	0.19E-7	0.68E-7	0.99E-2	0.70E-2
NP237	1.0E1	0.16E-7	0.65E-7	0.50E-5	0.20E-3
Pu239	3.5E2	0.59E-4	0.36E-3	0.53E-7	0.19E-7
Pu240	3.5E2	0.19E-3	0.12E-2	0.53E-7	0.19E-7
Pu242	3.5E2	0.40E-5	0.24E-4	0.45E-7	0.41E-6
SR90	5.0E0	0.21E0	0.86E0	0.24E-2	0.30E-3
TC99	1.5E1	0.14E-5	0.28E-3	0.99E-2	0.87E-2
SN126	3.0E3	0.77E-5	0.31E-4	0.12E-2	0.80E-1

2.1.3.1 Drinking Water

$$\text{amt of nuclide intake per year} = \begin{pmatrix}\text{nuclide conc}\\ \text{in surface water}\end{pmatrix} * \begin{pmatrix}\text{rate of water}\\ \text{ingestion}\end{pmatrix}$$

$$Ci/y = (Ci/\ell) * (603\ell/y)$$

2.1.3.2 Fish

$$\text{amt of nuclide intake per year} = \begin{pmatrix}\text{nuclide conc in}\\ \text{surface water}\end{pmatrix} * \begin{pmatrix}\text{conc}\\ \text{ratio}\end{pmatrix} * \begin{pmatrix}\text{rate of fish}\\ \text{ingestion}\end{pmatrix}$$

$$Ci/y = (Ci/\ell) * (\ell/kg) * (1.0\ kg/y)$$

where

$$\text{conc ratio} = \frac{\text{conc of nuclide in fish}}{\text{conc of nuclide in water}}$$

2.1.3.3 Crops

$$\text{amt of nuclide intake per year} = \begin{pmatrix}\text{nuclide conc}\\ \text{in crops}\end{pmatrix} * \begin{pmatrix}\text{rate of crop}\\ \text{ingestion}\end{pmatrix}$$

$$Ci/y = (Ci/kg) * (194\ kg/y)$$

$$\text{nuclide conc in crops} = \begin{pmatrix}\text{nuclide conc}\\ \text{in soil}\end{pmatrix} * \begin{pmatrix}\text{conc}\\ \text{ratio}\end{pmatrix} + \begin{pmatrix}\text{conc due to}\\ \text{sprinkler irrigation}\end{pmatrix}$$

$$Ci/kg = (Ci/kg) * (\text{dimensionless}) + (Ci/kg)$$

where

$$\text{conc ratio} = \frac{\text{conc of nuclide in crops}}{\text{conc of nuclide in soil}}$$

$$\text{nuclide conc due to sprinkler irrigation} = \frac{1}{\text{rate constant for weathering}}\left(\frac{\text{retention fraction} * \text{nuclide conc in surface water} * \text{irrigation rate}}{\text{standing crop}}\right)\left(1-e^{-\lambda_\omega t}\right)$$

$$Ci/kg = \left(\frac{1}{18.05\ y^{-1}}\right)\left(\frac{0.25 * (Ci/\ell) * 300\ \ell/m^2/y}{0.716\ kg/m^2}\right) \qquad (0.9535)$$

2.1.3.4 Milk

$$\text{amt of nuclide intake per year} = \begin{pmatrix}\text{nuclide conc}\\ \text{in milk}\end{pmatrix} * \begin{pmatrix}\text{rate of milk}\\ \text{ingestion}\end{pmatrix}$$

$$\mathrm{Ci/y} = (\mathrm{Ci/\ell}) * (112\ \ell/\mathrm{y})$$

$$\begin{matrix}\text{nuclide conc}\\ \text{in milk}\end{matrix} = \begin{pmatrix}\text{nuclide conc}\\ \text{in dairy feed}\end{pmatrix} * \begin{pmatrix}\text{conc}\\ \text{ratio}\end{pmatrix} * \begin{pmatrix}\text{consumption rate}\\ \text{of contaminated feed}\end{pmatrix}$$

$$\mathrm{Ci/\ell} = (\mathrm{Ci/kg}) * \left(\frac{\mathrm{day} \cdot \mathrm{kg}}{\mathrm{kg} \cdot \ell}\right) * \left(50\ \frac{\mathrm{kg}}{\mathrm{day}}\right)$$

where

$$\text{conc ratio} = \frac{\text{conc of nuclide in milk}}{\text{intake of nuclide per day}}$$

$$\begin{matrix}\text{nuclide conc in}\\ \underline{\text{dairy}}\text{ and }\underline{\text{beef}}\text{ feed}\end{matrix} = \begin{pmatrix}\text{nuclide conc}\\ \text{in soil}\end{pmatrix} * \begin{pmatrix}\text{conc}\\ \text{ratio}\end{pmatrix} + \begin{pmatrix}\text{nuclide}\\ \text{conc due to}\\ \text{sprinkling}\\ \text{pasture}\end{pmatrix}$$

$$\frac{\mathrm{Ci}}{\mathrm{kg}} = (\mathrm{Ci/kg}) * (\text{dimensionless}) + (\mathrm{Ci/kg})$$

where

$$\text{conc ratio} = \frac{\text{conc of nuclide in pasture}}{\text{conc of nuclide in soil}}$$

$$\begin{matrix}\text{nuclide}\\ \text{conc due}\\ \text{to}\\ \text{sprinkling}\\ \text{pasture}\end{matrix} = \frac{1}{\begin{matrix}\text{rate constant}\\ \text{for weathering}\end{matrix}}\left(\frac{\begin{matrix}\text{retention}\\ \text{fraction}\end{matrix} * \begin{matrix}\text{nuclide}\\ \text{conc in}\\ \text{surface}\\ \text{water}\end{matrix} * \begin{matrix}\text{irrigation}\\ \text{rate}\end{matrix}}{\text{standing crop}}\right)\left(1-e^{-\lambda_\omega t}\right)$$

$$\mathrm{Ci/kg} = \left(\frac{1}{18.05\ \mathrm{y}^{-1}}\right)\left(\frac{0.25 * (\mathrm{Ci/\ell}) * 300\ \ell/\mathrm{m}^2/\mathrm{y}}{0.28\ \mathrm{kg/m}^2}\right)(0.9535)$$

2.1.3.5 Beef

$$\begin{matrix}\text{amt of nuclide}\\ \text{intake per year}\end{matrix} = \begin{pmatrix}\text{nuclide conc}\\ \text{in beef}\end{pmatrix} * \begin{pmatrix}\text{rate of beef}\\ \text{ingestion}\end{pmatrix}$$

$$\mathrm{Ci/y} = (\mathrm{Ci/kg}) * (85\ \mathrm{kg/y})$$

$$\begin{matrix}\text{nuclide conc}\\ \text{in beef}\end{matrix} = \begin{pmatrix}\text{nuclide conc}\\ \text{in beef feed}\end{pmatrix} * \begin{pmatrix}\text{conc}\\ \text{ratio}\end{pmatrix} * \begin{pmatrix}\text{consumption}\\ \text{rate of}\\ \text{contaminated}\\ \text{feed}\end{pmatrix}$$

$$Ci/kg = \left(\frac{Ci}{kg}\right) * \left(\frac{day \bullet kg}{kg \bullet kg}\right) * (50\ kg/day)$$

where

$$\text{conc ratio} = \frac{\text{conc of nuclide in beef}}{\text{intake of nuclide per day}}$$

nuclide conc in beef feed = calculated the same as dairy feed (See 2.1.3.4)

2.2 Inhalation

The inhalation pathway considers inhaled radionuclides that are resuspended from the soil. The EPA obtained suspended radionuclide concentrations through multiplication of surface radionuclides concentration (expressed in Ci/m^2) by a resuspension factor of $10^{-9}m^{-1}$ (Smith, et al., 1982). In contrast, in this analysis the suspended radionuclide concentration was obtained by multiplying the soil concentration (Ci/kg) by an assumed concentration of suspended material in air of 3.5E-9 kg/m^3. The latter concentration of suspended material was taken from the listing of various soil types in the CRC Handbook of Environmental Control, Volume 1 (Bond and Straud, 1973).

2.2.1 Dose Factors and Health Effects Estimates

The dose conversion factors (rem/Ci) for the inhalation pathway were taken from Table 2.4 and were multiplied by the appropriate health effects estimates for the organs considered. INHAL1 dose factors are for insoluble (Y class) material retained in the lung for long biological half-times, while INHAL2 dose factors are for more soluble (W class) inhaled material and result in more dose to the other body organs. For this comparative calculation, the INHAL2 dose commitment factors were multiplied by the health effects estimators and summed over all organs for each radionuclide considered.

2.2.2 Population at Risk

The population at risk for the inhalation pathway was calculated by multiplying the population density (6.7E-5 persons/m^2) provided by EPA and the area considered in the reference site analysis (160 km^2). The area dependent population of 1.1E4 persons was used for these calculations.

2.2.3 Quantity Intake of Radionuclides

$$\text{amt of nuclide intake per year} = \begin{pmatrix}\text{nuclide conc}\\ \text{in soil}\end{pmatrix} * \begin{pmatrix}\text{conc of}\\ \text{suspended}\\ \text{material}\\ \text{in air}\end{pmatrix} * \begin{pmatrix}\text{average}\\ \text{breathing}\\ \text{rate}\end{pmatrix}$$

$$Ci/y = (Ci/kg) * (3.5E\text{-}9\ kg/m^3) * (8400m^3/y).$$

2.3 External Exposure

EPA considered external exposure from contaminated soil and air in their analysis. The soil concentrations calculated by the Pathways Model (see Table 2.3) were used to estimate the external exposure for this comparison analysis. The approach detailed in Subsection 2.2 for calculating the radionuclide concentration in the air was used to estimate the air concentrations for the air submersion exposure calculations. An assumed exposure time of 1/3 year was multiplied by the soil concentration and the air concentration to estimate the exposure level.

2.3.1 Dose Factors and Health Effects Estimates

The dose conversion factors for the air exposure pathway and for the soil exposure pathway were multiplied by the appropriate health effects estimates (Table 2.4) and were summed over all organs for each radionuclide.

2.3.2 Population at Risk

The population density of ($6.7E\text{-}5$ persons/m^2) provided by EPA was multiplied by the area of 160 km^2 considered in the reference site analysis. Again, the area dependent population of 1.1E4 persons was used for the calculation of air and soil exposure.

2.3.3 Exposure Level

2.3.3.1 <u>Contaminated Soil</u>

$$\text{Exposure Level} = \begin{pmatrix}\text{nuclide conc}\\ \text{in soil}\end{pmatrix} * \begin{pmatrix}\text{soil}\\ \text{density}\end{pmatrix} * \begin{pmatrix}\text{effective}\\ \text{depth}\end{pmatrix} * \begin{pmatrix}\text{exposure}\\ \text{time}\end{pmatrix}$$

$$\left(\frac{Ci \cdot y}{m^2}\right) = \left(\frac{Ci}{kg}\right) * \left(\frac{2.6E3\ kg}{m^3}\right) * (.15m) * \left(\frac{1}{3}\ y\right)$$

2.3.3.2 Contaminated Air

$$\text{Exposure Level} = \begin{pmatrix}\text{nuclide conc}\\ \text{in soil}\end{pmatrix} * \begin{pmatrix}\text{conc of}\\ \text{suspended}\\ \text{material}\\ \text{in air}\end{pmatrix} * \begin{pmatrix}\text{exposure}\\ \text{time}\end{pmatrix}$$

$$\left(\frac{Ci \cdot y}{m^3}\right) = \left(\frac{Ci}{kg}\right) * \left(\frac{3.5E\text{-}9\,kg}{m^3}\right) * \left(\frac{1}{3}\,y\right)$$

3.0 Description of the SANDIA Analysis

The SANDIA health effects per curie release values were calculated using the modeling approaches and input parameters presented in the Pathways Model (Helton and Kaestner, 1981) and the Dosimetry and Health Effects Model (Runkle, et al., 1981). The two compartment system of the Pathways Model, described in Chapter 2, was used in this analysis. The input parameters (distribution coefficients (Kd) and variables to vary flow between subzones) to the Pathways Model were assumed to be the point values presented in Table 2.1. The dose conversion factors (70 year intake/70 year dose commitment), concentration ratios, environmental parameters and health effects estimates from the Risk Assessment Methodology (Cranwell, et al., 1982) were used to calculate the SANDIA health effects per curie values. The average individual risk estimates were converted to population risk by multiplying the density values assumed by EPA (in persons/m^2) and the area considered in the reference site analysis for the land-based pathways. The population estimates for drinking water and fish intake were based on a linear relationship of world population to the river flow rate of the world's rivers and the flow rate of the river considered in the reference site analysis. The equations used in the calculations for the ingestion, inhalation and external exposures are given in Table 3.1. The input parameters that were used in the calculations are given in Tables 3.2-3.8. The dose conversion factors used in the Risk Assessment Methodology consider a 70 year chronic intake and estimate a 70 year dose commitment. The 70 year dose commitment is essentially equivalent to the 50 year dose commitment (considered by EPA), however, the 70 year chronic intake must be adjusted to account for the ~143 generation that can occur in 10,000 years. Therefore, the health effects estimates were divided by a factor of 70 for estimating the health effects per curie release values.

Many of the parameters used in the SANDIA Analysis are different from those preesented in the EPA analysis and may be the source of some of the differences between the SANDIA and EPA health effects per curie values. For example, in the

Table 3.1

Basic Equations for Calculating Radionuclide Concentrations for Various Pathways

WATER BASED

(1) Drinking Water Intake (Ci/yr)=Water Consumption (370 ℓ/yr) *Water Treatment Factor (1.0) * Water Conc. (Ci/ℓ)

(2) Fish (kg/yr) = Fish Consumption (6.9 kg/yr) *Water/Fish Conc. Factor (CF)[a] *Water Conc. (Ci/ℓ)

LAND WITHOUT IRRIGATION

(3) Plant Conc. (Ci/kg) = Soil/Plant CF[a] *Soil Conc. (Ci/kg)

(4) Plant Intake (Ci/yr) = Plant Consumption (190.0 kg/yr) * Plant Conc. (Ci/kg)

(5) Milk Intake (Ci/yr) = [Dairy Cow Consumption of Plants (50 kg/day) * Plant Conc. (Ci/kg)
+ Dairy Cow Drinking Rate Per Day (60.0 ℓ/day)
* Water Conc. (Ci/ℓ)] * Milk/Diet CF[a]
* Milk Consumption Rate (110.0 ℓ/yr)

(6) Meat Intake (Ci/yr) = [Beef Cattle Consumption of Plants (50 kg/day) * Plant Conc. (Ci/kg)
+ Beef Cattle Drinking Rate Per Day (500 ℓ/day)
* Water Conc. (Ci/ℓ)] * Beef/Diet CF[a]
* Meat Consumption Rate (95.0 kg/yr)

LAND WITH IRRIGATION

(7) Deposition Rate (Ci/kg-yr)=Retained Fraction on Plant (.25)
* Water Conc. (Ci/ℓ)
* [Rate Irrigation (300 l/m^2-yr)/Plant Density (5.2 kg/m^2)]

(8) Rate Constant for Weathering (yr^{-1}) = ln2/.0384 yr (14 Day Half Life)

(9) Plant Conc. (Ci/kg) = [Soil/Plant CF[a] *Soil Conc. (Ci/kg)]
+ [(Deposition Rate (Ci/kg)/Weathering Rate (yr^{-1})]
* [1 - [Exp -ln2/.0384 * Irrigation Time (.17 yr)]]

Plant, Beef, Milk Consumptions with Irrigation are Calculated Using Formulas 4-6 and the Plant Conc. (9).

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[a]See Table 3.2 These concentration factors are radionuclide dependent.

Table 3.1 (Continued)

INHALATION

(10) Air Conc. (Ci/m^3) = Soil Conc. (Ci/kg)
* Concentration of Suspended Material in the Air ($3.5E-9$ kg/m^3)

(11) Inhalation (Ci/yr) = Air Conc. (Ci/m^3)

* Breathing Rate (8000 m^3/yr)

EXTERNAL

(12) Air Submersion = (6.[illegible]E5 hrs (Lifetime Exposure))
* Air Conc. (Ci/m^3)

(13) Soil Exposure = [2.04E5 hrs (1/3 year Exposure for 70 years)

* Soil Conc. (Ci/kg) * Soil Density (2.6E3 kg/m^3)

* Soil Depth (.025m)]

(14) Sediment Exposure = [1.05E3 hrs (15 hrs/yr for 70 years)

* Sediment Conc. (Ci/kg) * Sediment Density (2.6E3 kg/m^3)

* Sediment Depth (.025m)]

(15) Water Immersion = (1.06E3 hrs (15 hrs/yr for 70 years)

* Water Conc. (Ci/ℓ) * 1000 ℓ/m^3)

Table 3.2

Concentration Ratios for Human and Animal Food Sources
(Used in Reference Site Analysis)

Radionuclide	FISH/WATER (Ci/kg per Ci/l)	CROP/SOIL PASTURE/SOIL (dimensionless)	MILK/FEED (day • kg/kg • l)	BEEF/FEED (day • kg/kg • kg)
[illegible]	2.5E01	2.5E-04	5.0E-06	2.0E-04
CS	2.0E03	1.0E-02	1.2E-02	4.0E-03
I	1.5E01	2.0E-02	6.0E-03	2.9E-03
NP	1.0E01	2.5E-03	5.0E-06	2.0E-04
Pu	3.5E00	2.5E-04	2.0E-06	1.4E-05
SR	3.0E01	1.7E-02	8.0E-04	6.0E-04
TC	1.5E01	2.5E-01	2.5E-02	4.0E-01
SN	3.0E03	2.5E-03	2.5E-03	8.0E-02

*Taken from NRC (1977)

Table 3.3

Ingestion, Inhalation and External Exposure Rates
for an Average Individual
(Used in Sandia Reference Site Analysis)

Ingestion Rates	
Water Consumption by Humans	3.7 E02 ℓ/yr
Plant Consumption by Humans	1.9 E02 kg/yr
Milk Consumption by Humans	1.1 E02 ℓ/yr
Beef Consumption by Humans	9.5 E01 kg/yr
Fish Consumption by Humans	6.9 E00 kg/yr
Inhalation Rate	
Average Air Consumption by Humans	8.0 E03 m^3/yr
External Exposure Rates	
Submersion in Air	8.7 E03 hr/yr
Groundshine from Soil	2.9 E03 hr/yr*

*An effective depth of 0.025 m was assumed for soil and sediment.

Taken from USNRC (1977) and USDOE (1979)

Table 3.4

Crop and Animal Parameters
(Used in Sandia Reference Site Analysis)

Animal Consumption Rates	
Plant Consumption by Dairy Cows	5.0E01 kg/day
Water Consumption by Dairy Cows	6.0E01 ℓ/day
Plant Consumption by Beef Cows	5.0E01 kg/day
Water Consumption by Beef Cows	5.0E01 ℓ/day
Sprinkler Irrigation of Crops and Pasture	
Irrigation Rate	3.0E02 ℓ/m^2
Retention Fraction	2.5E-01
Standing Crop (Plant Density)	5.2E00 kg/m^2
Constant Rate of Weathering (λ_ω)	1.8E01 yr^{-1} (14 day half life)
Irrigation Time (τ)	1.7E-01 yr
$e^{-\lambda_\omega \tau}$	4.65E-02

Table 3.5

Dose Conversion Factors - Ingestion
(rem/Ci)

(70-year intake/70-year dose commitment)

	TOTAL BODY	BONE	LUNG	GI TRACT
SR90	1.01E8	4.07E8	0.0	1.53E7
TC99	3.51E3	8.76E3	1.11E3	2.89E4
SN126	1.68E5	5.88E6	0.0	1.70E6
I129	6.41E5	2.29E5	0.0	3.11E4
CS135	5.55E5	1.35E6	1.42E5	2.95E4
CS137	4.96E6	5.53E6	8.51E5	1.48E5
NP237	2.77E6	6.80E7	0.0	5.56E6
Pu239	9.51E5	3.91E7	0.0	4.66E6
Pu240	9.50E5	3.91E7	0.0	4.75E6
Pu242	9.16E5	3.63E7	0.0	4.57E6
AM241	2.75E6	4.08E7	0.0	5.19E6
AM243	2.68E6	4.07E7	0.0	6.09E6

Taken from Runkle, et al., 1981.

Table 3.6

Dose Conversion Factors - Inhalation
(rem/Ci)

(70-year intake/70-year dose commitment)

	TOTAL BODY	BONE	LUNG	GI TRACT
SR90	1.35E8	2.17E9	8.67E7	6.31E6
TC99	3.51E3	8.76E3	7.32E6	5.28E5
SN126	9.39E5	2.35E7	8.47E7	1.11E6
I129	4.80E5	1.73E5	0.0	1.55E4
CS135	4.17E5	1.01E6	5.91E6	1.48E4
CS137	3.72E6	4.15E6	3.55E7	7.35E4
NP237	6.93E9	1.66E11	3.78E9	3.44E6
Pu239	7.93E9	3.26E11	1.22E10	2.89E6
Pu240	7.91E9	3.26E11	1.22E10	2.95E6
Pu242	7.63E9	3.02E11	1.18E10	2.83E6
AM241	6.86E9	1.03E11	4.39E9	3.22E6
AM243	6.70E9	1.03E11	4.16E9	3.78E6

Taken from Runkle, et al., 1981.

Table 3.7

Dose Conversion Factors - External

	TOTAL BODY	
	SOIL (rem/hr/Ci/m^2)	AIR (rem/hr/Ci/m^3)
SR90	0.0	2.40E-1
TC99	0.0	5.80E-2
SN126	9.00E0	1.32E4
I129	4.50E-1	1.80E1
CS135	0.0	2.80E-2
CS137	4.20E0	4.70E2
NP237	1.40E0	1.45E2
Pu239	7.90E-4	5.60E-2
Pu240	1.30E-3	6.50E-2
Pu242	1.10E-3	5.10E-2
AM241	1.80E-1	1.80E-1
AM243	1.30E0	1.40E2

Taken from Runkle, et al., 1981.

Table 3.8

Cancer Risk Estimates Used in the SANDIA Analysis

Type of Cancer	Individual Risk per rem*	Organ Dose Commitment Associated With This Cancer Type
Leukemia	2.9E-05	Bone
Lung	2.5E-05	Lung
GI Tract	1.9E-05	GI Tract
Breast	2.9E-05	Total Body
Bone	9.8E-06	Bone
All Other	3.6E-05	Total Body

*Based on a lifetime plateau period for the solid tumor cancers.

Taken from Runkle et al., 1981.

ingestion calculations for land-based food sources, the contributions from crop irrigation were taken into account in the SANDIA Analysis. Also, the intake of contaminated drinking water by the animals that provide milk and beef was considered. In contrast, the EPA considered only the intake of contaminated forage by the milk and beef producing animals.

4.0 Description of SAMPLED SANDIA Analysis

This set of calculations was performed to consider some of the uncertainty that results from variability in the input parameters. However, only a few of the parameters were varied and the uncertainties in many other aspects of the modeling effort were not addressed. In this analysis, the Pathways Model utilized a set of sampled input parameters selected by the Latin Hypercube sampling technique (Iman, et al., 1980). The distribution coefficients (Kd) and variables to adjust the flow rates between various subzones were sampled and the range, description and assigned distribution of each input parameter are defined in Table 4.1. The results of the analysis represent a 3σ variation in the input data for those variables with a log-normal or normal distribution assigned to their ranges. Those variables with a uniform or log-uniform distribution assigned were sampled over the entire range. Variables 1 to 4, that adjust the flow rates, are further described in Table 4.2. Fifteen runs of the computer code were made, each with a different sampled set of input variables. The output of each computer run (in the form of radionuclide concentration in the soil and surface water) was processed by the Dosimetry and Health Effects Computer Code, and health effects (cancer deaths) per curie release were calculated. The concentration ratios, dose conversion factors and risk estimates used in this analysis are described in Chapter 3.

The population for the water based pathways was based on the linear relationship between river flow rate and population described above. To estimate the population at risk for this calculation, the flow rate of the river was varied by the sampled variable (R_1) and the population was adjusted for each of the fifteen computer runs. The population for the land based and external pathways was based on the density defined by EPA and the area of the reference site of 160 km^2. These populations, which are area dependent, were kept constant for the fifteen computer runs for land based and external pathways.

As discussed in Chapter 3, the health effects per curie release were divided by 70 to account for the ~ 143 generations that can occur in a 10,000 year period.

Two types of calculations were performed depending on whether or not adsorption was allowed to influence the solid phase (particulates) of the surface water. For the first set

Table 4.1

Latin Hypercube Sample

TITLE-LHS PATH EPA

RANDOM SEED = 5114652675042517

NUMBER OF VARIABLES = 12 SAMPLE SIZE = 15

DISTRIBUTION AND RANGE ASSUMED FOR EACH VARIABLE

Variable	Distribution Assumed	Range			
1	Uniform	.250	to	2.00	Scale Factor Rivr Dischrg
2	Log Uniform	1.000E-02	to	1.00	Scale Factor Water Xchng
3	Log Uniform	1.000E-04	to	1.000E-02	Scale Factor Solid Xchng
4	Uniform	3.00	to	15.0	Regional Erosion Rate
5	Log Normal	1.000E-02	to	2.500E+05	KD for CM(AM)
6	Log Normal	1.000E-02	to	1.000E+04	KD for Pu
7	Log Normal	1.000E-02	to	50.0	KD for NP
8	Log Normal	1.000E-02	to	1.000E+03	KD for TC
9	Log Normal	1.000E-02	to	3.000E+03	KD for SR
10	Log Normal	1.000E-02	to	1.000E+04	KD for CS
11	Log Normal	1.000E-02	to	1.000E+03	KD for I
12	Log Normal	1.000E-02	to	1.000E+03	KD for SN

Table 4.2

Variables Which Affect the Physical Description of the Surface Environment

R_1:	scale factor used to introduce variation in hydrologic properties. New values for water flow from the soil compartment to the ground-water compartment are obtained by multiplication with this factor. As the reference site was defined with an annual rainfall of 1 m, use of R_1 amounts, in a crude way, to varying the rainfall from .25 m to 2 m. This is only approximate, as the indicated rates do not move in a strictly linear manner with rainfall; however, it is felt that this provides a way of varying between wet and dry conditions. (Units: Unitless; Range: .25, 2.; Sampling Dist.: Uniform.)
R_2:	scale factor used to introduce variation in water movement between the soil compartment and the surface water compartment. New values for such movements are obtained by multiplication of the pore volume of the soil compartment by R_2. This variable is introduced to allow for variation in water movements which might result from runoff, irrigation or overbank flooding. (Units: yr^{-1}; Range: 10^{-2}, 10^{0}; Sampling Dist.: Log Uniform.)
R_3:	scale factor used to introduce variation in solid movement between the soil compartment and the surface water compartment. New values for such movements are obtained by multiplication of the mass of solids contained in a soil compartment by R_3. This variable is introduced to allow for variation in solid movements which might result from runoff, irrigation or overbank flooding. (Units: yr^{-1}; Range: 10^{-4}, 10^{-2}; Sampling Dist.: Log Uniform.)
R_4:	regional erosion rate. (Units: cm/1000 yr; Range: 3., 15.; Sampling Dist.: Uniform.)

of calculations, the radionuclides were input into the surface water with no adsorption onto the solid phase (particulates) of the water (i.e., Kd = 0 for all radionuclides in the water). However, the Kd influence in the soil compartment was considered. This technique is similar to the procedures used by EPA in their analysis and in the EPA/SANDIA and SANDIA calculations.

When flooding of a river occurs, the particulates suspended in the surface water may carry the adsorbed radionuclides onto the surrounding land mass. If adsorption of radionuclides onto solid phase of the surface water is ignored, there is a much smaller quantity of a radionuclide carried to the soil compartment by the surface water. In the second set of calculations, the radionuclides were allowed to adsorb onto the solid phase of the surface water as well as the liquid phase. The exchange to the soil compartment was influenced by the particulates suspended in the water, and the distribution coefficients (Kd) determined the partition of a radionuclide between the solid and liquid phases. The results of this analysis may simulate exchange that could occur with flooding and erosion or with irrigation and erosion.

5.0 Results and Discussion

The health effects per curie release for the individual pathways are given in Table 5.1. The EPA values were taken from the Health Effects per Curie Release Model and Subpathway Table provided to the author by the EPA. A slightly revised version of this table was published in Smith, et al., 1982. These values represent the health effects (deaths) per curie release. The EPA/SANDIA values were calculated using the procedures outlined in Chapter 2. This procedure utilized the Pathways Model and point Kd values provided by EPA to calculate the radionuclide concentrations in the soil and surface water. Other parameters (e.g., dose conversion factors, health effects estimates, etc.) from EPA were also used. The SANDIA values were calculated with Pathways Model and Dosimetry and Health Effects Model using the 70-year intake/ 70-year dose commitment factors, environmental parameters and risk estimates used in the reference site analysis. However, the same point Kd values from EPA (and used in the EPA/SANDIA calculations) were used in the analysis.

There is good agreement between the EPA and the EPA/SANDIA results for the drinking water and the fish pathways for most of the radionuclides. Marked differences are noted for the crop, milk and meat subpathways. EPA assumed that 0.5 curies were released to the soil over the 10,000-year interval and further assumed that 50% of the contaminated land was used for crop production for direct human consumption, 25% for milk

Table 5.1

Individual Pathways and Dosimetry and Health Effects Comparison Table
Expressed as Deaths Per Curie

		Drinking Water	Fish	Crop	Milk	Meat	Inhalation	External Soil	External Air
Am241	EPA	1.29E-1	3.7E-3	5.5E-1	8.2E-4	2.7E-6	2.2E-5	1.4E-5	2.9E-12
	EPA/Sandia	1.32E-1	5.45E-3	6.18E-3	2.62E-5	1.24E-7	3.03E-7	2.72E-5	4.34E-15
	Sandia	3.23E-3	1.51E-3	3.42E-5	1.84E-8	8.00E-8	2.27E-7	6.84E-7	1.02E-14
Am243	EPA	3.4E-1	1.2E-2	2.1E0	3.2E-3	1.5E-5	5.7E-5	7.3E-5	3.0E-12
	EPA/Sandia	1.06E-1	4.4E-3	5.03E-3	2.17E-5	1.03E-7	4.74E-6	7.01E-4	2.43E-13
	Sandia	3.25E-3	1.52E-3	4.62E-5	2.10E-8	9.28E-8	1.40E-6	3.08E-5	4.97E-13
Cs135	EPA	2.6E-4	1.7E-4	2.1E-3	9.9E-4	2.6E-4	2.4E-10	0	0
	EPA/Sandia	1.83E-4	1.21E-4	8.24E-6	5.11E-6	1.3E-6	3.01E-12	0.0	0.0
	Sandia	1.62E-4	6.02E-3	5.79E-6	4.33E-6	1.66E-7	1.01E-11	0.0	1.49E-17
Cs137	EPA	2.1E-3	1.3E-3	7.8E-3	2.1E-3	5.5E-4	1.9E-9	1.5E-4	8.4E-12
	EPA/Sandia	2.0E-3	1.33E-3	9.25E-5	6.42E-5	1.71E-5	1.71E-12	1.6E-5	7.53E-15
	Sandia	9.79E-4	3.65E-2	1.15E-5	1.40E-5	5.09E-7	4.42E-12	1.09E-6	1.82E-14
I129	EPA	1.6E-3	4.0E-5	6.4E-3	2.4E-3	1.8E-4	1.5E-9	1.1E-5	1.8E-13
	EPA/Sandia	1.63E-3	4.04E-5	7.32E-5	8.02E-5	6.03E-6	1.64E-14	1.48E-8	2.05E-18
	Sandia	8.95E-5	2.50E-5	8.89E-7	5.95E-7	3.12E-8	1.63E-15	1.45E-9	8.70E-18
Np237	EPA	1.3E-1	2.2E-3	4.6E-1	9.2E-5	3.9E-4	2.2E-5	1.0E-4	4.7E-12
	EPA/Sandia	1.3E-1	2.15E-3	5.84E-3	3.23E-6	1.38E-5	1.87E-8	3.76E-8	2.03E-8
	Sandia	5.08E-3	9.48E-4	5.28E-5	2.06E-8	1.25E-7	2.47E-8	3.77E-7	5.85E-15
Pu239	EPA	4.3E-3	2.5E-3	2.5E-2	5.4E-8	2.1E-9	3.1E-2	1.9E-7	1.0E-15
	EPA/Sandia	4.31E-3	2.5E-3	1.97E-4	1.19E-9	4.52E-11	2.37E-6	2.47E-6	1.09E-16
	Sandia	2.90E-3	1.89E-4	4.50E-5	7.83E-9	6.07E-9	5.42E-6	2.43E-8	2.58E-16
Pu240	EPA	4.3E-3	2.5E-3	2.4E-2	5.2E-8	2.0E-9	2.2E-5	3.8E-7	2.0E-15
	EPA/Sandia	3.31E-3	1.92E-3	1.55E-4	9.67E-10	3.70E-11	1.71E-6	3.48E-6	1.48E-16
	Sandia	2.90E-3	1.89E-4	4.03E-5	7.42E-9	5.73E-9	3.89E-6	2.87E-8	2.15E-16
Pu242	EPA	4.1E-3	2.4E-3	2.4E-2	4.4E-8	4.3E-8	2.1E-5	3.5E-7	1.8E-15
	EPA/Sandia	4.10E-3	2.38E-3	1.85E-4	9.22E-10	8.92E-10	2.58E-6	5.17E-6	2.18E-14
	Sandia	2.70E-3	1.76E-4	4.41E-5	7.48E-9	5.81E-9	5.76E-6	3.87E-8	2.69E-16
Sr90	EPA	8.0E-3	6.0E-5	1.0E-1	7.8E-3	1.0E-4	2.6E-8	0	0
	EPA/Sandia	7.99E-3	6.63E-5	4.78E-4	1.46E-4	1.95E-6	1.42E-11	0.0	0.0
	Sandia	3.94E-2	2.20E-2	4.65E-4	3.74E-5	3.07E-6	1.92E-10	0.0	5.53E-18
Tc99	EPA	2.4E-5	6.0E-7	1.9E-4	4.3E-5	5.8E-6	6.2E-10	0	0
	EPA/Sandia	2.39E-5	5.95E-7	1.08E-4	1.18E-6	1.10E-7	6.96E-15	0.0	0.0
	Sandia	2.02E-6	5.64E-7	2.11E-8	5.70E-8	9.93E-8	8.30E-15	0.0	2.80E-20
Sn126	EPA	1.4E-3	7.0E-3	6.7E-3	2.9E-4	2.1E-3	1.7E-8	4.6E-4	2.6E-11
	EPA/Sandia	1.38E-3	6.83E-3	6.19E-5	8.22E-6	5.82E-5	2.62E-10	8.54E-4	3.91E-13
	Sandia	4.72E-4	2.64E-2	8.49E-6	1.72E-6	6.14E-6	1.02E-10	3.98E-5	8.74E-12

production and 25% for beef production. The soil concentrations calculated by the Pathways Model used an asymptotic solution, dependent upon the flow rates between the soil and surface water subzones, and were based on a different input rate than the EPA analysis. The calculations performed by the Pathways Model resulted in an input of 2.3E-3 Ci to the soil over the 10,000 year period. Another contributor to the difference between the EPA and EPA/ SANDIA values is the different rate of input to the plants via sprinkler irrigation. For the calculations presented in this report, the input to plants by irrigation was 2.5E-7 Ci/yr, while EPA assumed a value of 5.0E-5 Ci/yr. This difference of greater than two orders of magnitude in the input rate is reflected in the results.

Generally, the SANDIA health effects per curie values are smaller than the EPA values for most of the paths and this difference appears to be due to differences in the input rates, concentration factors, dose conversion factors and exposure times used in the calculations. Again, the land based pathways are affected by differences in the input rates.

When the health effects per curie values from EPA and SANDIA are summed over subpathways 1-5 (includes drinking water, fish, crop, milk and meat) and 6-8 (includes inhalation, external soil and external air) the SANDIA values are lower in all cases (Table 5.2). Some values differ by factors of greater than 10^2; however, pathways 1-5 do not show as much variation as pathways 6-8. The risk of adverse health effects from pathways 6-8 is lower than the risk from pathways 1-5; therefore, the difference noted in pathways 6-8 is less significant. We have not attempted to account for all the differences; but the input rates, dose factors, and concentration ratios used in the two analyses appear to account for the major differences.

The results of the SANDIA SAMPLED calculations (described in Chapter 4) are presented graphically in Figures 5.1 to 5.4. The Kd ranges and the R_1 to R_4 variables were sampled using the Latin Hypercube Sampling technique for this analysis. The populations for the various subpathways, defined in Sections 2.1.2; 2.2.2; and 2.3.2, were used in this analysis. The population for the drinking water and fish intakes were adjusted by the sampled variable, R1, to account for changes in the river flow. The population for land based pathways was held constant for all 15 calculations.

In Figures 5.1 and 5.2 the results are given for the case when there was no adsorption of the radionuclide onto the solid phase of the surface water. The subpathways 1 to 5 (Figure 5.1) and 6 to 8 (Figure 5.2) were summed and the mean, maximum and minimum values of the fifteen computer runs are presented

Table 5.2

Pathway and Dosimetry and Health Effects
Comparison Table

Health Effects Per Curie

Radionuclide		EPA Pathways 1-5	EPA Pathways 6-8
Am241	EPA	7.0E-1	2.0E-2
	Sandia	4.8E-3	9.1E-7
Am243	EPA	2.5E00	2.0E-1
	Sandia	4.8E-3	3.2E-5
Cs135	EPA	3.8E-3	1.1E-7
	Sandia	6.2E-3	1.0E-11
Cs137	EPA	1.4E-2	6.0E-3
	Sandia	3.8E-2	1.1E-6
I129	EPA	1.1E-2	9.2E-5
	Sandia	1.2E-4	1.5E-9
Np237	EPA	5.9E-1	2.5E-3
	Sandia	6.1E-3	4.0E-7
Pu239	EPA	3.2E-2	3.7E-2
	Sandia	3.1E-3	5.4E-6
Pu240	EPA	3.1E-2	3.5E-2
	Sandia	3.1E-3	3.9E-6
Pu242	EPA	3.1E-2	3.7E-2
	Sandia	2.9E-3	5.8E-6
Sr90	EPA	1.2E-1	7.9E-7
	Sandia	6.2E-2	1.9E-10
Tc99	EPA	2.9E-4	4.9E-10
	Sandia	2.8E-6	8.3E-15
Sn126	EPA	1.7E-2	1.0E-1
	Sandia	2.7E-2	4.0E-5

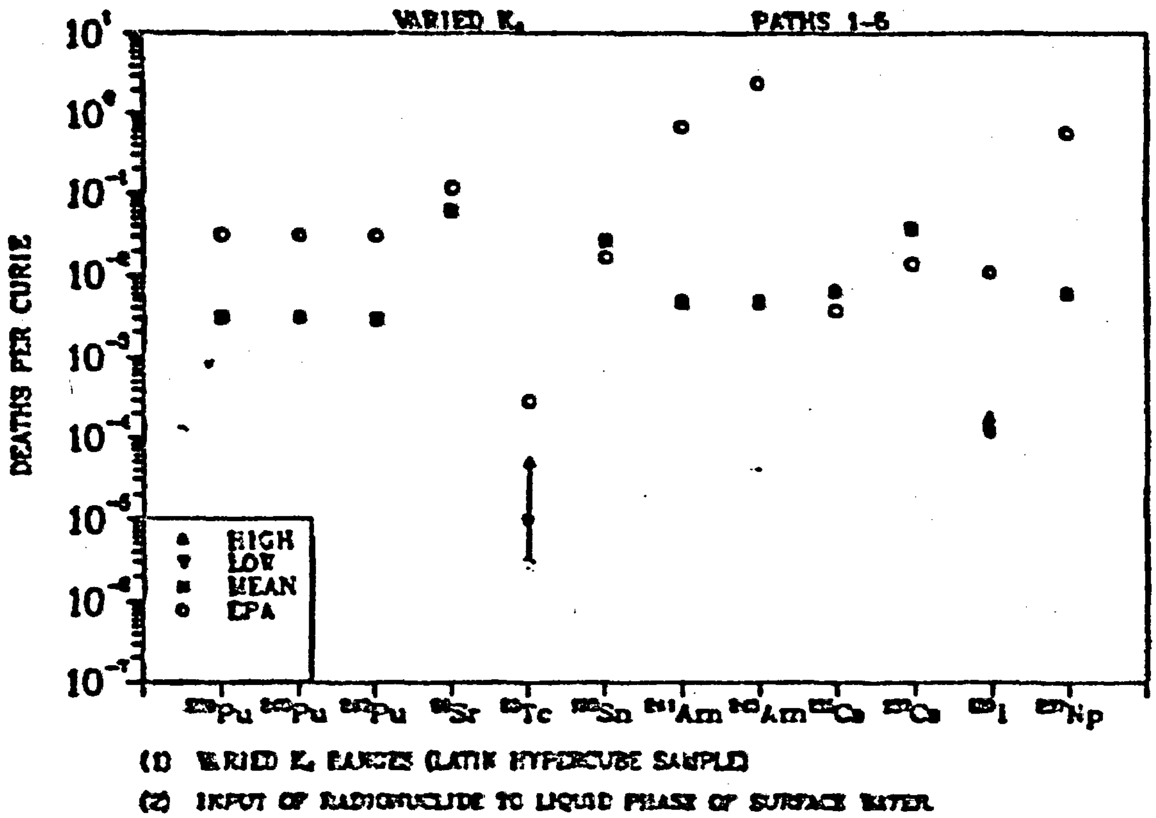
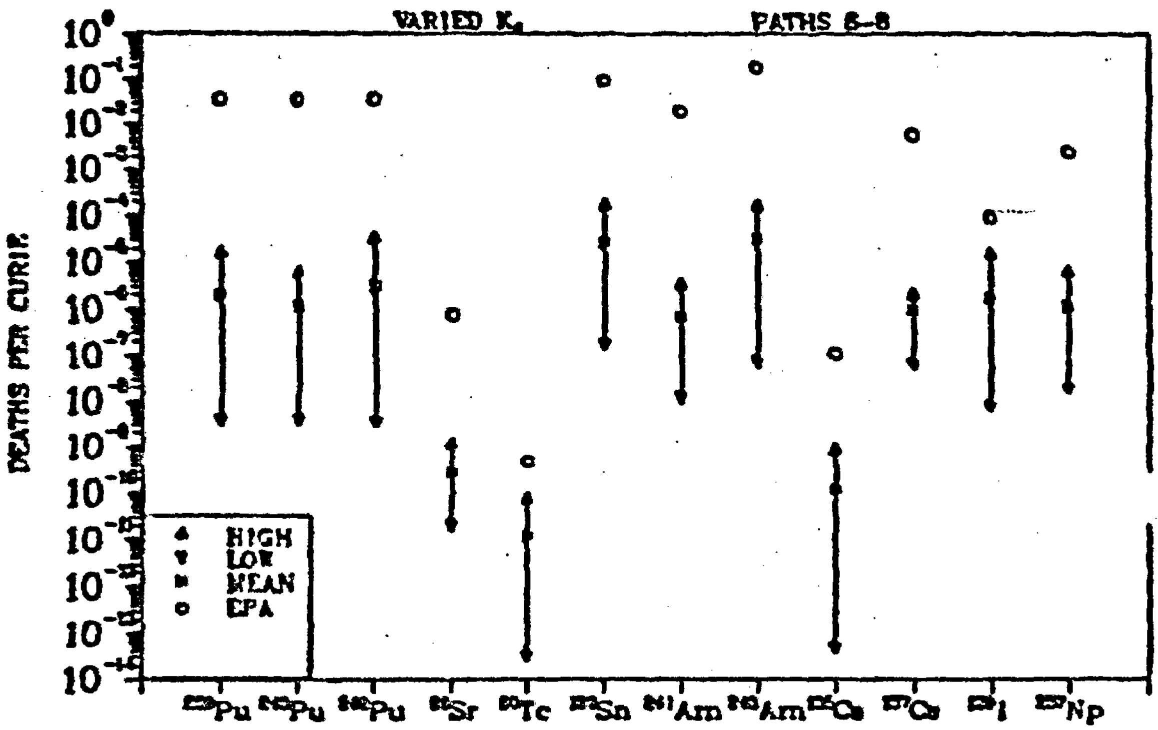


Figure 5.1.

Deaths per curie calculated with sampled Kd ranges and no adsorption onto solid phase of the surface water for Pathways 1-5.



(1) VARIED K RANGES (LATIN HYPERCUBE SAMPLE)

(2) INPUT OF RADIONUCLIDE TO LIQUID PHASE OF SURFACE WATER

Figure 5.2.

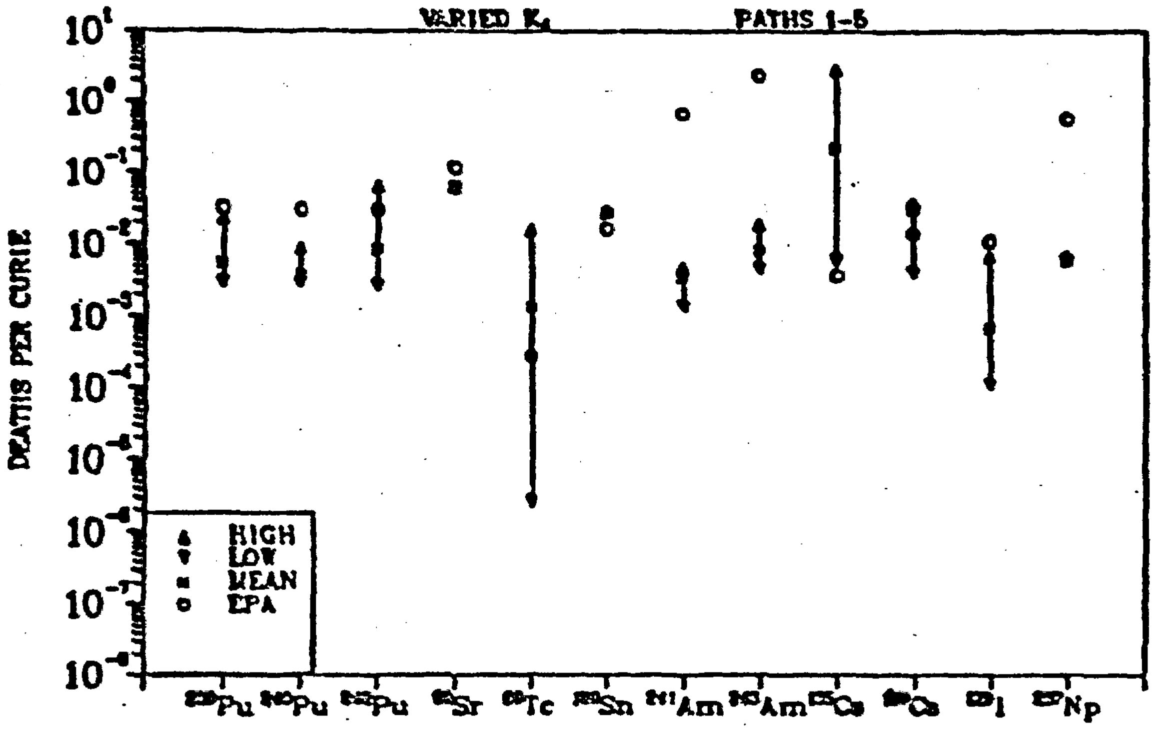
Deaths per curie calculated with sampled Kd ranges and no adsorption onto solid phase of the surface water for Pathways 6-8.

along with the point values from EPA. In general, the EPA values for pathways 1-5 are higher than the results calculated with the sampled values. The exceptions are ^{126}Sn, ^{135}Cs and ^{137}Cs. The sum of pathways 1-5 is dominated by the water based pathways and, since the populations are adjusted by the sampled variable R1, the results are clustered. If a constant population were assumed for the calculation and the flow rate were varied, the results would vary in an approximately linear fashion. That is, a one order of magnitude variation in the flow rate would result in a one order variation in the response. In pathways 6-8, there is more variability than in Paths 1-5; however the EPA values are always higher than the deaths per curie values calculated by the sampled values.

In Figures 5.3 and 5.4 the results are presented for the case when adsorption of the radionuclide onto the solid phase was assumed. The partitioning was determined by the distribution coefficients (Kd). This approach significantly affects the soil concentration and the resulting risk to the human population. For the analysis that considers adsorption, the EPA values for both the 1-5 and 6-8 pathways are generally within the range or only slightly higher than the results using the sampled ranges, for most radionuclides.

Of note are the EPA values for ^{241}Am, ^{243}Am and ^{237}Np for pathways 1-5 (Figure 5.3). The results of this analysis for ^{241}Am and ^{243}Am indicate that the release limits for these radionuclides may be overly conservative and may warrant a reexamination by the EPA. Also, the EPA release limit for ^{135}Cs would appear not to be restrictive enough from the results of this analysis and again may warrant some reconsideration.

Although these results certainly do not establish that the EPA release limits proposed in the Standard are overly conservative, generally they do suggest that the allowed release limits might be higher if the health effects per curie calculated in this analysis were used.



(1) VARIED K_d RANGES (LATIN HYPERCUBE SAMPLE)

(2) INPUT OF RADIONUCLIDE TO LIQUID AND SOLID PHASE OF SURFACE WATER

Figure 5.3.

Deaths per curie calculated with sampled Kd ranges and adsorption onto solid phase of the surface water for Pathways 1-5.

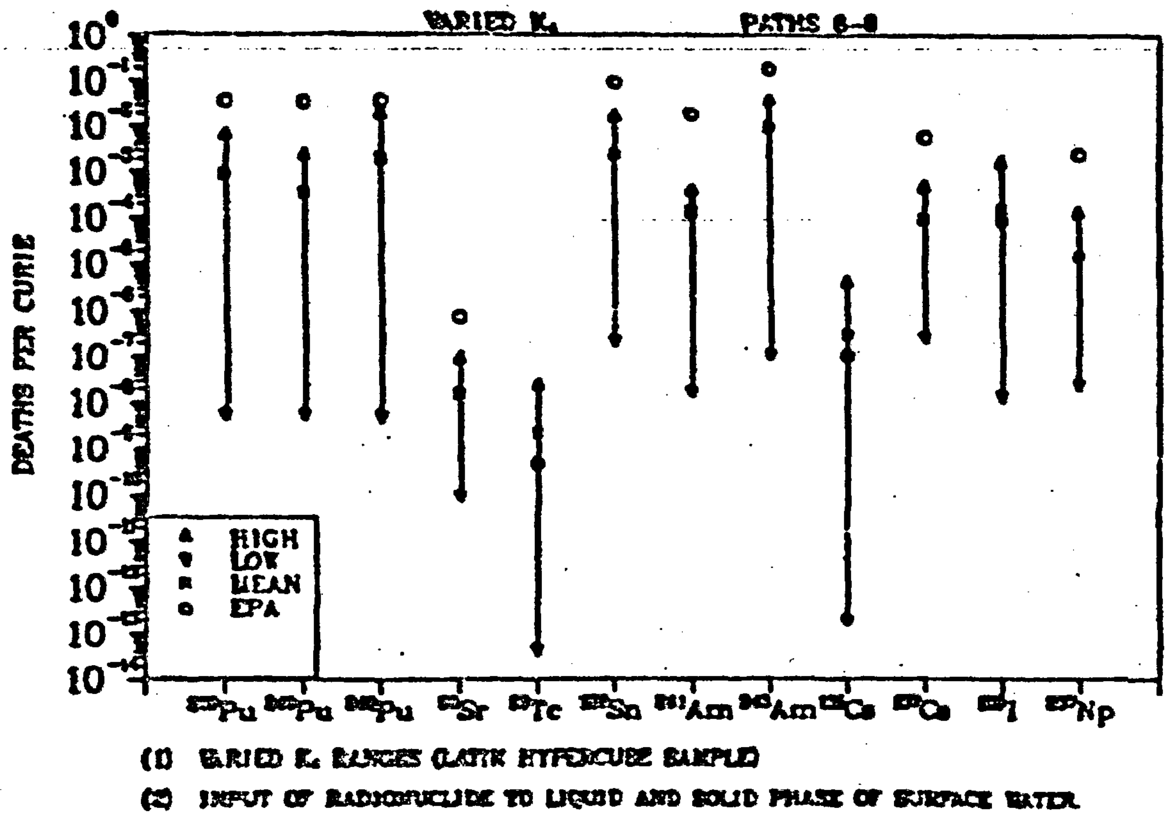


Figure 5.4.

Deaths per curie calculated with sampled Kd ranges and adsorption onto solid phase of the surface water for Pathways 6-8.

References

Bond, R. G., and C. P. Stroud (Eds.), CRC Press, Handbook of Environmental Control, Volume 1, 1973.

Cranwell, R. M., J. E. Campbell, J. C. Helton, R. L. Iman, D. E. Longsine, N. R. Ortiz, G. E. Runkle, and M. J. Shortencarier, Sandia National Laboratories, "Risk Methodology for Geologic Disposal of Radioactive Waste: Final Report," SAND81-2573, NUREG/CR-2452, 1982.

Helton, J. C., and P. C. Kaestner, Sandia National Laboratories, "Risk Methodology for Geologic Disposal of Radioactive Waste: User's Manual Pathways Model," SAND78-1711, NUREG/CR-1636, 1981.

Iman, R. L., J. M. Davenport, and D. K. Leigler, Sandia National Laboratories, "Latin Hypercube Sampling Program User's Guide," SAND79-1473, January 1980.

Runkle, G. E., R. M. Cranwell, and J. D. Johnson, Sandia National Laboratories, "Risk Methodology for Geologic Disposal of Radioactive Waste: Dosimetry and Health Effects," SAND80-1372, NUREG/CR-2166, 1981.

Smith, J. M., T. W. Fowler, and A. S. Goldin, U.S. Environmental Protection Agency, Montgomery, Alabama, "Draft -- Environmental Pathway Models for Estimating Population Health Effects From Disposal of High-Level Radioactive Waste in Geologic Repositories," EPA 520/5-80-002, July 1981.

Smith, J. M., T. W. Fowler and A. S. Goldin, U.S. Environmental Protection Agency, Montgomery, Alabama, "Environmental Pathways Model for Estimating Population Health Effects from Disposal of High-Level Radioactive Waste in Geologic Repositories," EPA 520/5-80-002, December 1982).

U.S. DOE (U.S. Department of Energy), Office of Nuclear Waste Management, Washington, DC, "Environmental Aspects of Commercial Radioactive Waste Management," DOE/ET-0029, UC-70, 1979.

U.S. NRC (U.S. Nuclear Regulatory Commission), Office of Standards Development, "Calculations of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10 CFR, Part 50, Appendix I," Regulatory Guide 1.109, 1977.