
U.S. NUCLEAR WASTE TECHNICAL
REVIEW BOARD

Report to
The U.S. Congress
And
The Secretary of Energy



January 1, 2001, to January 31, 2002

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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April 2002

The Honorable J. Dennis Hastert
Speaker of the House
United States House of Representatives
Washington, D.C. 20515

The Honorable Robert C. Byrd
President Pro Tempore
United States Senate
Washington, D.C. 20510

The Honorable E. Spencer Abraham
Secretary
U.S. Department of Energy
Washington, D.C. 20585

Dear Speaker Hastert, Senator Byrd, and Secretary Abraham:

The Nuclear Waste Technical Review Board submits this *Report to the U.S. Congress and The Secretary of Energy* in accordance with provisions of the Nuclear Waste Policy Amendments Act of 1987, Public Law 100-203, which requires the Board to report its findings and recommendations to Congress and the Secretary of Energy at least two times each year.

Congress created the Board to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy in characterizing a site at Yucca Mountain, Nevada, for its suitability as the location of a permanent repository for disposing of spent nuclear fuel and high-level radioactive waste. The Board also reviews the Department of Energy's (DOE) work that is related to the design of the repository and to the packaging and transport of spent nuclear fuel and high-level radioactive waste. In this report, the Board summarizes its major activities between February 1, 2001, and January 31, 2002.

During that period, the Board focused on evaluating the technical basis of the DOE's work related to a site recommendation, including the DOE's characterization of the Yucca Mountain site, the DOE's design of the repository and waste package, and the DOE's estimates of how a repository system developed at the site might perform. The Board's review culminated in a January 24, 2002, letter report to Congress and the Secretary of Energy. The major points of that letter and a description of activities undertaken by the Board in developing its evaluation are included in the enclosed summary report.

We believe that the information in the Board's report will be useful to policy-makers faced with important decisions on the management of the nation's spent nuclear fuel and high-level radioactive waste.

We thank you for this opportunity to present the Board's views.

Sincerely,

A handwritten signature in black ink, appearing to read "Jared L. Cohon". The signature is written in a cursive style with a long horizontal stroke at the end.

Jared L. Cohon
Chairman

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Executive Summary

In 1987, the U. S. Nuclear Waste Technical Review Board (Board) was created as an independent federal agency by Congress in the Nuclear Waste Policy Amendments Act. The Board was charged with evaluating the technical and scientific validity of the U. S. Department of Energy's (DOE) efforts to develop a system for disposing of high-level radioactive waste and spent nuclear fuel. The Board is required to report its findings and recommendations to Congress and the Secretary of Energy at least twice a year. This document describes activities undertaken by the Board between January 1, 2001, and January 31, 2002.

Four full Board meetings, three panel meetings, and an extended Board business meeting were held during this period. The meetings were designed to develop the basis for the Board's views on the work related to the DOE's characterization of the Yucca Mountain site, on its design of the repository and waste package, and on its estimates of how a repository system, if developed at the site, might perform. The Board's review and evaluation culminated in a January 24, 2002, letter report to the Speaker of the House of Representatives, Dennis Hastert; the President Pro Tempore of the Senate, Robert Byrd; and the Secretary of Energy, Spencer Abraham. The Board made the following key points.

- In evaluating the DOE's technical and scientific work related to individual natural and engineered components of the proposed repository system, the Board finds varying degrees of strength and weakness. Such variability is not surprising, given that the Yucca Mountain project is in many respects a first-of-a-kind, complex undertaking. When the DOE's technical and scientific work is taken as a whole, the Board's view is that the

technical basis for the DOE's repository performance estimates is weak to moderate at this time.

- The Board makes no judgment on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public policy considerations as well as an assessment of how much technical certainty is necessary at various decision points, go beyond the Board's congressionally established mandate.
- The DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model.
- This limited confidence is not an assessment of the Board's level of confidence in the Yucca Mountain site. At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository.
- An international consensus is emerging that a fundamental understanding of the potential behavior of a proposed repository system is of importance comparable to the importance of showing

compliance with regulations. The Board agrees that such basic understanding is very important.

- Confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.
- The DOE can increase confidence in its performance estimates by, among other things, developing multiple lines of evidence and strengthening its arguments about defense-in-depth. It also can work to ensure better integration of new data and

analyses, monitor repository performance, develop a strategy for modifying or stopping repository construction and waste emplacement if unforeseen circumstances are encountered, and continue external review of its technical and scientific activities.

In addition to this significant evaluation in advance of the President's site recommendation decision, the Board focused on many specific issues during 2001. Those issues included multiple lines of evidence, corrosion processes, hydrothermal upwelling, and potential consequences of igneous activity at the Yucca Mountain site. The remainder of this report describes those issues and other activities in more detail.

Board Activities

The U. S. Nuclear Waste Technical Review Board (Board) is charged in the Nuclear Waste Policy Amendments Act (NWPAA) (Congress 1987) with evaluating the technical and scientific validity of the work undertaken by the U. S. Department of Energy (DOE) to develop a mined geologic repository system for disposing permanently of the high-level radioactive waste (HLW) and spent nuclear fuel (SNF) produced by the nation's nuclear defense complex and commercial nuclear power plants. Between January 1, 2001, and January 31, 2002, the period covered by this report, several important milestones were reached, not only by the DOE but also by the two agencies that would regulate any repository that is developed, the U. S. Environmental Protection Agency (EPA) and the U. S. Nuclear Regulatory Commission (NRC). This report begins with a brief description of these milestones and then summarizes the Board's activities.

I. Program and Regulatory Milestones

For more than two decades, the DOE has been characterizing Yucca Mountain in Nevada to evaluate the suitability of the site for constructing a mined geologic repository for the permanent disposal of HLW and SNF. The DOE also has been preparing designs of the package that would contain the waste for disposal and of the subsurface repository facilities. On May 7, 2001, the DOE released a summary of its technical work, *Yucca Mountain Science and Engineering Report, Revision 0 (S&ER)* (DOE 2001a), and a supplement to the draft environmental impact statement (EIS) for the proposed Yucca Mountain

repository (DOE 2001b). At the same time, the DOE solicited public comments on whether the Secretary of Energy should recommend to the President that a repository be developed at the site.

On June 13, 2001, the EPA published its final environmental standard for a Yucca Mountain repository, 40 CFR 197 (EPA 2001). In that standard, the EPA established preclosure performance criteria for the repository. Of particular interest to the Board, the EPA also set the rules under which the postclosure behavior of a Yucca Mountain repository would be judged. The EPA required the DOE to use a complex modeling methodology, called "total system performance assessment" (TSPA), to project the ability of a repository system to isolate and contain HLW and SNF. For a repository system to be approved, the DOE would have to show, using TSPA, that there is a "reasonable expectation" that the system would satisfy three standards for at least 10,000 years.

- The repository would have to limit the individual total effective dose equivalent (TEDE) from released radionuclides so that it would be no higher than 15 millirems (mrem)/year using a scenario that combines nominal repository performance as well as performance under disruptive conditions, such as igneous activity.
- The repository would have to be sufficiently robust so that a dose no higher than 15 mrem/year would be received in the case of a stylized human intrusion scenario.
- Radionuclide contamination of groundwater in the vicinity of Yucca Mountain would not exceed

the permissible levels specified in existing drinking water regulations.

The EPA set the compliance point for the three standards at 18 kilometers south (the putative direction of groundwater flow) of the footprint of the proposed repository.

In July 2001, the DOE authorized the release of *FY 01 Supplemental Science and Performance Analyses (SSPA)* (BSC 2001). The DOE requested this document partly in response to concerns that the Board had raised in an August 2000 letter to Representative Joseph Barton (Cohon 2000) and in Board Chairman Jared Cohon's comments at a January 2001 meeting in Amargosa Valley, Nevada (NWTRB 2001a). On August 21, 2001, the DOE released *Yucca Mountain Preliminary Site Suitability Evaluation (PSSE)* (DOE 2001c). The Secretary also sought public comment on this document.

On November 2, 2001, the NRC published its final licensing rule for a Yucca Mountain repository, 10 CFR 63 (NRC 2001). The rule incorporated the provisions in the EPA's environmental standard. It also specified the details of the licensing process and described the information that the DOE must submit to receive approval for constructing a repository.

The DOE promulgated its final site-suitability guidelines, 10 CFR 963 (DOE 2001d), on November 14, 2001. Under the guidelines, the DOE may determine that the site is suitable if it meets the EPA's preclosure and postclosure requirements. The DOE would use safety analyses to show that the preclosure criteria are met. The DOE would use TSPA to show that the postclosure criteria have been met for 10,000 years.

On January 10, 2002, Secretary of Energy Spencer Abraham notified the State of Nevada's governor that he intended to recommend to President George W. Bush that Yucca Mountain be approved as the site of a geologic repository for HLW and SNF (Abraham 2002a). The Secretary officially recommended the site to President Bush (Abraham 2002b, DOE 2002a) on February 14, 2002. At the same time, the DOE published the final environmental impact statement for Yucca Mountain (DOE 2002b); *Yucca*

Mountain Science and Engineering Report, Revision 1 (DOE 2002c); *Yucca Mountain Site Suitability Evaluation* (DOE 2002d); and a document compiling the DOE's responses to public and agency comments on previously released reports (DOE 2002e). On February 15, 2002, President Bush informed Congress that he had accepted the Secretary's recommendation (Bush 2002).

II. Board Findings and Recommendations

January 30-31, 2001, Winter Board Meeting in Amargosa Valley, Nevada (NWTRB 2001a)

At this meeting, the Board described its four priorities, which it termed "essential elements of any DOE site recommendation." (See NWTRB 2001b for a fuller discussion of the priorities.) These priorities are as follow:

1. Meaningful quantification of conservatisms and uncertainties in the DOE's performance assessments
2. Progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion
3. An evaluation and a comparison of the base-case repository design with a low-temperature design
4. Development of multiple lines of evidence to support the safety case of the proposed repository. The lines of evidence should be derived independently of performance assessment [TSPA] and thus not be subject to the limitations of performance assessment [TSPA].

In addition to these overarching priorities, the Board made a number of suggestions about other investigations and studies that can support, complement, and supplement these four areas. Those investigations and studies include research on the unsaturated and saturated zones.

Later on in the meeting, the DOE answered five specific questions dealing with its analyses of

waste package corrosion, flow and transport of radionuclides in the unsaturated and saturated zones, the importance of the waste package in isolating and containing radionuclides, and the criteria the DOE might use to select a repository design. The DOE discussed its ongoing efforts to evaluate uncertainties in the latest iteration of TSPA, its revision of *Repository Safety Strategy* (CRWMS 2000), and its ability to learn from experience and new information.

In a March 30, 2001, letter to the DOE (Cohon 2001a), the Board commented on the DOE's studies for addressing the four priorities. The Board observed that it was "pleased with the efforts made so far to quantify better the uncertainties and conservatisms" in TSPA. The Board noted, however, that the DOE had not yet considered possible differences that may evolve over time between the performance of the engineered barrier systems as they have been designed and their performance as they actually might be built. The Board commended the DOE for developing a set of investigations that could lead to improved understanding of fundamental waste package corrosion processes. The Board also recognized that work had begun in evaluating and comparing repository designs. Finally, the Board noted that additional effort is needed to develop multiple lines of evidence derived independently of TSPA. In other matters, the Board restated its concern that the DOE has not yet reconciled the conflicting findings of its National Laboratory contractors on the possible presence of bomb-pulse chlorine-36 at the repository horizon. Moreover, the Board commented that questions remain about the compositions and corrosion effects of electrolytes that may form on waste package surfaces.

April 13, 2001, Ad Hoc Panel Meeting in Washington, D.C. (NWTRB 2001c)

This meeting focused on how the DOE might develop multiple lines of evidence derived independently of performance assessment. The meeting included a roundtable discussion involving six Board members, five members of the DOE and its contractor team, and three independent researchers identified by the Board. These participants addressed how natural and engineered analogues and

simplified calculations might add confidence to the conclusions generated by performance assessment, the reasons that developing multiple lines of evidence might be important, and the relationship between traditional notions of defense-in-depth and the use of multiple lines of evidence.

In a June 11, 2001, letter to the DOE (Cohon 2001b), the Board reiterated its view that developing multiple lines of evidence is an essential element in any site recommendation decision that the DOE might make. The Board observed that although multiple lines of evidence might support some performance assessment conclusions, other conclusions might not be supported. It would be important for the DOE to investigate both possibilities. The Board also urged the DOE to use multiple lines of evidence to gain insight into phenomena whose uncertainty significantly affects estimates of repository performance. Finally, the Board was encouraged to hear from DOE representatives that a case for multiple barriers and defense-in-depth might be advanced using lines of evidence other than performance assessment.

May 8-9, 2001, Spring Board Meeting in Arlington, Virginia (NWTRB 2001d)

At this meeting, the Board heard presentations dealing with each of its four priorities. In addition, the DOE addressed several specific questions about its latest TSPA analyses. Finally, participants in the joint State of Nevada-DOE study of fluid inclusions reported on how they interpreted the latest round of findings.

In a July 17, 2001, letter to the DOE (Cohon 2001d), the Board observed that it continued to be encouraged by the work undertaken to quantify uncertainties and conservatisms in TSPA. The Board, however, expressed two concerns. First, the DOE may be dismissing some sources of uncertainty prematurely simply because they seem to have very minor effects on the performance of a particular barrier or component. Second, even if uncertainty in a single component or barrier does not have a large effect on final dose calculations, it may, together with other "minor" uncertainties, have a nonnegligible cumulative effect. The Board cautioned the DOE that although obtaining corrosion

data to better specify model parameters had obvious short-term appeal, investigations also need to focus on improving the validity of the underlying models. The Board withheld judgment on the appropriateness of the DOE's approach of taking a single general repository design and comparing its performance and associated uncertainties when operated in a high-temperature mode and in a selected low-temperature mode. The Board looked forward to reviewing the additional analyses that the DOE promised would address this priority area. Finally, the Board urged the DOE to give priority to the study of natural and engineering analogues, such as Peña Blanca and josephinite.

June 20-21, 2001, Joint Panel Meeting in Las Vegas (NWTRB 2001e)

This meeting was devoted to a draft of *SSPA*, which sought to quantify uncertainties and conservatisms, provide additional system and subsystem analyses, and evaluate the performance of low- and high-temperature operating modes for a fixed design concept. The primary vehicle for these analyses was an updated and more realistic *TSPA* than the December 2000 *Total System Performance Assessment for Site Recommendation (TSPA-SR)* (DOE 2000).

All the important components of the draft *SSPA* were discussed at the meeting. The Board noted that a great deal of work had been carried out and that the DOE appeared to have been responsive in addressing the Board's four priority areas. Subsequently, the Board reviewed the final version of *SSPA* (BSC 2001), issued in July 2001. The Board found that *SSPA* represents a considerable improvement over *TSPA-SR*. (Improvement is defined here as reflecting a more accurate representation of reality, the state of knowledge, and uncertainties. See NWTRB 2002a.) The improvement was most substantial in the portrayal of the engineered components of the repository system and less so for the natural barrier system. Problematic areas still remain, however, such as the fact that the performance estimates exhibit instability, changing significantly with each iteration of *TSPA*.

September 10-12, 2001, Fall Board Meeting in Las Vegas, Nevada (NWTRB 2001g)

At this meeting, the DOE discussed *SSPA* and *PSSE*. The Board also heard from representatives of the State of Nevada and the NRC's Center for Nuclear Waste Regulatory Analysis (CNWRA) about their work on waste package corrosion. In addition, the work of the DOE-sponsored peer review on waste package materials was described. Finally, the DOE and a representative of CNWRA presented their models of the consequences of igneous activity.

In an October 17, 2001, letter to the DOE (Cohon 2001e), the Board observed that, on the basis of its preliminary review of *SSPA*, "progress has been made." The Board's main message in the letter, however, was that its upcoming evaluation of the status of the DOE's program, including progress in addressing the Board's four priority areas, has been made more difficult because of gaps in data and analyses. The Board specifically pointed to the following:

1. Incomplete comparison of high- and low-temperature repository designs
2. Unanswered questions about the contributions of natural and engineered barriers to the repository system's capacity to isolate and contain radionuclides
3. Lack of a rationale for going forward to a possible site-recommendation decision in the face of unresolved issues relating to the consequences of igneous activity.

The Board asked the DOE to forward any additional information or letter reports that relate to these gaps in time to be considered at the Board's business meeting at the end of November 2001.

November 27-29, 2001, Board Business Meeting in San Diego, California

The Board held a three-day business meeting to review and evaluate the DOE's Yucca Mountain site-characterization work and its efforts related to the designs of the repository and the waste package.

In addition, the Board considered the DOE's analyses of how a potential repository for disposing of HLW and SNF might perform if developed at the site. The Board closely examined the DOE's documented investigations and analyses of 10 natural and engineered components of the repository system as well as the disruptive-event scenarios. In carrying out the examination, the Board posed 10 questions. The Board also considered the degree to which the DOE had addressed each of the Board's priority areas. Finally, the Board held an extended discussion of how to integrate the Board's evaluation of various elements of the work conducted by the DOE. Individual Board members and the Board collectively arrived at an overall assessment of the DOE's scientific and technical work, particularly its estimates of repository performance, using a three-point scale: "weak," "moderate," and "strong."

In a January 24, 2002, letter to the Speaker of the House of Representatives, Dennis Hastert; the President Pro Tempore of the Senate, Robert Byrd; and the Secretary of Energy, Spencer Abraham, the Board made the following key points (NWTRB 2002a).

- In evaluating the DOE's technical and scientific work related to individual natural and engineered components of the proposed repository system, the Board finds varying degrees of strength and weakness. Such variability is not surprising, given that the Yucca Mountain project is in many respects a first-of-a-kind, complex undertaking. When the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time.
- The Board makes no judgment on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public policy considerations as well as an assessment of how much technical certainty is necessary at various decision points, go beyond the Board's congressionally established mandate.
- The DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model.
- This limited confidence is not an assessment of the Board's level of confidence in the Yucca Mountain site. At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository.
- An international consensus is emerging that a fundamental understanding of the potential behavior of a proposed repository system is of importance comparable to the importance of showing compliance with regulations. The Board agrees that such basic understanding is very important.
- Confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.
- The DOE can increase confidence in its performance estimates by, among other things, developing multiple lines of evidence and strengthening its arguments about defense-in-depth. It also can work to ensure better integration of new data and analyses, monitor repository performance, develop a strategy for modifying or stopping repository construction and waste emplacement if unforeseen circumstances are encountered, and continue external review of its technical and scientific activities.

January 29-30, 2002, Winter Board Meeting in Pahrump, Nevada (NWTRB 2002b)

At this meeting, the Board heard presentations on several recent external reviews of the DOE's estimates of projected repository performance. The Board also was briefed on recent regulatory developments at the NRC. The latest work on modeling fluid flow and transport of radionuclides in the unsaturated and saturated zones was presented. Finally, the DOE described to the Board its efforts to portray and communicate the uncertainties associated with TSPA.

III. Board Reviews and Investigations***Field Trips***

Field excursions to Yucca Mountain and to other geologically relevant places are an important component of Board activities. In addition to making multiple trips to Yucca Mountain, Board members and professional staff visited Amargosa Valley, Nevada; Death Valley, California; and Peña Blanca, Mexico, in 2001. What follows is a description of the last field trip.

In May 2001, Board members and staff, along with representatives of the DOE's Yucca Mountain Project team, made a geological field excursion to Peña Blanca, a potential analogue site to Yucca Mountain, Nevada. A former CNRWA scientist led the trip. Located in Chihuahua, Mexico, Peña Blanca is the site of an approximately 8-million-year-old hydrothermal deposit of uranium ore.

As noted above, the Board believes that the DOE may be able to use analogues to develop multiple independent lines of evidence for evaluating and informing predictive process models. By possibly reducing admissible ranges of uncertainty in features or processes or possibly invalidating alternative conceptual models, analogues can contribute to increasing confidence in TSPA projections. As an analogue, Peña Blanca has the following features in common with Yucca Mountain: unsaturated fractured silicic

volcanic rocks, arid climate, oxidizing geochemical environment, and an underlying carbonate aquifer.

Uranophane, an oxidized secondary mineral incorporating uranium, was observed in the field. A variety of uranium-bearing minerals was sorbed onto iron oxide surfaces coating fractures at the site. Although uranium and ferrous minerals are not present now either at Yucca Mountain or in the groundwater beneath it, they will be introduced if waste is emplaced there. Because each of them can substantially slow radionuclide migration, secondary mineralization and sorption have potentially significant implications for radionuclide transport from a nuclear waste repository at Yucca Mountain. Even after millions of years, natural hydrogeologic transport processes had removed no more than 20 percent of the initial uranium-bearing mineral mass at Peña Blanca. Board members were favorably impressed with the potential of Peña Blanca as an analogue site.

Board Comments on the DOE's Supplement to the Draft Environmental Impact Statement

The DOE issued a draft EIS for the proposed Yucca Mountain repository in July 1999 (DOE 1999). After publication of the document, the repository design evolved, incorporating possible design options and operating modes. The current design, referred to as the "flexible design," is documented in *S&ER* (DOE 2001a). According to the DOE, this design can be operated in a range of higher and lower temperatures and associated humidity conditions. In *higher-temperature* operating modes, parts of the emplacement-drift rock walls would have maximum temperatures above the boiling point of water; *lower-temperature* operating modes would keep the maximum temperatures of all emplacement-drift rock walls below boiling. The supplement to the draft EIS (DOE 2001b) evaluated potential environmental impacts that could occur for the range of possible operating modes of the flexible design and compares the impacts to those presented in the draft EIS.

In comments on the supplement to the draft EIS (Cohon 2001c), the Board reiterated its belief that the technical basis for projecting the long-term performance of a higher-temperature design has

weaknesses. The Board urged the DOE to justify using the design operated in a low-temperature mode as a surrogate for a true low-temperature design to project environmental effects, especially long-term releases of radionuclides to the environment. The Board recommended that the DOE revise its performance assessment models to capture the effects of temperature more accurately, allowing an improved assessment of the merits of higher-temperature versus lower-temperature repository designs.

Workshop on Long-Term Extrapolation of Passive Behavior (NWTRB 2001f)

The 2-centimeter-thick Alloy 22 outer shell of the waste package is a very important barrier for the 10,000-year repository regulatory period and beyond. Alloy 22, a very corrosion-resistant alloy consisting principally of nickel, chromium, molybdenum, tungsten, and iron, belongs to a class of metals and alloys that owe their corrosion resistance to a nearly impervious, very tenacious passive layer only nanometers thick. Generally, such passive layers form spontaneously on exposure to ambient conditions and consist of oxides of one or more metals of the underlying material. Because engineering experience with *any* corrosion-resistant metal or alloy that depends on a passive layer for its corrosion resistance spans little more than a century, there are questions about the technical basis for extrapolating the behavior of the passive layer for 10,000 years.

To address these questions, the Board decided to conduct a workshop on issues related to predicting corrosion behavior for periods of unprecedented duration. The Workshop on Long-Term Extrapolation of Passive Behavior was held on July 19 and 20, 2001, in Arlington, Virginia. Fourteen international experts from a spectrum of corrosion disciplines were invited to participate. To ensure that broad, diverse, and independent views were obtained, most of the participants were selected from among those with little or no direct recent involvement in the Yucca Mountain Project.

The Board's Web site, www.nwtrb.gov, contains thorough documentation of the workshop,

including the agenda, a complete transcript, and a compendium of short papers submitted by the invited experts after the workshop. The documentation describes the ideas furnished by the participants regarding mechanisms that could create or aggravate corrosion over long periods of time but that may remain unobserved in the relatively short-term tests conducted to date. The participants also suggested research that could be conducted to evaluate the likelihood of those processes occurring.

Hydrothermal Upwelling

In a July 24, 1998, letter to the DOE (NWTRB 1998), the Board presented the results of its review of material submitted by Jerzy Szymanski to the Board at its January 1997 meeting in Pahrump, Nevada. The Board concluded, "The material reviewed by the Board does not make a credible case for the assertion that there has been ongoing, intermittent hydrothermal activity at Yucca Mountain or that large earthquake-induced changes in the water table are likely at Yucca Mountain." However, there was some evidence from fluid inclusions in secondary mineral deposits of the past presence of fluids at elevated temperatures (at least 72° C) in the vicinity of the proposed repository. The critical question is the age of these fluid inclusions. Are the inclusions relatively recent? If so, they might be viewed as evidence of ongoing hydrothermal activity. Are the inclusions millions of years old? If so, they might be related to other processes, such as the original formation of Yucca Mountain 10 to 13 million years ago, and thus would have no bearing on the hypothesis of ongoing hydrothermal activity. The Board recommended that a joint State of Nevada-DOE program be initiated to study fluid inclusions at Yucca Mountain and determine their ages.

The DOE sponsored such a study, which was coordinated by scientists at the University of Nevada, Las Vegas (UNLV). U. S. Geological Survey (USGS), State of Nevada, and UNLV scientists presented the results of the study at the May 2001 meeting of the Board in Washington, D. C. The Board was impressed by the studies, particularly by the systematic approach taken by UNLV scientists in which fluid inclusions were found to be at least 2 or more million years old. The UNLV scientists also

concluded, "This study demonstrates that the hypothesis of geologically recent upwelling hydrothermal fluids is untenable and should not disqualify Yucca Mountain as a potential nuclear waste storage site." These conclusions were supported by independent studies carried out by USGS scientists but were not supported by State of Nevada scientists.

The DOE discussed its overall conclusions in a January 24, 2002, letter to the Board (Dyer 2002) and in a presentation at the Board's January 2002 meeting. The DOE concluded that upwelling waters or seismic pumping hypotheses have been "adequately addressed and may be discounted." The Board concurs with the conclusions of the UNLV, USGS, and DOE scientists and considers this issue resolved. The Board also fully supports the DOE's stated commitment to continuing to examine secondary minerals in conjunction with infiltration, flux rate, thermal effects, waste package geochemistry, paleohydrology, and other studies and to continuing ongoing studies of the thermal history of younger fluid inclusions.

Potential Consequences of Igneous Activity at the Yucca Mountain Site

In an October 17, 2001, letter to the DOE (Cohon 2001e), the Board expressed concern about disagreements arising from different igneous consequence models proposed by the DOE on the one hand and by CNWRA on the other. The conflicting models were discussed at the Board's September meeting in Las Vegas. Because of the events of September 11, 2001, invited Board consultants on igneous consequence models were not able to travel to the Las Vegas meeting. On November 8, 2001, several Board members and professional staff met with the consultants at the Board offices in Arlington, Virginia. A former Board member, Dr. Clarence Allen, also participated in the discussions. When the reports by the consultants were received, they were made available on the Board's Web site.

On the basis of the meeting with the consultants and their reports, the Board believes that the model proposed by the NRC-sponsored CNWRA may be a conservative end-member model, and, consequently, the Board's concern over this issue has lessened.

However, additional work on, and a better understanding of, igneous consequences is needed, particularly in light of performance-assessment calculations that show that igneous activity is the largest contributor by far to radioactive dose during the first 10,000 years. The Board's understanding is that both the DOE and the NRC are supporting additional studies in this area.

The Board, however, has one specific recommendation on igneous issues and their presentation. The DOE needs to devote thought and effort to better portraying the nature of igneous activity to decision-makers and the public. Although the use of probability-weighted calculations may be computationally correct, it fails to convey the unique nature of igneous activity as being a high-consequence, low-probability event.

International Activities

Since its first meeting in 1989, the Board has sought to increase its knowledge and understanding of the problems shared by other nations as they try to find safe ways to dispose of HLW and SNF. In 2001, the Board made two international trips.

In July, a small delegation from the Board traveled to Switzerland to meet with representatives of the National Cooperative for the Disposal of Radioactive Waste (NAGRA). The purpose of the visit was to meet and discuss NAGRA's approach to developing and implementing a research and development (R&D) plan for investigating opalinus clay as a potential geology for a permanent repository for Switzerland's high-level radioactive waste. Topics of mutual interest that were discussed included development of a repository safety case, characterization of uncertainty, setting priorities in the R&D program and integrating the work, and the Swiss approach to conducting performance assessment. Sites visited included Mont Terri Underground Rock Laboratory (opalinus clay), Grimsel Underground Laboratory (granite), and ZWILAG facility (interim storage of high-level radioactive waste).

At the conclusion of the trip, Board representatives spent part of a day in Berlin in a meeting with members of Arbeitskreis Auswahlverfahren Endlagerstandorte. This committee of 15 experts,

appointed by Germany's Federal Minister for the Environment, is responsible for recommending procedures on the selection of sites for disposing of radioactive waste in Germany.

In October, a delegation from the Board traveled to Japan to meet with representatives of the following organizations: Ministry of Economy, Trade and Industry; Nuclear Safety Commission; Nuclear Waste Management Organization; Radioactive Waste Management Funding and Research Center; Japan Nuclear Cycle Development Institute (Tokai Works and Tono Geoscience Center); Japan Nuclear Fuel Limited (Rokkoshomura); and the City of Mizunami. The purpose of the visit was to meet with those involved in organizing, managing, conducting R&D, setting regulations, or potentially hosting R&D sites since the 1998-2000 reorganization of the country's program. Included were site visits to R&D, HLW vitrification, and storage facilities.

IV. Evaluation of the Board's Performance During 2001

The Board believes that measuring its effectiveness by directly correlating improvements in the DOE program with Board actions and recommendations would be ideal. However, the Board has no implementing authority, so it cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program is, in most cases, (1) subjective and (2) an imprecise indicator of the Board's performance because implementation of Board recommendations by the DOE is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following:

1. Were the reviews, evaluations, and other activities undertaken under the auspices of the goal completed?

2. Were the results of the reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures have been met, the Board's performance in meeting the annual goal will be judged effective. If only one measure has been met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal.

During 2001, the Board identified four priority areas and a number of other issues that it believed should be addressed as part of any site recommendation, and it communicated this information to the DOE and Congress. Throughout the year, the Board was involved in an intensive and comprehensive review of DOE activities related to a secretarial decision on whether to recommend the Yucca Mountain site. On the basis of these activities and consistent with performance measures described above, the Board's performance for 2001 related to site investigations and other activities undertaken by the Secretary in preparation for a decision on site recommendation was judged effective. However, because of the focus on site investigations, the Secretary's activities related to transportation and packaging of spent fuel and high-level radioactive waste were extremely limited during the last year. The Board therefore deferred its performance goals related to the waste management system until such time as the Secretary undertakes technical and scientific work in this area. A more detailed evaluation of the Board's performance in 2001 is included in Appendix H.

Abbreviations and Acronyms

BSC	Bechtel SAIC Company, LLC	NWTRB	U. S. Nuclear Waste Technical Review Board
CFR	<i>Code of Federal Regulations</i>	OCRWM	Office of Civilian Radioactive Waste Management
CNWRA	Center for Nuclear Waste Regulatory Analysis	PSSE	<i>Preliminary Site Suitability Evaluation</i>
DOE	U. S. Department of Energy	R&D	research and development
EIS	environmental impact statement	S&ER	<i>Science and Engineering Report</i>
EPA	U. S. Environmental Protection Agency	SNF	spent nuclear fuel
HLW	high-level radioactive waste	SSPA	<i>Supplemental Science and Performance Analyses</i>
mrem	millirem	TEDE	total effective dose equivalent
NAGRA	National Cooperative for the Disposal of Radioactive Waste	TSPA	total system performance assessment
NRC	U. S. Nuclear Regulatory Commission	TSPA-SR	total system performance assessment—site recommendation
NWPAA	Nuclear Waste Policy Amendments Act of 1987	UNLV	University of Nevada, Las Vegas
		USGS	U.S. Geological Survey

Glossary

The following list of terms was compiled to help the reader understand some of the terms used in this report.

analogue Phenomena or materials that can provide information on or add understanding to aspects of repository performance. Analogues are of two types: natural and anthropogenic. Natural analogues may arise from natural phenomena or from materials that have been naturally formed. Anthropogenic analogues result from human activity. An “archaeological analogue” is an anthropogenic analogue resulting from the activities of ancient cultures.

characterization Collecting information necessary to evaluate the suitability of a region or site for geologic disposal. Data from characterization also will be used during licensing.

container A receptacle used to hold radioactive material.

defense high-level waste High-level waste generated by defense programs, as distinguished from waste generated by commercial and research facilities.

defense-in-depth Incorporation of multiple barriers in the design of a repository to make the performance of the overall system less susceptible to the unexpected failure of any individual barrier. Defense-in-depth is greatest when the barriers are fully redundant.

disposal The isolation of radioactive materials from the accessible environment with no intent of recovering them.

engineered barrier system The constructed components of a disposal system designed to retard or prevent the release of radionuclides from the underground facility. They can include the waste forms, fillers, waste containers, shielding, material placed over and around such containers, and backfill materials.

environmental impact statement (EIS) A detailed written statement to support a decision whether to proceed with major actions affecting the quality of the human environment. Required by the National Environmental Policy Act, the environmental impact statement describes the environmental impact of the proposed action; any adverse environmental effects that cannot be avoided if the proposal is implemented; alternatives to the proposed action; the relationship between local, short-term uses of humankind’s environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources that would be involved in the proposed action if it is implemented.

fluid inclusion A tiny (100 micron in diameter) cavity containing liquid or gas, or both, formed by the entrapment of liquid in crystal irregularities.

geologic repository A facility for the disposal of radioactive waste in excavated geologic media, including surface and subsurface areas of operation and the adjacent part of the natural setting.

high-level radioactive waste Highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing or any solid material derived from such liquid waste; and any other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines requires permanent isolation by disposal in a geologic repository.

high-temperature operating mode Allowing the temperature of the waste package surface to exceed the boiling point of water for a significant period of time.

igneous Formed by volcanic activity.

license application A document submitted to the U.S. Nuclear Regulatory Commission containing general information and a safety analysis for a nuclear reactor, a geologic repository, or an interim storage facility for spent nuclear fuel and high-level radioactive waste.

low-temperature operating mode Keeping the temperature of the waste package surface significantly below the boiling point of water.

multiple lines of evidence Varied methodological approaches used to infer the behavior of the repository system (or its major components) for extended time periods. Examples include analogues, simplified calculations, and arguments based on defense-in-depth.

natural analogue See **analogue**.

performance assessment (PA) A complex, computer-based analysis that predicts the behavior of an entire repository system under a given set of conditions.

preclosure The time before the repository is closed.

postclosure The time after the repository is closed.

radioactivity The spontaneous emission of radiation from the nucleus of an atom. Radioisotopes of elements lose particles and energy through radioactive decay. Radioactivity is measured in terms of the number of nuclear disintegrations occurring in a unit of time. Units of radioactivity are the curie (Ci) and the becquerel (Bq).

radionuclide A radioactive isotope, as specified by its atomic number, atomic mass, and energy state.

radionuclide transport The movement of radionuclides, generally in liquid or gas forms, through a rock formation.

repository system The combination of natural features and engineered barriers that together isolate and contain radioactive waste.

retrievability The ability to remove waste packages from the repository.

saturated zone The part of the earth's crust in which all empty spaces are filled with water.

site recommendation The President's recommendation to Congress that a site be developed as a repository. The site recommendation process is set forth in the Nuclear Waste Policy Act.

site suitability A determination by the U.S. Department of Energy that if a repository were developed at a particular site, it would likely meet the environmental standards established by the U.S. Environmental Protection Agency.

siting guidelines Guidelines set forth in 10 CFR 963, that are to be used by the U.S. Department of Energy in assessing the suitability of the site.

spent nuclear fuel Fuel that has been withdrawn from a nuclear reactor after irradiation, the constituent elements of which have not been separated by reprocessing.

thermal-loading strategies Placing waste in a repository so that the heat produced by it will cause specific effects on repository performance. The strategies are based on whether it is desirable for the repository to be at a temperature below or above the boiling point of water and the effect that different temperature ranges will have on long-lived waste packages.

total system performance assessment (TSPA) Analyses undertaken by the U.S. Department of Energy to assess the ability of a potential repository at Yucca Mountain to provide long-term waste isolation and containment.

unsaturated rock A rock in which some or all of the connected interstices or voids are filled with air.

waste isolation Separation of waste from the environment so that any radioactive material reentering the environment will be kept within prescribed limits.

waste package The waste form, any fillers, and any containers, shielding, packing, or other absorbent materials immediately surrounding an individual waste container.

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Appendix A

U.S. Nuclear Waste Technical Review Board Members

Jared L. Cohon, Ph.D.; Chairman

On June 29, 1995, President Bill Clinton appointed Jared Cohon to the Nuclear Waste Technical Review Board. President Clinton appointed Dr. Cohon chairman on January 17, 1997.

Dr. Cohon is president of Carnegie Mellon University in Pittsburgh, Pennsylvania. He has more than 25 years of teaching and research experience, has written one book, and is author, coauthor, or editor of more than 80 professional publications. Among the awards that Dr. Cohon has received is the 1996 Joan Hodges Queneau Medal for outstanding engineering achievement in environmental conservation, awarded jointly by the American Association of Engineering Societies and the National Audubon Society. He is a member of Tau Beta Pi (National Engineering Honor Society) and of Sigma Xi (Scientific Research Society). Dr. Cohon is a registered Professional Engineer.

Dr. Cohon brings to the Board special expertise as a national authority on environmental and water resource systems analysis. His research interests focus on multiobjective programming, a technique for decision-making in situations with multiple conflicting objectives. He also has focused on water resources planning and management in the United States, South America, and Asia and on energy facility siting, including nuclear waste shipping and storage. In addition to his academic experience, he served as legislative assistant for energy and the environment to the Honorable Daniel P. Moynihan, United States Senator from New York, from 1977 to 1978.

Dr. Cohon is a member of the American Geophysical Union, the Institute for Operations Research and Management Science, the American Water Resources Association, and the American Society of Civil Engineers. He has served on several committees for the National Research Council, chairing the studies on the probabilities of extreme floods and on measuring and improving infrastructure.

In 1969, Dr. Cohon earned a bachelor of science degree in civil engineering from the University of Pennsylvania. He worked as a construction inspector in Philadelphia and as an engineering assistant for the Philadelphia Water Department before attending the Massachusetts Institute of Technology, where he earned a master's degree in civil engineering in 1972 and a Ph.D. in civil engineering in 1973. Dr. Cohon began his teaching career in 1973 at Johns Hopkins University, where he served as assistant, associate, and full professor in the Department of Geography and Environmental Engineering and as Assistant and Associate Dean of Engineering and Vice Provost for Research. In 1992, he became dean of the School of Forestry and Environmental Studies and professor of environmental systems analysis at Yale University. Dr. Cohon assumed his duties as president of Carnegie Mellon University in July 1997.

Dr. Cohon resides in Pittsburgh, Pennsylvania.

John W. Arendt, P.E.

On June 11, 1999, President Bill Clinton reappointed John Arendt to serve on the Nuclear Waste Technical Review Board. Mr. Arendt was first appointed to the Board in 1995.

John W. Arendt is senior consultant and founder of John W. Arendt Associates, Inc. Created in 1986, the firm offers consultation on program and project management, safety assessments and investigations, quality assurance, standards and regulations for uranium handling and processing, chemical safety audits, and safeguards and accountability. Mr. Arendt is a registered Professional Engineer and a certified nuclear materials manager.

Mr. Arendt brings to the Board five decades of experience in various phases of the nuclear fuel cycle, especially uranium processing, handling, safeguards and accountability, packaging, and transportation. He has extensive experience in the management of engineering projects, including uranium processing facilities and their quality assurance, quality control, and inspection. He is chairman of American National Standards Institute (ANSI) Accredited Standards Committee N14 on packaging and transportation of radioactive materials and nonnuclear hazardous wastes.

Mr. Arendt earned a bachelor of science degree in chemical engineering from Marquette University in 1943 and was a research engineer for the Manhattan Project at the University of Chicago from 1943 to 1945. He gained the bulk of his experience at Union Carbide Corporation's Nuclear Division in Oak Ridge, Tennessee, where he began as a production supervisor in 1945 and served in various department and project management positions through 1984. Before founding John W. Arendt Associates, Inc., in 1986, Mr. Arendt was a senior engineer with JBF Associates, Inc., where he provided technical and management assistance in uranium enrichment, standards and regulations, waste management, packaging and shipping, reactor activities, quality assurance, and safety.

Mr. Arendt resides in Oak Ridge, Tennessee.

Daniel B. Bullen, Ph.D.

On January 17, 1997, President Bill Clinton appointed Daniel Bullen to the Nuclear Waste Technical Review Board.

Dr. Daniel B. Bullen is associate professor of mechanical engineering, Department of Mechanical Engineering, at Iowa State University in Ames, Iowa. He has been teaching since 1989, and he served as Nuclear Engineering Program Coordinator at Iowa State University from 1993 to 1996 and as director of the Iowa State University Nuclear Reactor Laboratory from 1993 to 2001. He has 12 years of industry experience in nuclear engineering and materials science. He has edited and reviewed articles for such professional publications as Nuclear Technology, Journal of the American Ceramic Society, American Nuclear Society Transactions, and Encyclopedia of Chemical Technology. He has written or co-written more than 65 technical publications and reports and has contributed to three books. He is a registered Professional Engineer in mechanical, metallurgical, and nuclear engineering. Dr. Bullen's honors and awards include Tau Beta Pi (National Engineering Honor Society), Phi Kappa Phi, Sigma Xi (Scientific Research Society), Alpha Nu Sigma (Nuclear Engineering Scholastic Honor Society), a Lilly Teaching Fellowship at the Georgia Institute of Technology (1991), and two Outstanding Professor awards. He has appeared in Who's Who in Science and Engineering, Who's Who in America, and Who's Who in the World.

Dr. Bullen brings to the Board special expertise in performance assessment modeling of radioactive waste disposal facilities, performance assessment of engineered barrier systems, radiolysis effects in spent-fuel dry casks in storage environments, radiation effects on materials, and materials degradation in severe service environments.

Dr. Bullen is a member of the American Nuclear Society; ASM International; the American Society of Mechanical Engineers; the National Society of Professional Engineers; and the Minerals, Metals & Materials Society.

In 1978, Dr. Bullen earned a bachelor of science degree in engineering science from Iowa State University. He was a research assistant at the University of Wisconsin-Madison while earning master of science degrees in nuclear engineering in 1979 and materials science in 1981 and a Ph.D. in nuclear engineering in 1984. He then worked for Lawrence Livermore National Laboratory as an engineer until 1986, when he became senior engineer for Science & Engineering Associates, Inc., in Pleasanton, California. In 1988, he became president of DG Engineering Associates, providing technical consulting services to Lawrence Livermore National Laboratory. Dr. Bullen moved to North Carolina State University in 1989 as an assistant professor of nuclear engineering and to the Georgia Institute of Technology in 1990 as an assistant professor of mechanical engineering. He moved to Iowa State University in 1992 as an associate professor of nuclear engineering.

Dr. Bullen resides in Ames, Iowa.

Norman L. Christensen, Jr., Ph.D.

On January 17, 1997, President Bill Clinton appointed Norman Christensen to the Nuclear Waste Technical Review Board.

Dr. Norman L. Christensen, Jr., is professor of ecology in the Environmental Sciences and Policy Division of the Nicholas School of the Environment and Earth Sciences at Duke University in Durham, North Carolina. He has been teaching for more than 27 years and has more than 80 scientific articles and books to his credit. Dr. Christensen is the recipient of the 1977 Duke Endowment Award for Teaching Excellence, the 1991 Distinguished Teaching Award for Trinity College of Arts and Sciences at Duke, and the 1994 Distinguished Scholar-Alumni Award from California State University-Fresno. He was the E.V. Komarek Lecturer at the 1989 Tall Timbers Fire Ecology Conference, a Fellow of the American Association for the Advancement of Science in 1993, and a recipient of the National Park Service's A. Starker Leopold Award for distinguished service. Dr. Christensen has served on more than 25 national and regional panels and commissions and on the editorial boards of *American Midland Naturalist*, *Journal of Vegetation Science*, and *Journal of Wildland Fire*.

Dr. Christensen brings to the Board special expertise in biology and ecology. His research interests include the effects of disturbance on structure and function of populations and communities; comparative biogeochemical and community responses to varying fire regimes; use of remote sensing systems (such as synthetic aperture radar) to evaluate long-term changes in forest ecosystems; and pattern analysis of forest development following cropland abandonment as affected by environment, stand history, and plant demographic patterns. He has written widely on the importance of natural disturbance in the management of forests, shrublands, and wetlands, and he is interested in applying basic ecological theory and models to ecosystem management.

Dr. Christensen is a member of the American Association for the Advancement of Science, the British Ecological Society, the Ecological Society of America, Sigma Xi (Scientific Research Society), the Society of American Foresters, and the National Association of Environmental Professionals.

In 1968, Dr. Christensen earned a bachelor's degree in biology from Fresno State College. He earned a master's degree in biology from Fresno State College in 1970 and a Ph.D. in biology from the University of California-Santa Barbara in 1973. He began his teaching career as an assistant professor in the Department of Botany at Duke University in 1973. He became an associate professor in 1979 and was elevated to full professor in 1987. He served as dean of the Nicholas School of the Environment and Earth Sciences in 1991-2001.

Dr. Christensen resides in Chapel Hill, North Carolina.

Paul P. Craig, Ph.D.

On January 30, 1997, President Bill Clinton appointed Paul Craig to the Nuclear Waste Technical Review Board.

Dr. Paul P. Craig is Professor of Engineering Emeritus at the University of California, Davis, and is a member of the university's Graduate Group in Ecology. He has more than 21 years of teaching experience and more than 100 refereed publications to his credit. Dr. Craig is a member of the Sierra Club's Global Warming and Energy committees and of the American Association for the Advancement of Science and is a Fellow of the American Physical Society. His awards include a John Simon Guggenheim Memorial Foundation Fellowship and a National Science Foundation Meritorious Service Award. He is a member of Phi Beta Kappa.

Dr. Craig brings to the Board special expertise and research interest in energy policy issues associated with energy system responses to global environmental change.

In 1954, Dr. Craig earned a bachelor's degree in mathematics and physics from Haverford College. He earned a Ph.D. in physics from the California Institute of Technology in 1959. He began his career as a staff scientist at Los Alamos National Laboratory in 1959 and moved to Brookhaven National Laboratory in 1962 as a physicist and a group leader. In 1971, he became deputy and acting director of the Office of Energy Research and Development Policy of the National Science Foundation, where he provided policy analysis support to the President's science advisor and to the Office of Management and Budget. Dr. Craig became director of the University of California Council on Energy and Resources in 1975 and professor of engineering at the University of California, Davis, in 1977. He received his emeritus standing in 1994.

Until his appointment to the Nuclear Waste Technical Review Board, Dr. Craig was a Lawrence Berkeley National Laboratory Participating Guest Scientist (beginning in 1976) and a member of the National Academy of Sciences–National Research Council Board on Radioactive Waste Management.

Dr. Craig resides in Martinez, California.

Debra S. Knopman, Ph.D.

On January 17, 1997, President Bill Clinton appointed Debra Knopman to the Nuclear Waste Technical Review Board.

Dr. Debra S. Knopman is Associate Director, RAND Science and Technology, and a senior engineer at RAND Corporation in Arlington, Virginia. She has more than 24 publications in scientific and technical journals to her credit. Dr. Knopman is a member of the National Research Council's Commission on Geosciences, Environment, and Resources. She served briefly on the Board on Radioactive Waste Management and the Panel for the Review of the DOE Environmental Restoration Priority System before accepting a position in the Clinton administration in 1993. She is a member of the American Geophysical Union. Dr. Knopman was a 1978-1979 Henry Luce Foundation Scholar.

Dr. Knopman brings to the Board special expertise in hydrology, environmental and natural resources policy, systems analysis, and public administration.

In 1975, Dr. Knopman earned a bachelor's degree in chemistry from Wellesley College. She earned a master of science degree in civil engineering from the Massachusetts Institute of Technology in 1978 and a Ph.D. from the Department of Geography and Environmental Engineering at Johns Hopkins University in 1986. Dr. Knopman began her career as a freelance science writer and editor in Israel and the United States in 1975. Following her Luce Scholar fellowship, which she served in Taiwan from 1978 to 1979, she served as legislative assistant for energy and environmental issues to Senator Daniel P. Moynihan in Washington, D.C., from 1979 to 1980. She served as a professional staff member of the U.S. Senate Committee on Environment and Public Works from 1980 to 1983. She moved to the U.S. Geological Survey in 1984, beginning as a student assistant and progressing through being a research hydrologist to becoming chief of the systems analysis branch. In 1993, Dr. Knopman was appointed Deputy Assistant Secretary for Water and Science, U.S. Department of the Interior. She served as director of the Progressive Policy Institute's Center for Innovation and the Environment from 1995 to 2000.

Dr. Knopman resides in Washington, D.C.

Priscilla P. Nelson, Ph.D.

On January 17, 1997, President Bill Clinton appointed Priscilla Nelson to the Nuclear Waste Technical Review Board.

Dr. Priscilla P. Nelson is Director, Division of Civil and Mechanical Systems, for the Directorate for Engineering at the National Science Foundation. She formerly was professor of civil engineering at The University of Texas at Austin. Dr. Nelson has more than 13 years of teaching experience and more than 100 technical and scientific publications to her credit. She has served as a member of the U.S. National Committee for Rock Mechanics, the U.S. National Committee for Tunneling Technology, and the Board on Radioactive Waste Management, all activities of the National Research Council. She is a member of the American Rock Mechanics Association (ARMA), the American Society of Civil Engineers (ASCE), the International Tunnelling Association, the American Underground Construction Association, the Association of Engineering Geologists, the British Tunnelling Society, and other professional organizations. She is past president of the Geo-Institute of ASCE and of ARMA. Her honors and awards include Exxon Teaching Fellowships at The University of Texas at Austin (1985-1987), the Case Studies Award from the U.S. National Committee for Rock Mechanics (1988), the Haliburton Education Foundation Award of Excellence (1991), the Basic Research Award from the U.S. National Committee for Rock Mechanics (1993), and election to The Moles, an association of the heavy construction industry (1995). At the National Science Foundation, she has received the Director's Award for Integrative Collaboration three times, and she received the Director's Award for Meritorious Service in 1997. In 1999, she was appointed to the Senior Executive Service. Also in 1999, she received the Director's Award for Superior Accomplishment from the NSF.

Dr. Nelson brings to the Board special expertise in rock engineering and underground construction. In 1970, Dr. Nelson earned a bachelor's degree in geological sciences from the University of Rochester. She earned master's degrees in geology from Indiana University in 1976 and in structural engineering from the University of Oklahoma in 1979. She was awarded a Ph.D. in geotechnical engineering by Cornell University in 1983. Dr. Nelson's career has included service as a Peace Corps volunteer and employment as a field engineer for the Alaskan Resource Sciences Corporation from 1975 to 1977. She joined the faculty of The University of Texas at Austin in 1983 and became full professor and holder of the John Focht Teaching Fellowship before joining the National Science Foundation in 1996. She has served as a consultant for major underground construction projects, including for the Superconducting Super Collider project from 1985 through 1992.

Dr. Nelson resides in Arlington, Virginia.

Richard R. Parizek, Ph.D.

On February 11, 1997, President Bill Clinton appointed Richard Parizek to the Nuclear Waste Technical Review Board.

Dr. Richard R. Parizek is a professor of geology and geoenvironmental engineering at The Pennsylvania State University; president of Richard R. Parizek and Associates, consulting hydrogeologists and environmental geologists; and a registered Professional Geologist. He has more than 37 years of teaching experience and numerous journal publications to his credit. His awards include a cooperative fellowship from the National Science Foundation (1960), a superior achievement award from the U.S. Environmental Protection Agency (1976), the Clearwater Conservancy Award (1985), the Matthew J. and Anne C. Wilson Teaching Award (1986), and the medal for distinguished service to environmental science and engineering of the Institute of Meteorology and Water Management, Warsaw, Poland (1991). Dr. Parizek was appointed an administrative law judge of the Atomic Safety and Licensing Board Panel of the U.S. Nuclear Regulatory Commission in 1990, a position he left upon appointment to the Nuclear Waste Technical Review Board.

Dr. Parizek brings to the Board special expertise in hydrogeology and environmental geology. His research interests include the hydrogeology of karst, fractured rock, and glaciated terranes; factors controlling groundwater occurrence and movement; and the relationship between land use and groundwater pollution resulting from disposal of nuclear waste and other hazardous substances.

Dr. Parizek is a member of the American Association for the Advancement of Science, the American Geophysical Union, the American Institute of Hydrology, the Geological Society of America, and Sigma Xi (Scientific Research Society).

In 1956, Dr. Parizek earned a bachelor's degree in geology from the University of Connecticut. He earned a master of science degree in geology in 1960 and a Ph.D. in geology in 1961, both from the University of Illinois. Dr. Parizek began his career as a research assistant with the Illinois State Geological Survey in 1956 and began teaching in 1961 as an assistant professor of geology and geophysics at The Pennsylvania State University. He became a full professor in 1971 and continues to teach in the Department of Geosciences. Dr. Parizek also has been a visiting scientist with the U.S. Geological Survey and a visiting scholar at Stanford University, the Desert Research Institute, Changchun College of Geology and the Institute of Karst Geology in the People's Republic of China, and National Cheng Kuug University in Taiwan.

Dr. Parizek resides in State College, Pennsylvania.

Donald D. Runnells, Ph.D.

On June 23, 1998, President Bill Clinton appointed Donald Runnells to the Nuclear Waste Technical Review Board.

Dr. Donald D. Runnells is professor emeritus in the Department of Geological Sciences at the University of Colorado. He also is a corporate consultant to Shepherd Miller, a firm providing environmental and engineering consultation primarily to the mining industry and to government agencies and other concerns. He has more than 27 years of teaching experience and numerous journal publications to his credit. Dr. Runnells is a Fellow of the Geological Society of America. His awards include selection as a National Science Foundation Graduate Fellow, election to Phi Kappa Phi Honorary Scholastic Fraternity, and election to the presidency of the Association of Exploration Geochemists. Dr. Runnells has been an editor or on the editorial board for *Journal of Geochemical Exploration*, *Interface*, *Science of the Total Environment*, *Chemical Geology*, and *Journal of Applied Geochemistry*. He has been a member of the Colorado Governor's Council on Science and Technology, the Review Board on Disposal and Permanent Storage of Inactive Uranium Tailings at Sandia National Laboratory, the Materials Review Board at Argonne National Laboratory, the Scientific Advisory Board on Toxics in Water for the Electric Power Research Institute, and several boards and panels of the National Research Council of the National Academy of Sciences.

Dr. Runnells brings to the Board special expertise in geochemistry, hydrochemistry, and mineral deposits.

He is a member of the Geochemical Society, the Association of Exploration Geochemists, and the American Chemical Society.

In 1958, Dr. Runnells earned a bachelor's degree in geology from the University of Utah. He earned a master of arts degree in geology in 1960 and a Ph.D. in geochemistry and geology in 1964, both from Harvard University. Dr. Runnells began his career as a teaching assistant at Harvard University in 1961. In 1963, he began working with Shell Development Company as a geochemist. He returned to teaching in 1967 as an assistant professor at the University of California at Santa Barbara. He moved to the University of Colorado in 1969. He was appointed full professor in 1975 and was elected chairman of the Department of Geological Sciences in 1990. He continued in that position until 1993, when he became president of Shepherd Miller. He now serves as a corporate consultant to Shepherd Miller, specializing in water-rock interaction and water contamination.

Dr. Runnells resides in Fort Collins, Colorado.

Alberto A. Sagüés, Ph.D.

On June 11, 1999, President Bill Clinton reappointed Alberto Sagüés to serve on the Nuclear Waste Technical Review Board. Dr. Sagüés was first appointed to the Board in 1997.

Dr. Alberto A. Sagüés is Distinguished University Professor in the Department of Civil and Environmental Engineering at the University of South Florida and is a registered Professional Engineer. He has 20 years of teaching experience and more than 120 technical publications to his credit. From 1988 to 1992, Dr. Sagüés served as an expert task group member of the Strategic Highway Research Program of the National Research Council. He has made technical presentations to professional and scientific audiences across the United States and Canada and throughout Europe, Central America, and South America. He holds three patents related to corrosion control.

Dr. Sagüés brings to the Board special expertise in corrosion and materials engineering, physical metallurgy, and electrochemical measurements. His research interests are in corrosion of engineering materials, especially concerning reinforcing steel in concrete and durability forecasting of civil infrastructure.

Dr. Sagüés is a member of NACE International (formerly the National Association of Corrosion Engineers), the Electrochemical Society, the American Society for Testing and Materials, the American Concrete Institute, and ASM International (formerly the American Society for Metals).

A native of Argentina, Dr. Sagüés earned his undergraduate degree in physics from the National University of Rosario, Argentina, in 1968. He earned a Ph.D. in metallurgy from Case Western Reserve University in Cleveland in 1972. A citizen of the United States since 1979, Dr. Sagüés began his career as a visiting assistant professor at Columbia University in 1972, performed postdoctoral research in 1973, and was a guest scientist at the Solid State Research Institute of the Jülich Nuclear Research Center in West Germany from 1974 to 1976. He served as a research associate at Argonne National Laboratory from 1976 to 1978 and as senior metallurgist, manager, and associate laboratory director of the Kentucky Center for Energy Research Laboratory from 1978 to 1985. At the same time, he continued his teaching career at the University of Kentucky. In 1985, he moved to the University of South Florida as an associate professor. Dr. Sagüés became professor of materials engineering in 1991 and Distinguished University Professor, Department of Civil and Environmental Engineering, in 1999.

Dr. Sagüés resides in Lutz, Florida.

Jeffrey Wong, Ph.D.

On June 11, 1999, President Bill Clinton reappointed Jeffrey Wong to serve on the Nuclear Waste Technical Review Board. Dr. Wong was first appointed to the Board in 1995.

Dr. Jeffrey Wong is Deputy Director for Science, Pollution Prevention and Technology; Department of Toxic Substances Control; California Environmental Protection Agency. Dr. Wong has nearly 20 years of experience in toxicology, including assessment of exposure risks at hazardous waste sites, at hazardous waste treatment, storage, and disposal facilities, and at hazardous material spills and accidents. He is an instructor in environmental toxicology at the University of California, Davis, and he has worked with the California Department of Justice in forensic toxicology. Dr. Wong was a National Institutes of Environmental Health Sciences Predoctoral Fellow in environmental toxicology and was the recipient of the American Academy of Forensic Sciences Regional Award in Toxicology in 1984.

Dr. Wong brings to the Board extensive experience in risk assessment and scientific team management. He served as the risk evaluation expert on the external expert review panel to the Consortium for Environmental Risk Evaluation, a program of Tulane and Xavier universities.

Dr. Wong also has served on National Academy of Sciences/National Research Council committees relating to remedial action for hazardous waste sites and the U.S. Department of Energy's environmental restoration program. He is a member of the editorial board of *Journal of Contaminated Soils* and is an advisory board member for the Association for the Environmental Health of Soils.

Dr. Wong earned a bachelor of arts degree in bacteriology in 1973, a master of science degree in food science and technology in 1976, and a Ph.D. in pharmacology and toxicology in 1981, all from the University of California, Davis. He worked for the California Department of Justice as a senior forensic toxicologist after his doctoral work. He moved to the California Department of Food and Agriculture as a staff toxicologist before beginning his career with the California Environmental Protection Agency in July 1985. Before assuming his current position, he was chief of the Human and Ecological Risk Division of the Department of Toxic Substances Control, California Environmental Protection Agency.

Dr. Wong resides in Sacramento, California.

Appendix B

Meeting List

January 30-31, 2001**Winter Board Meeting***Amargosa Valley, Nevada*

Topic:

- Scientific and technical issues

Transcript available

February 1, 2001**Board Business Meeting***Las Vegas, Nevada*

Minutes available

April 13, 2001**Ad Hoc Panel Meeting***Arlington, Virginia*

Topic:

- Developing multiple lines of evidence

Transcript available

May 8-9, 2001**Spring Board Meeting***Arlington, Virginia*

Topic:

- Scientific and technical issues

Transcript available

May 10-11, 2001**Board Business Meeting***Arlington, Virginia*

Minutes available

June 20-21, 2001**Joint Meeting of Performance Assessment
and Repository Panels***Las Vegas, Nevada*

Topic:

- Supplemental science and performance analysis

Transcript available

July 19-20, 2001**Meeting of the Panel on the Repository***Arlington, Virginia*

Topic:

- Workshop on long-term extrapolation of passive behavior

Transcript available

September 10-12, 2001**Fall Board Meeting***Las Vegas, Nevada*

Topic:

- Status of DOE's efforts to characterize site at Yucca Mountain, Nevada

Transcript available

September 12-13, 2001**Board Business Meeting***Las Vegas, Nevada*

Minutes available

November 27-29, 2001**Board Business Meeting***Coronado, California*

Minutes available

January 29-30, 2002**Winter Board Meeting***Pahrump, Nevada*

Transcript available

January 31, 2002**Board Business Meeting***Las Vegas, Nevada*

Minutes available

Appendix C

Panel Organization

Panel on Site Characterization

Chairman: Dr. Debra S. Knopman
 Members: Dr. Priscilla P. Nelson
 Dr. Richard R. Parizek
 Dr. Donald D. Runnells
 Dr. Alberto A. Sagüés

Staff: Leon Reiter*
 David M. Diodato

Panel on the Repository

Chairman: Dr. Daniel B. Bullen
 Members: Mr. John W. Arendt
 Dr. Priscilla P. Nelson
 Dr. Donald D. Runnells
 Dr. Alberto A. Sagüés

Staff: Carlos A. W. Di Bella*
 John H. Pye
 Karyn D. Severson

Panel on the Waste Management System

Chairman: Mr. John W. Arendt
 Members: Dr. Daniel B. Bullen
 Dr. Norman L. Christensen, Jr.
 Dr. Paul P. Craig
 Dr. Debra S. Knopman

Staff: Carlos A. W. Di Bella
 Daniel J. Fehringer
 Daniel S. Metlay
 Karyn D. Severson

Panel on the Environment, Regulations, and Quality Assurance

Chairman: Dr. Jeffrey J. Wong
 Members: Mr. John W. Arendt
 Dr. Norman L. Christensen, Jr.
 Dr. Paul P. Craig
 Dr. Debra S. Knopman

Staff: Daniel J. Fehringer*
 Daniel S. Metlay

Panel on Performance Assessment

Chairman: Dr. Daniel B. Bullen
 Members: Dr. Paul P. Craig
 Dr. Richard R. Parizek
 Dr. Alberto A. Sagüés
 Dr. Jeffrey J. Wong

Staff: Leon Reiter*
 Carlos A. W. Di Bella
 David M. Diodato
 Daniel S. Metlay

* Staff coordinator

Appendix D

U.S. Nuclear Waste Technical Review Board Publications

The following publications are available by mail from the Nuclear Waste Technical Review Board or electronically from the Board's Web site at www.nwtrb.gov.

Report by letter to Congress and the Secretary of Energy. January 24, 2002.

Letter report summarizing the Board's evaluation of the DOE's technical and scientific investigation of the Yucca Mountain site.

Report to the Secretary of Energy and the Congress. April 2001.

In this report, the Board summarizes its major activities in calendar year 2000. During 2000, the Board identified four priority areas for evaluating the potential repository at Yucca Mountain. The areas are the following:

- meaningful quantification of conservatisms and uncertainties in the DOE's performance assessments
- progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion
- an evaluation and a comparison of the base-case repository design with a low-temperature design
- development of multiple lines of evidence to support the safety case of the proposed repository, the lines of evidence being derived independently of

performance assessment and thus not being subject to the limitations of performance assessment.

The report summarizes the Board's views on each priority area. A more detailed discussion of the priorities can be found in letters to the DOE included among the appendices to the report.

Report by letter to the Secretary of Energy and Congress. December 2000.

This report, in the form of a letter, presents a brief update of the Board's views on the status of the DOE program.

Report to the U.S. Congress and the Secretary of Energy. April 2000.

In this report, the Board summarizes its major activities in calendar year 1999. Among the activities discussed in the report is the Board's 1999 review of the DOE's viability assessment (VA) of the Yucca Mountain site. The Board's evaluation of the VA concludes that Yucca Mountain continues to warrant study as the candidate site for a permanent geologic repository and that work should proceed to support a decision on whether to recommend the site for repository development. The Board suggests that the 2001 date for a decision is very ambitious, and focused study should continue on natural and engineered barriers. The Board states that a credible

technical basis does not currently exist for the above-boiling repository design included in the VA. The Board recommends evaluation of alternative repository designs, including lower-temperature designs, as a potential way to help reduce the significance of uncertainties related to predictions of repository performance.

Report to the U.S. Congress and the Secretary of Energy. April 1999.

In this report, the Board summarizes its major activities during calendar year 1998. The report discusses the research needs identified in the DOE's recently issued *Viability Assessment* of the Yucca Mountain site, including plans to gather information on the amount of water that will eventually seep into repository drifts, whether formations under the repository will retard the migration of radionuclides, the flow-and-transport properties of the groundwater that lies approximately 200 meters beneath the repository horizon, and long-term corrosion rates of materials that may be used for the waste packages. The report describes other activities undertaken by the Board in 1998, including a review of the hypothesis that there were hydrothermal upwellings at Yucca Mountain, a workshop held to increase understanding of the range of expert opinion on waste package materials, and a review of the DOE's draft environmental impact statement for the Yucca Mountain site.

Report to the U.S. Congress and the Secretary of Energy: Moving Beyond the Viability Assessment. April 1999.

In its report, the Board offers its views on the DOE's December 1998 *Viability Assessment* of the Yucca Mountain site in Nevada. The Yucca Mountain site is being characterized to determine its suitability as the location of a permanent repository for disposing of spent nuclear fuel and high-level radioactive waste. The Board discusses the need to address key uncertainties that remain about the site, including the performance of the engineered and natural barriers. The Board addresses the DOE's plans for reducing those uncertainties and suggests that consideration be given to alternative repository designs, including ventilated low-temperature designs that have the

potential to reduce uncertainties and simplify the analytical bases for determining site suitability and for licensing. The Board also comments on the DOE's total system performance assessment, the analytical tool that pulls together information on the performance of the repository system.

Report to the U.S. Congress and the Secretary of Energy. November 1998.

In its report, the Board offers its views on the direction of future scientific and technical research under way and planned by the DOE as part of its program for characterizing a site at Yucca Mountain, Nevada, as a potential repository for spent fuel and high-level radioactive waste. The Board discusses some of the remaining key scientific and technical uncertainties related to performance of a potential repository. The Board's report addresses some of these uncertainties by examining information about the proposed repository system presented to it in meetings and other technical exchanges. The Board considers and comments on some of the important connections between the site's natural properties and the current designs for the waste package and other engineered features of the repository.

Review of Material on Hydrothermal Activity. July 24, 1998.

This series of documents concerns the Board's review of material related to Mr. Jerry Szymanski's hypothesis of ongoing, intermittent hydrothermal activity at Yucca Mountain and large earthquake-induced changes in the water table there. The series includes a cover letter, the Board's review, and the reports of the four consultants the Board contracted with to assist in the review.

1997 Findings and Recommendations. April 1998.

This report details the Board's activities in 1997 and covers, among other things, the DOE's viability assessment, due later this year; underground exploration of the candidate repository site at Yucca Mountain, Nevada; thermal testing under way at the site; what happens when radioactive waste reaches the water table beneath Yucca Mountain;

transportation of spent fuel; and the use of expert judgment. The Board makes four recommendations in the report concerning (1) the need for the DOE to begin now to develop alternative design concepts for a repository, (2) the need for the DOE to include estimates of the likely variation in doses for alternative candidate critical groups in its interim performance measure for Yucca Mountain, (3) the need for the DOE to evaluate whether site-specific biosphere data is needed for license application, and (4) the need for the DOE to make full and effective use of formally elicited expert judgment.

Report by letter to the Secretary of Energy and the Congress. December 23, 1997.

This report, in the form of a letter, addresses several key issues, including the DOE's viability assessment of the Yucca Mountain site, design of the potential repository and waste package, the total system performance assessment, and the enhanced characterization of the repository block (east-west crossing).

Report to the U.S. Congress and the Secretary of Energy: January to December 1996. March 1997.

This report summarizes Board activities during 1996. Chapter 1 provides an overview of the Department of Energy's high-level nuclear waste management program from the Board's perspective, including the viability assessment, program status, and progress in exploration and testing. The chapter ends with conclusions and recommendations. Chapter 2 examines the three technical issues—hydrology, radionuclide transport, and performance assessment—and provides conclusions and recommendations. Chapter 3 deals with design, including the concept for underground operations, repository layout and design alternatives, construction planning, thermal loading, and engineered barriers. The Board also makes conclusions and recommendations. Chapter 4 provides an overview of recent Board activities, including the international exchange of information, the Board's visit to the River Mountains tunnel, and a presentation to the NRC. Appendices include information on Board members, the organization of the Board's panels, meetings held in 1996 and scheduled for 1997, the DOE's

responses to previous Board recommendations, a list of Board publications, references for the report, and a glossary of technical terms.

Nuclear Waste Management in the United States—The Board's Perspective. June 1996.

This publication was developed from remarks made by Dr. John Cantlon, Chairman of the Nuclear Waste Technical Review Board, at Topseal '96, an international conference on nuclear waste management and disposal. The meeting was sponsored by the Swedish Nuclear Fuel and Waste Management Company and the European Nuclear Society. The publication highlights the Board's views on the status of the U.S. program for management and disposal of commercial spent nuclear fuel and provides a brief overview of the program's organization. It summarizes the DOE's efforts to characterize the Yucca Mountain site and to develop a waste isolation strategy for the site. The publication also outlines legislative and regulatory changes under consideration at that time and the Board's views on the technical implications of those possible changes.

Report to the U.S. Congress and the Secretary of Energy: 1995 Findings and Recommendations. April 1996.

This report summarizes Board activities during 1995. Chapter 1 provides an overview of the DOE's high-level waste management program, including highlights, current status, legislative issues, milestones, and recommendations. Chapter 2 reports on Board Panel activities and Chapter 3 provides information on new Board members, meetings attended, interactions with Congress and congressional staff, Board presentations to other organizations, interactions with foreign programs, and a review of the Board's report on interim storage of spent nuclear fuel. Appendices include Board testimony and statements before Congress, Board correspondence of note, and the Department of Energy's responses to recommendations in previous Board reports.

Disposal and Storage of Spent Nuclear Fuel—Finding the Right Balance. March 1996.

This special report caps more than two years of study and analysis by the Board into the issues surrounding the need for interim storage of commercial spent nuclear fuel and the advisability and timing of the development of a federal centralized storage facility. The Board concludes in the report that the DOE's efforts should remain focused on permanent geologic disposal and the site investigations at Yucca Mountain, Nevada; that planning for a federal centralized spent fuel storage facility and the required transportation infrastructure be begun now, but actual construction delayed until after a site-suitability decision is made about the Yucca Mountain site; that storage should be developed incrementally; that limited, emergency backup storage capacity be authorized at an existing nuclear facility; and that, if the Yucca Mountain site proves unacceptable for repository development, other potential sites for both centralized storage and disposal be considered.

Report by letter to the Secretary of Energy and the Congress. December 13, 1995.

This report, in the form of a letter, addresses the DOE's progress in underground exploration with the tunnel boring machine, advances in the development of a waste isolation strategy, new work on engineered barriers, and progress being made in performance assessment.

Report to the U.S. Congress and the Secretary of Energy: 1994 Findings and Recommendations. March 1995.

This report summarizes Board activities during 1994. It covers aspects of the DOE's Program Approach, their emerging waste isolation strategy, and their transportation program. It also explores the Board's views on minimum exploratory requirements and thermal-loading issues. The report focuses a chapter on the lessons that have been learned in site assessment from projects around the world. Another chapter deals with volcanism and resolution of difficult issues. The Board also details its observations from its visit to

Japan and the Japanese nuclear waste disposal program. Findings and recommendations in the report centered around structural geology and geoen지니어ing, hydrogeology and geochemistry, the engineered barrier system, and risk and performance analysis.

Report to the U.S. Congress and the Secretary of Energy: January to December 1993. May 1994.

This report summarizes Board activities primarily during 1993. It reviews the nuclear waste disposal programs of Belgium, France, and the United Kingdom; elaborates on the Board's understanding of the radiation protection standards being reviewed by the National Academy of Sciences; and, using "future climates" as an example, examines the DOE's approach to "resolving difficult issues." Recommendations center on the use of a systems approach in all of The Office of Civilian Radioactive Waste Management's (OCRWM) programs, prioritization of site-suitability activities, appropriate use of total system performance assessment and expert judgment, and the dynamics of the Yucca Mountain ecosystem.

Letter Report to Congress and the Secretary of Energy. February 1994.

This report is issued in letter format due to impending legislative hearings on the DOE's fiscal year 1995 budget and new funding mechanisms sought by the Secretary of Energy. The 8-page report restates a recommendation made in the Board's Special Report, that an independent review of the OCRWM's management and organizational structure be initiated as soon as possible. Also, it adds two additional recommendations: ensure sufficient and reliable funding for site characterization and performance assessment, whether the program budget remains level or is increased, and build on the Secretary of Energy's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders during the decision-making process—not afterward.

Underground Exploration and Testing at Yucca Mountain: A Report to Congress and the Secretary of Energy. October 1993.

This report focuses on the exploratory studies facility (ESF) at Yucca Mountain, Nevada: the conceptual design, planned exploration and testing, and excavation plans and schedules. In addition to a number of detailed recommendations, the Board makes three general recommendations. First, the DOE should develop a comprehensive strategy that integrates exploration and testing priorities with the design and excavation approach for the exploratory facility. Second, underground thermal testing should be resumed as soon as possible. Third, the DOE should establish a geoengineering board with expertise in the engineering, construction, and management of large underground projects.

Special Report to Congress and the Secretary of Energy. March 1993.

The Board's report provides a nontechnical approach for those not familiar with the details of the DOE's high-level nuclear waste management program. It highlights three important policy issues: the program is driven by unrealistic deadlines, there is no integrated waste management plan, and program management needs improvement. The Board makes three specific recommendations: amend the current schedule to include realistic intermediate milestones; develop a comprehensive, well-integrated plan for the overall management of all spent nuclear fuel and high-level defense waste from generation to disposal; and implement an independent evaluation of the OCRWM organization and management. These recommendations should be implemented without slowing the progress of site-characterization activities at Yucca Mountain.

Sixth Report to the U.S. Congress and the U.S. Secretary of Energy. December 1992.

The Board's report begins by summarizing recent Board activities, congressional testimony, changes in Board makeup, and the Little Skull Mountain earthquake. Chapter 2 details panel activities and offers seven technical recommendations on the dangers of a schedule-driven program; the need for top-level

systems studies; the impact of defense high-level waste; the use of high capacity, self-shielded waste package designs; and the need for prioritization among the numerous studies included in the site-characterization plans. In Chapter 3, the Board offers candid insights to the high-level waste management program in five countries, specifically those areas that might be applicable to the U.S. program, including program size and cost, utility responsibilities, repository construction schedules, and alternative approaches to licensing. Appendix F provides background on the Finnish and Swiss programs.

Fifth Report to the U.S. Congress and the U.S. Secretary of Energy. June 1992.

The Board's report focuses on the cross-cutting issue of thermal loading. It explores thermal-loading strategies (U.S. and others) and the technical issues and uncertainties related to thermal loading. It also details the Board's position on the implications of thermal loading for the U.S. radioactive waste management system. Also included are updates on Board and panel activities during the reporting period. The report offers 15 recommendations to the DOE on the following subjects: ESF and repository design enhancements, repository sealing, seismic vulnerabilities (vibratory ground motion and fault displacement), the DOE approach to the engineered barrier system, and transportation and systems program status.

Fourth Report to the U.S. Congress and the U.S. Secretary of Energy. December 1991.

The Board's report provides update on the Board's activities and explores in depth the following areas: ESF construction; test prioritization; rock mechanics; tectonic features and processes; volcanism; hydrogeology and geochemistry in the unsaturated zone; the engineered barrier system; regulations promulgated by the EPA, the NRC, and the DOE; the DOE performance assessment program; and quality assurance in the Yucca Mountain project. Ten recommendations are made across these diverse subject areas. Chapter 3 offers insights from the Board's visit with officials from the Canadian nuclear power and spent fuel disposal programs. Background on the Canadian program is in Appendix D.

Third Report to the U.S. Congress and the U.S. Secretary of Energy. May 1991.

The Board's report briefly describes recent Board activities and congressional testimony. Substantive chapters cover exploratory shaft facility alternatives, repository design, risk-benefit analysis, waste package plans and funding, spent fuel corrosion performance, transportation and systems, environmental program concerns, more on the DOE task force studies on risk and performance assessment, federal quality assurance requirements for the repository program, and the measurement, modeling, and application of radionuclide sorption data. Fifteen specific recommendations are made to the DOE. Background information on the German and Swedish nuclear waste disposal programs is included in Appendix D.

Second Report to the U.S. Congress and the U.S. Secretary of Energy. November 1990.

The Board's report begins with the background and framework for repository development and then opens areas of inquiry, making 20 specific

recommendations concerning tectonic features and processes, geoengineering considerations, the engineered barrier system, transportation and systems, environmental and public health issues, and risk and performance analysis. The report also offers concluding perspectives on DOE progress, the state of Nevada's role, the project's regulatory framework, the nuclear waste negotiator, other oversight agencies, and the Board's future plans.

First Report to the U.S. Congress and the U.S. Secretary of Energy. March 1990.

The Board's report sets the stage for the Board's evaluation of the DOE program to manage the disposal of the nation's spent fuel and high-level waste. The report outlines briefly the legislative history of the nation's spent fuel and high-level waste management program including its legal and regulatory requirements. The Board's evolution is described, along with its protocol, panel breakdown, and reporting requirements. The report identifies major issues based on the Board's panel breakdown, and highlights five cross-cutting issues.

Appendix E

Communication Between U.S. Nuclear Waste Technical Review Board and U.S. Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide the OCRWM with the Board's views on specific technical areas earlier than do Board reports. The letters are posted on the Board's Web site after they have been sent to the OCRWM. For archival purposes, the eight Board letters written during the period covered by this report are reproduced here.

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2001. Inclusion of these responses does not imply the Board's concurrence.

- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; March 30, 2001.
Subject: Board reactions to presentations at January 2001 Board meeting and statement of Board priorities.
- Letter from Chairman Jared L. Cohon to Lake Barrett, Acting Director, OCRWM; June 11, 2001.
Subject: Results of the *Ad Hoc* Panel meeting on multiple lines of evidence.
- Letter from Chairman Jared L. Cohon to Jane R. Summerson, EIS Document Manager, Yucca Mountain Site Characterization Office; July 2, 2001.
Subject: Board comments on DOE supplement to the draft environmental impact statement for a geologic repository at Yucca Mountain, Nevada.
- Letter from Daniel B. Bullen, Board member, to Stephan J. Brocoum, Assistant Manager, Office of Licensing and Regulatory Compliance, Yucca Mountain Site Characterization Office; July 2, 2001.
Subject: Board reaction to presentations at the Board Joint Panel meeting on the DOE *Supplemental Science and Performance Analysis*, June 20-21, 2001.
- Letter from Chairman Jared L. Cohon to Lake Barrett, Acting Director, OCRWM; July 17, 2001.
Subject: Board reactions to presentations at May 2001 Board meeting.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; September 7, 2001.
Subject: Department of Energy Responses to the July 17, 2001 letter.
- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; October 16, 2001.
Subject: Board response to request for comments on the *Yucca Mountain Preliminary Site Suitability Evaluation*.

- Letter from Chairman Jared L. Cohon to Lake H. Barrett, Acting Director, OCRWM; October 17, 2001.
Subject: Board reactions to presentations at September 2001 Board meeting.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; November 20, 2001.
Subject: Department of Energy Responses to the October 17, 2001 letter.
- Letter from Chairman Jared L. Cohon to Spencer Abraham, Secretary, U.S. Department of Energy; December 11, 2001.
Subject: Board comments on the technical and scientific validity of work at the Yucca Mountain site.
- Letter from Lake H. Barrett, Acting Director, OCRWM to Chairman Jared L. Cohon; December 18, 2001.
Subject: Department of Energy Responses to the December 11, 2001 letter.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

March 30, 2001

Mr. Lake H. Barrett
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

On behalf of the Nuclear Waste Technical Review Board, I would like to convey our reactions to the presentations made by the Department of Energy's (DOE) Yucca Mountain Project personnel at the Board's January meeting in Amargosa Valley.

Overall, the Board was pleased with the quality of the presentations. A wealth of information was conveyed succinctly. Difficult concepts and models were described clearly and in a manner that was easily understood by a broad range of listeners. In particular, the Board commends Gerald Gordon, Gudmundur Bodvarsson, Al Eddebbarh, Robert Andrews, and Paul Harrington, who responded directly and candidly to specific questions posed in advance by the Board. They were all instrumental in making the meeting a success. The Board anticipates using this new format at future meetings.

As you will recall, at the beginning of the meeting, I read into the record a statement of Board priorities. I noted that the Board

... has recommended that DOE focus significant attention on four priority areas dealing with managing uncertainty and coupled processes, which, in the Board's view, are essential elements of any DOE site recommendation.

- (1) Meaningful quantification of conservatisms and uncertainties in DOE's performance assessments
- (2) Progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion
- (3) An evaluation and comparison of the base-case repository design with a low-temperature design

(4) Development of multiple lines of evidence to support the safety case of the proposed repository. These lines of evidence should be derived independently of performance assessment and thus not be subject to the limitations of performance assessment.

In addition to these overarching priorities, the Board has made a number of suggestions about other investigations and studies that can support, complement, and supplement these four areas. Those investigations and studies include research on the unsaturated and saturated zones as well as work to make the performance assessments more transparent and informative. As the Board continues its review of DOE's technical activities, other elements essential to the site recommendation may be identified.

Although schedule considerations may preclude completing all work before the site recommendation decision, the Board believes it is reasonable to assume that the more those investigations have advanced, the more likely it is that the technical basis for the decision will be strengthened. In what follows, the Board comments on each area.

Meaningful Quantification of Uncertainties and Conservatism

The Board is pleased with the efforts made so far to quantify better the uncertainties and conservatism present in the performance assessments of the proposed Yucca Mountain repository. However, aside from the consideration of early failures of the waste packages, there seems to be no explicit consideration of possible differences that may evolve over time between performance of the engineered barrier systems as they have been designed and their performance as they actually may be built.

Progress in Increasing Fundamental Understanding of Corrosion Processes

The Board commends the project for developing a set of investigations that could lead to improved understanding of the fundamental processes relevant to waste package corrosion, especially the stability of the passive layer of Alloy 22. The Board is pleased that many of these investigations have started and encourages the project to begin the others as soon as possible and to expedite work in this area.

Evaluation and Comparison of Repository Designs

In its June 23, 2000, testimony before the House Subcommittee on Energy and Power, the Board observed: "Understanding the differences in estimated performance and associated uncertainties under different temperature conditions is an important component of our overall understanding of potential repository performance at the Yucca Mountain site." At its January 2001 meeting, the Board made its position more explicit when it called for an evaluation and a comparison of repository designs. We understand that work in this area has begun.

The Board is interested in obtaining an evaluation and a comparison of the base-case, high-temperature repository design with a low-temperature, ventilated design. Evaluating a possible low-temperature, ventilated design could clarify the advantages—and disadvantages—associated with keeping waste package temperatures below, say, 85° C. In particular, the Board believes that DOE should use performance assessment to evaluate a low-temperature, ventilated design concept. If necessary, performance assessment models should be modified to portray accurately the effects of temperature changes on performance. Associated levels of uncertainty in repository performance should be developed for both high- and low-temperature design concepts. The Board realizes that DOE also may want to examine other design-related considerations, including licensability, operations and logistics, flexibility, cost, etc. The more technically defensible and quantitative the evaluation and comparison, the more useful it will be for policy-makers.

Development of Multiple Lines of Evidence

The project's latest revision of its *Repository Safety Strategy* appears to be an improvement over the previous iteration. As was observed in the project's presentation, however, more work needs to be done to identify or develop multiple lines of evidence to supplement and support the safety strategy. The Board is encouraged that the project recognizes the importance of this work and is pleased that the Board and the project will be holding a public meeting on April 13, 2001, in Arlington, Virginia, to explore specifically what further steps might be taken.

Other Issues

The Board also has some specific reactions to several of the presentations (listed here generally in order of increasing specificity).

- The Board is concerned that project descriptions of short-term testing are not cast broadly enough. Testing plans mostly appear to be directed at developing better parameter estimates for performance assessment. Although better parameter estimates are necessary, the Board also would like to see testing of fundamental scientific concepts, particularly when such tests can challenge accepted models. Moreover, the project should specify better what it would do with the results of its tests.
- The project's development of a long-term, comprehensive "test and evaluation" plan is a step in the right direction. The plan, however, appears to be very general in nature. The Board believes that a much more detailed and well-integrated plan would significantly enhance the quality of the site recommendation decision. Such a plan, among other things, should detail how testing after repository closure would occur, including relevant monitoring activities.

- The project recognizes the importance of incrementally adjusting proposed repository design and operations in response to new technical information. Such a strategy makes sense, and indeed, the Board encourages the program to continue thinking along these lines. However, the implementation of such an incremental learning and adjustment process is neither easy nor straightforward. The Board looks forward to hearing more from the project about this issue in the future.
- The project needs to continue efforts to reconcile the conflicting chlorine-36 findings. Because DOE seems to believe that the conflict results from different sample-preparation methodologies, the project should develop a technically defensible strategy, implemented in a sound, peer-reviewed process, for deciding which methodology is more appropriate for the problem being investigated and for identifying which findings are more valid.
- The Board is pleased that the project will be undertaking a peer review of the performance assessment used in the site recommendation decision as well as a peer review of the project's material testing plans.
- There is still some confusion about "degraded" and "neutralized" barrier studies and about the consistent application of these terms to the different components of the repository system. The project should reexamine these studies and consider implementing an approach recommended in the Board's September 20, 2000, letter to Dr. Ivan Itkin. Under such an approach, the analysis would start off by estimating the dose, assuming that the radioactive waste is lying exposed at the earth's surface. Individual elements of the geologic and engineered systems then would be added, and resulting dose estimates would be calculated until the repository system reaches its completed form.
- Questions remain about the compositions and corrosion effects of electrolytes that may form on waste package surfaces. The Board urges the project to continue its investigations in this area and to ensure, in particular, that electrolytes chosen for future testing represent environments derived from repository pore water (as opposed to J-13 water) in its evolved state. That evolved state includes the effect of thermally driven processes caused by the decay heat from the waste and interactions with condensate, seepage, dust that may settle on waste packages during ventilation, and the engineered system materials themselves. The Board also reiterates its belief that long-term projections from performance testing in model solutions must be supported by sound mechanistic understanding, including theoretical development and experimental evaluation of theories.

In conclusion, the Board appreciates the project's responsiveness to its concerns, especially considering the importance of rapidly approaching project milestones. The Board looks forward in the next few months to commenting on specific project plans for additional technical studies and to interacting productively with project personnel.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

June 11, 2001

Mr. Lake Barrett
Acting Director, Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Barrett:

The U.S. Nuclear Waste Technical Review Board (Board) thanks you for your opening comments and for supporting the participation of personnel from the Department of Energy (DOE) and its contractor team at the April 13, 2001, meeting on developing multiple lines of evidence. The Board is pleased to provide you with its impressions of that meeting.

As you know, the Board's view is that developing multiple lines of evidence is an essential element of any site recommendation decision by the DOE. Board members and representatives of the DOE who participated in the meeting agreed that some multiple lines of evidence could increase the level of confidence in the projections of repository behavior derived from the DOE's integrated performance assessment of Yucca Mountain. However, the Board believes that other lines of evidence could reduce confidence in the conclusions of performance assessment. Therefore, the DOE should indicate which performance assessment conclusions are supported by multiple lines of evidence, which are contradicted by multiple lines of evidence, and which are not supplemented at all by multiple lines of evidence.

There seemed to be agreement on potential approaches that the DOE might take to develop multiple lines of evidence, such as natural and anthropogenic analogues, simplified calculations, direct observation and measurement, first principles, and laboratory and field testing of predictions. (Of course, the last two approaches should be an integral part of any rigorous model development program as well.) The choice of approaches used will need to be determined on a case-by-case basis; none of the approaches appears to be inherently superior to any other.

The more these lines of evidence can be derived independently of performance assessment, the more they can serve as a "check" on the conclusions of performance assessment. Multiple lines of evidence that provide insights into phenomena whose uncertainty significantly affects estimates of repository performance are especially useful. Furthermore, the Board was encouraged to hear from DOE representatives that a case for multiple barriers and defense-in-depth might be advanced using lines of evidence other than performance assessment.

In the final analysis, however, the meeting demonstrated to the Board that talking about multiple lines of evidence in the abstract is less useful than examining specific examples that reinforce (or call into question) a particular scientific conclusion. The technical basis of the site recommendation decision for the proposed Yucca Mountain repository would be strengthened by

the extensive use of such examples. William Dudley's thoughtful analysis of multiple lines of evidence corroborating the estimate of mean present-day infiltration is a good model for what the Board has in mind.

The DOE also mentioned other possible approaches for developing multiple lines of evidence, such as confirmatory monitoring, additional field-testing after licensing approval, and peer review. Although each of these latter approaches can improve the technical rigor of performance assessment models and assumptions, the Board would view these approaches as carrying less weight for site recommendation than physically based lines of evidence assembled before the site recommendation.

The Board appreciates the DOE's participation in this meeting and looks forward to additional interactions as the DOE develops multiple lines of evidence to broaden the basis of its repository safety case.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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July 2, 2001

Jane R. Summerson, EIS Document Manager
Yucca Mountain Site Characterization Office
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
P.O. Box 30307, M/S 010
North Las Vegas, NV 89036-0307

Dear Dr. Summerson:

The Nuclear Waste Technical Review Board appreciates the opportunity to comment on the Department of Energy's (DOE) recently published supplement to its draft environmental impact statement (EIS) for a geologic repository at Yucca Mountain, Nevada. The Board submits these comments as part of its responsibility under the Nuclear Waste Policy Act, as amended, to evaluate the scientific and technical validity of the activities carried out by the Secretary of Energy and the DOE Office of Civilian Radioactive Waste Management.

The Board believes that the technical basis for projecting the long-term performance of the base-case (high-temperature) repository design has weaknesses. They include the apparently large uncertainties in projections of repository performance caused by the relatively high temperatures produced by the base-case design. The Board has urged the DOE to evaluate a low-temperature design so that its performance (and uncertainties in performance) can be compared with that of the high-temperature design. The DOE decided to address this area of Board concern by taking a single general repository design (referred to as the "Science and Engineering Report [S&ER] flexible design") and comparing its performance and associated uncertainties when it is operated at a high temperature and at a representative lower temperature. This choice was influenced, in part, by the fact that the same process models and performance assessments could be used to evaluate both the higher- and the lower-temperature design concepts. Information in the *Supplemental Science and Performance Assessment* report should provide some indication of the validity of this analytical approach. The final EIS should justify use of the S&ER design operated in a low-temperature mode as a surrogate for a true low-temperature design for purposes of projecting environmental effects, especially long-term releases of radionuclides to the environment.

The supplement to the draft EIS shows, in Table 3-14, that the peak annual dose and the time of the peak are exactly the same for the higher- and lower-temperature operating modes. Because corrosion rates, coupled processes, and the size of the repository footprint are likely to be temperature-dependent, the Board is concerned that this result may reflect model limitations. In its September 2000 letter to the DOE,^{*} the Board identified a number of limitations in the

* Letter from Jared L. Cohon, Board chairman, to Dr. Ivan Itkin, dated September 20, 2000.

DOE's performance assessment models that could hinder an accurate prediction of the effects of temperature on repository performance. The Board recommends that the DOE revise its performance assessment models to capture the effects of temperature more accurately, allowing an improved assessment of the merits of higher-temperature versus lower-temperature repository designs.

Section 3.2.3 discusses the predicted long-term performance of a Yucca Mountain repository. According to this section, predicted radiation doses during the first 10,000 years are zero ". . . because waste packages would remain intact for more than 10,000 years." Unclear from this section is whether the analysis considered the potential for defective waste packages to be produced that could fail in less than 10,000 years, potentially causing radiation doses earlier than predicted in the supplemental draft EIS. The final EIS should discuss the potential for early (first 10,000 years) waste package failures.

For the S&ER design, the waste packages may contain more potentially toxic metals, such as chromium and nickel, because stainless steel has replaced carbon steel as a component of the packages. The final EIS should provide new estimates of the concentrations of these elements that humans could be exposed to through groundwater near Yucca Mountain and should evaluate the potential cumulative public health and environmental hazards that could occur if groundwater also contains radionuclides released from a Yucca Mountain repository.

The Board realizes that the potential environmental impacts of transportation were addressed in the draft EIS and that those impacts are not the subject of this supplemental draft EIS. The Board previously offered its views on transportation impacts when it commented on the draft EIS and expects the DOE to respond to those comments when it prepares the final EIS.

Again, the Board appreciates the opportunity to comment on the supplemental draft EIS for a Yucca Mountain repository.

Sincerely,

{Signed By}

Jared L. Cohon
Chairman



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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July 2, 2001

Dr. Stephan J. Brocoum
Assistant Manager, Office of Licensing and Regulatory Compliance
Yucca Mountain Site Characterization Office
U.S. Department of Energy
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P.O. Box 30307
North Las Vegas, NV 89036

Dear Dr. Brocoum:

On behalf of the Nuclear Waste Technical Review Board, I thank you and your staff for their very hard work in preparing for and presenting material at the joint June 20-21, 2001, meeting in Las Vegas of the Board's Panel on Performance Assessment and Panel on the Repository. The meeting was completely devoted to the Department of Energy's *Supplemental Science and Performance Analyses (SSPA)*. Clearly, a great deal of work has been carried out, and the DOE appears to have been very responsive in addressing the Board's four priority areas.

The meeting was very interesting, and the presentations stimulated many questions. We appreciate DOE management's willingness to present and discuss the *SSPA* before it becomes final. The Board is looking forward to receiving the final version of the *SSPA* so that we may gain a better understanding of the new information, models, and assumptions presented. Any comments that the Board may have on the *SSPA* will be made subsequent to our evaluation of the material in the final version of the report.

Again, please convey our appreciation to all the presenters.

Sincerely,

{Signed by}

Daniel B. Bullen
Chair, Panel on the Repository
Chair, Panel on Performance
Assessment

cc.

Lake H. Barrett
J. Russell Dyer



UNITED STATES
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2300 Clarendon Boulevard, Suite 1300
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July 17, 2001

Mr. Lake Barrett
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

On behalf of the Nuclear Waste Technical Review Board, thank you for attending and supporting the Board's meeting in Arlington, Virginia, on May 8 and 9, 2001. This letter conveys the Board's reactions to the presentations made by the Department of Energy (DOE) and its Yucca Mountain Project contractor team at that meeting.

Meaningful Quantification of Uncertainties and Conservatisms

The Board is encouraged by the work being undertaken by the Project to quantify uncertainties and conservatisms in its performance assessments (PA). The work appears to be responsive to the concerns that the Board has voiced in the past. The Board will have more detailed comments on this issue when it completes its review of the *Supplemental Science and Performance Analyses (SSPA)* report.

Dealing adequately with uncertainty inherent in a large and complex system is challenging and requires many difficult analytical judgments. The Board has two concerns in this regard. First, the Project may be dismissing some sources of uncertainty prematurely simply because they seem to have very minor effects on the performance of a particular barrier or component. One purpose of carrying out a PA is to gain insights into the behavior of the system as a whole that cannot necessarily be gleaned from looking at the subsystems alone. Some subsystems may have nonlinear interactions. Second, even if uncertainty in a single component or barrier does not have a large effect on final dose calculations, it may, together with other "minor" uncertainties, have a nonnegligible cumulative effect. As the questions from the Board at the meeting suggest, the criteria for including some variables and not others in the next round of PA are not clear.

Progress in Understanding the Underlying Fundamental Processes of Corrosion

The Board continues to believe in the importance of developing an understanding of underlying physical phenomena of corrosion processes. Although obtaining better model parameters has obvious appeal in the short run, the Board continues to have concerns about the validity of the underlying models. We are encouraged that the Nuclear Regulatory Commission's Center for Nuclear Waste Regulatory Analyses is trying to develop insights into conceptual models of corrosion processes.

The Board is pleased that the Project will obtain an independent peer review in this area and urges the Project to make the review process as open and accessible as possible to interested and affected parties. The review will complement the international workshop on long-term extrapolation of passive behavior of metals that the Board will sponsor in July.

Evaluation and Comparison of Base-Case and Low-Temperature Repository Designs

In its response to a written question from Representative Joe Barton last August, the Board concluded that the technical basis for projecting the long-term performance of the Project's base-case (high-temperature) repository design has "critical weaknesses." These weaknesses include the apparently large uncertainties associated with projections of repository performance that are due to the relatively high temperatures produced by the base-case design. The Board therefore urged the Project to evaluate a low-temperature design and to compare its performance with the high-temperature design as a means of gaining further insights into system performance and reducing key uncertainties.

The Project decided to address this area of Board concern by taking a single general repository design and comparing its performance and associated uncertainties when it is operated in a high-temperature mode and in a selected low-temperature mode. This choice was influenced, in part, by the fact that the same process models and PA's could be used to evaluate both modes.

It is premature to determine whether the Project's approach, presented at the May meeting and elaborated in a letter to the Board dated May 30, 2001, will address adequately the questions the Board raised. We look forward to examining closely the content of the *SSPA* to ascertain whether the Project actually has gained the needed further insight. In particular, the Board is looking for clarity of objectives, transparency in design evaluation and comparison (including the Project's choice of designs), adequacy of representations and analysis between natural and engineered systems, and technical defensibility of the underlying models included in PA.

Development of Multiple Lines of Evidence to Support the Proposed Repository Safety Case

The presentation on multiple lines of evidence was candid and gave the Board specific and useful information. The Board is encouraged that the Project now intends to develop

multiple lines of evidence more aggressively than it has in the past. The Board urges the Project to integrate those lines fully into its analyses and documents. As the Board stated in its June 11, 2001, letter on multiple lines of evidence, "...the DOE should indicate which [PA] conclusions are supported by multiple lines of evidence, which are contradicted by multiple lines of evidence, and which are not supplemented at all by multiple lines of evidence."

More specifically, analogues that provide insights into the areas that PA suggests have substantial uncertainty and effect on performance should be given priority. Thus, the Board encourages the Project to explore analogues, such as those at Peña Blanca, Paiute Ridge, and Yellowstone National Park. An examination of natural analogues to man-made metals, including, but not limited to, josephinite, also may be promising.

Observations About Other Technical Investigations

The Board believes that the Project continues to make important progress in gathering data and developing models that can be useful in supporting PA. The infiltration studies in the cross-drift and the development of more-sophisticated climate models are examples. Nevertheless, the Board reiterates its earlier comments about the importance of expeditiously resolving ambiguities in interpreting the source of moisture in the bulk-headed drift and in determining if bomb-pulse chlorine-36 has migrated to the repository horizon.

Furthermore, the Board is concerned that investigations needed to connect the near-field natural environment with the engineered repository system, such as studies of deliquescence of brines on the waste package and drip shield, colloid transport, and thermal conductivity of the lower lithophysal rock unit, still have not been completed.

Finally, the presentations at the meeting revealed what appeared to be an instance of poor communication among Project scientists, designers, and modelers. The repository layout described in the *Science and Engineering Report* extends over a new area that includes a part of the large hydraulic gradient, but the repository layout evaluated in the PA for site recommendation does not include this area. This inconsistency may have significant potential consequences. The Board urges the Project's management to understand why this occurred and to resolve whatever problems are discovered so that inconsistencies like this are prevented in the future.

The Board again thanks you and your colleagues for participating in its May meeting.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman



Department of Energy
Washington, DC 20585

September 7, 2001

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear Dr. Cohon:

We appreciate the Nuclear Waste Technical Review Board's letter of July 17, 2001 providing comments on the information we presented at the Full Board Meeting on May 8 and 9, 2001. Our responses to the specific comments raised in your letter with regard to the Board's priority issues and observations on other aspects of our technical program are enclosed.

We continue to value the Board's feedback and look forward to the Board's detailed comments on the Supplemental Science and Performance Analyses Report. If you have any questions, please contact me at (202) 586-6842.

Sincerely,

Lake H. Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosure:
Department of Energy Responses to the
July 17, 2001 letter from Jared L. Cohon



DOE Responses to Comments and Concerns Raised in the July 17, 2001 letter from the Nuclear Waste Technical Review Board

Meaningful Quantification of Uncertainties and Conservatism-Inclusion/Exclusion of variables in performance assessment

The U. S. Department of Energy (DOE) agrees that the decision to include some variables, and not others, in the Total System Performance Assessment (TSPA) is important. Many of the subsystem level results described in Volume 1 of the Supplemental Science and Performance Analyses (SSPA) Report were abstracted and carried forward into the supplemental performance assessment model. Some new results were only evaluated through sensitivity analyses and were not included in the SSPA supplemental performance assessment model. Other results were only considered at the component model level. There are several reasons for not including a new parameter or model in the supplemental performance assessment model. These reasons include:

- low probability of occurrence
- no significant effect at the component model level
- no significant effect at the system level
- results are sufficiently uncertain so that inclusion would be non-conservative
- model is still conceptual

For example, the effects of coupled thermal-hydrologic-chemical (THC) processes on fracture porosity in the unsaturated zone were included in the subsystem model and described in the SSPA Report, Volume 1. However, the effects were not carried forward and evaluated in the supplemental performance assessment model, because the THC effects on fracture porosity were less than one percent for the higher-temperature operating mode and would be smaller for the lower-temperature operating mode. These changes are within the degree of uncertainty for this parameter and are thought to be insignificant. In addition, the effects of THC are relatively short-lived and local. Changes in the flow field at the mountain scale are influenced more by the boundary conditions, such as infiltration, rather than THC processes.

The DOE acknowledges that cumulative effects of uncertainties may have a non-negligible effect on performance. We will continue to re-evaluate the validity of the screening decisions as new data and refined models become available. We will also strengthen project reports to clearly articulate the rationale for including or excluding variables, related to features, events and processes, from evaluations of system-level performance.

Progress in Understanding the Underlying Fundamental Processes of Corrosion

The DOE agrees that it is important to develop an understanding of the underlying physical phenomena of corrosion processes. The DOE has implemented a detailed experimental program and development of a more advanced theoretical corrosion model to reduce uncertainties in the long-term performance of waste package and drip shield materials. Specific areas of study

include general corrosion, localized corrosion, waste package environmental conditions, and stability of passive films.

Long-term passive film stability is particularly important to long-term performance of the waste package. Additional theoretical and experimental work is ongoing to address specific processes that may affect the passive layer, including defect and debris accumulation in the passive layer and quasitranspassive dissolution.

The experimental program will provide data leading to a better understanding of the fundamental corrosion processes in passive materials such as Alloy 22 and confirm our ability to extrapolate short-term data to predict long term behaviors, which is important to postclosure performance. In addition, Alloy 22 samples that reflect heat lot variability are included in the test program to determine the effects of chemical compositional variations on alloy performance.

As noted by the Board, the DOE has also initiated a Peer Review of the technical basis for waste package performance. The Peer Review Panel (Panel) is reviewing the current technical basis for predictions of waste package and drip shield performance, and the long-term testing and modeling program. Several panelists attended and were able to benefit from discussions at the Board's recent International Workshop on long-term extrapolation of passive behavior of waste package materials. The Panel recently (July 24, 2001) held a public meeting at which experts from both the State of Nevada and the Nuclear Regulatory Commission's contractor, the Center for Nuclear Waste Regulatory Analyses, made detailed presentations to the Panel and attending public. The Panel will provide recommendations for augmenting planned tasks and underlying models in areas that will reduce uncertainties in predicting material performance. They will provide an interim report on their comments, conclusions, and recommendations in September 2001.

Evaluation and Comparison of Base-Case and Low-Temperature Repository Designs

The DOE has evaluated and compared the performance of a potential repository over a range of temperatures. For this evaluation, two specific examples (one higher- and one lower-temperature operating mode) were analyzed. These examples represent only two of many combinations of the design and operating parameters that can be used to achieve a range of thermal objectives. The primary purposes of this evaluation and comparison were to provide insights into the effects of thermal parameters on overall repository performance, including uncertainties, and to develop confidence in repository performance over a range of thermal conditions. The results of this comparison and evaluation are documented in the SSPA Report. The results were summarized at the Board's June 20 and 21, 2001 joint meeting of its Repository and Performance Assessment Panels. The SSPA report evaluated and compared subsystem as well as total system level repository performance during the post-closure period. The DOE is looking forward to the Board's comments on the Project's approach to the comparison and evaluation of performance over a range of temperatures.

We believe that the needs of the Nation may best be met by preserving the ability to select from a broad thermal range a design for repository licensing and initial operations. Preserving this

ability, however, may require testing and analytical efforts to support production of licensing documentation for the lower end of the thermal range. This documentation would supplement the analysis for the upper end of the thermal range and the technical and programmatic information developed would be used to further support the lower end of the thermal range in a potential license application. Accordingly, the Department has issued technical direction to Bechtel-SAIC Company, our Management and Operating Contractor, to begin evaluating this work in accordance with our project control processes so that the overall cost and schedule impacts of this effort can be fully understood. The Program's 2002 budget, which at this point is very uncertain, will strongly influence our ability to implement this work. We will evaluate these cost and schedule impacts in light of these broader program constraints and make appropriate management decisions regarding implementation of the technical work. We will keep the Board informed of our progress and decisions on this important topic.

Development of Multiple Lines of Evidence to Support the Proposed Repository Safety Case

The expanded consideration of multiple lines of evidence during the development of the recent Supplemental Science and Performance Analyses Report has improved the DOE's understanding of processes important to repository performance, independent of the results of the quantitative TSPA. As a consequence, the DOE intends to continue the expanded evaluation of multiple lines of evidence to provide additional confidence in the results of TSPA. Current plans include additional studies of various analogs, including work at Peña Blanca, Paiute Ridge, Yellowstone National Park, and examination of evaluation of analogs to man-made metals, such as Josephinite. We will consider both supporting and opposing lines of evidence to provide a balanced discussion of the available lines of evidence.

Ambiguities in interpreting the source of moisture in the bulk-headed drift and in determining if bomb-pulse chlorine-36 has migrated to the repository horizon.

The DOE has given high priority to studies investigating the source of moisture in the bulk-headed section of the cross drift and determining if bomb-pulse chlorine-36 has migrated to the repository horizon. Those studies are still underway. We will be providing the Board an update on the current progress in resolving these issues in the September 2001 Full Board meeting.

Investigations to connect the near-field natural environment with the engineered repository system

The DOE is aware of the Board's concern that studies to connect the near-field natural environment with the engineered barrier system are still under way. The Board's examples include studies of deliquescence of brines on the waste package and drip shield, colloid transport, and thermal conductivity of the lower lithophysal rock unit of the Topopah Spring. The DOE believes that there are sufficient data to bound the natural environment in the near field for evaluations of the effects of the near-field environment on the engineered barrier system.

Additional testing and analysis are ongoing to improve the defensibility of these bounds and possibly move toward more realistic bounds.

These studies include investigations of the potential occurrence of hygroscopic salts that could lead to concentrated brines such as sodium nitrate, sodium chloride, sodium sulfate, sodium carbonate, calcium sulfate, and possibly calcium or magnesium chloride. Corrosion test conditions include many of these constituents and provide a reasonable representation of water characteristics relative to the effects on corrosion. Along these lines, samples of dust are being collected in the Exploratory Studies Facility from horizontal or near-horizontal surfaces. These samples are being analyzed to determine the total organic components, major and minor ionic species, and particle analyses using petrographic and scanning-electron microscopes. To strengthen the colloid transport database, the DOE is continuing work at Busted Butte, the Alluvial Testing Complex, and in the laboratory. In addition, a study is ongoing to collect data on the thermal properties of the Topopah Spring Tuff lower lithophysal unit.

The repository layout described in the *Science and Engineering Report* extends over a new area that includes a part of the large hydraulic gradient, but the repository layout evaluated in the PA for site recommendation does not include this area. This inconsistency may have significant potential consequences.

The DOE's performance assessments are iterative. As new data become available and as the underlying processes are better understood, the models and inputs are refined. These models are then abstracted and analyzed in an updated TSPA model. Because this is an iterative process, the inputs, and therefore the simulation results, are a snapshot of the information available at the time the simulations are run. The Total System Performance Assessment-Site Recommendation (TSPA-SR) implemented the results of analyses in the Process Model Reports and supporting Analysis and Modeling Reports that were based on the modified Enhanced Design Alternative II. Since that time, the layout of potential repository development areas for site recommendation has continued to evolve. Therefore, the effects of the water table rise on the large hydraulic gradient beneath the northernmost emplacement drifts were not explicitly included in the TSPA-SR.

The SSPA (Volume 1, Section 3.3.4) does, however, include information on the performance implications of the expanded repository footprint to the north. The extensive zeolitization of the Calico Hills Formation in this area diverts water flow above the water table. Consequently, the values of total percolation flux at the water table are generally among the lowest in the area of the northernmost emplacement drifts. In addition, the fraction of the total number of radionuclide particles released from the repository and reaching the water table is generally lowest in this area for the medium infiltration case and the glacial transition climate case. This information suggests that any errors introduced by the simplified model of a uniform climate induced water table rise in the TSPA are likely to be small.

As noted in the Science and Engineering Report, the layout of potential repository development areas illustrates parts of the upper and lower blocks that could be used for emplacement of waste. If the site is designated, then as the design evolves to support a license application the performance implications of the northernmost drifts will be evaluated in TSPA analyses.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 16, 2001

Mr. Lake H. Barrett
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW, RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

Thank you for your August 28, 2001, letter to each member of the Nuclear Waste Technical Review Board (Board) asking for comments on *Yucca Mountain Preliminary Site Suitability Evaluation (PSSE)*. I am responding on behalf of the Board.

The information in the *PSSE* will be assessed by the full Board as part of its continuous evaluation of the validity of technical and scientific activities related to the Department of Energy's (DOE) radioactive waste management program. Because the *PSSE* addresses issues that are at the core of the Board's congressional mandate, the Board feels strongly that it is inappropriate for its members to respond as individuals.

As you know, the Board will hold a business meeting in late November to begin preparing its comments on the DOE's technical bases for a decision on whether to recommend the Yucca Mountain site for repository development. On the basis of these and subsequent discussions, the Board expects to comment on the *PSSE* and other relevant DOE documents in the coming months. The Board's comments will be sent in letters and reports to the program, the Secretary, and Congress.

Thank you again for your letter.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

cc. Robert G. Card



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

October 17, 2001

Mr. Lake H. Barrett
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW, RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

Thank you for attending and supporting the Nuclear Waste Technical Review Board's (Board) meeting in Las Vegas on September 10-12, 2001. That the meeting went forward in such a professional manner despite the difficult circumstances caused by the events of September 11 is a tribute to your staff and contractors. The Board appreciates your efforts.

It is clear from presentations at the Board's September meeting and from our preliminary review of *Science and Engineering Report, Preliminary Site Suitability Evaluation (PSSE)*, and *Supplemental Science and Performance Analysis (SSPA)* that progress has been made. The amount of work described at the Board's September meeting and the range of analyses conducted by the program in a relatively short time are commendable. We understand that work is continuing in several areas, including uncertainty analyses and corrosion studies.

As you know, the Board will hold a business meeting in late November to begin preparing its comments on the Department of Energy's (DOE) technical bases for a decision on whether to recommend the Yucca Mountain site for repository development. However, the Board's evaluation of the status of the DOE's program, including progress on the Board's four priority areas, will be made more difficult because of gaps in data and analyses. A few key examples of such gaps follow:

Incomplete comparison of high- and low-temperature repository designs. The Board has stated several times that it believes there are significant problems associated with the technical basis for the DOE's base-case repository design, which is a high-temperature design. Because it appears that a lower-temperature design could reduce the significance of some of the uncertainties related to coupled processes and corrosion of the waste packages, the Board recommended that the DOE undertake a comparison of higher- and lower-temperature designs. The DOE's May 30, 2001, letter to the Board indicated that an integrated evaluation and comparison of designs would be completed before a decision on site recommendation is made. This comparison does not appear to have been completed.

Although the *PSSE* suggests that the DOE believes that its repository design can be operated over a range of temperatures, the DOE's plans, if any, to increase its understanding of low-temperature operations are unclear. For example, in general, the analyses in the *PSSE* show little difference in performance and levels of uncertainty between high- and low-temperature operations. This could mean that repository performance and levels of uncertainty are not affected by the repository's thermal regime or that the DOE's performance assessment models are not sufficiently sensitive to show differences between high- and low-temperature regimes.

Questions about the contributions of natural and engineered barriers. In previous "one-off" analyses presented by the DOE, barriers have been "neutralized," (i.e., *individually removed*) to evaluate the performance of the repository system. The Board noted in letters to the DOE dated September 20, 2000, and March 30, 2001, that the neutralization was not consistently defined and suggested that the program conduct an alternative analysis in which barriers would be *incrementally added* to the repository system to determine the contribution of each barrier to overall repository performance. To the Board's knowledge, the DOE has not implemented this suggestion, particularly with respect to the new TSPA carried out as part of the *SSPA*.

Lack of a rationale for going forward in the face of unresolved issues. The disagreements between the DOE and the Nuclear Regulatory Commission's staff and consultants over igneous consequence models seem unlikely to be resolved before the scheduled site recommendation. Thus far, the DOE has not presented a clear and persuasive rationale for going forward with a site recommendation before resolving this important issue.

The DOE asserted at the Board's September meeting that water in the bulkheaded part of the cross-drift was the result of condensation, not seepage. However, no data supporting this conclusion were presented. In addition, we understand that significant amounts of moisture have been found in that portion of the cross-drift within the last two weeks.

To facilitate the Board's November deliberations, we request that you send to the Board as soon as it is available any additional information or letter reports that relate to the issues raised above or to ongoing work that will be completed before a decision on site recommendation is made. If the analyses referred to in the examples cited above will not be available before the DOE's decision is made, we would appreciate receiving the DOE's rationale for why they are not important for site recommendation as well as any plans for subsequently conducting the work if the site is recommended and approved for repository development.

In addition, we encourage additional communication at the staff level in the following weeks to explore details in relevant DOE documents that will aid our understanding of some of the subtleties in the documents. We realize that this may create an additional burden on program staff who are already working at capacity to meet program milestones. However, the Board must have all relevant information before the end of November so that it can adequately review the DOE's technical documents while trying to accommodate the time constraints imposed by the DOE's schedule for decision-making.

Thank you again for participating in the Board's meeting and for your cooperation. We look forward to receiving additional information on the issues raised in this letter and other relevant issues as we prepare for our November review.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

cc: Robert G. Card



Department of Energy

Washington, DC 20585

NOV 26 2001

NOV 20 2001

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Cohon:

Thank you for your letter of October 17, 2001, providing the Board's perspective on information presented by the Department of Energy (DOE) at the Board's September meeting and from the Board's preliminary review of recent DOE/contractor reports. These reports included the Yucca Mountain Science and Engineering Report, the Preliminary Site Suitability Evaluation, and the Supplemental Science and Performance Analysis Report. The Board's letter indicates that there are some specific gaps in data and analyses that are making the Board's evaluation of the status of the Department's program more difficult. In an attempt to help the Board's evaluation process, we have provided the Board with reports, such as the Technical Update Impact Letter Report, that contain additional information on the Board's specific concerns, as noted in enclosure 1. DOE and contractor staff have been in regular and frequent contact with the Board's staff, as suggested in your letter. We trust that the information provided to your staff through telephone conversations and transmittals of requested information has been helpful to your understanding of the program.

We look forward to continuing our discussion on these issues with the Board.

Sincerely,

A handwritten signature in black ink, appearing to read "Lake Barrett", written over a large, stylized flourish.

Lake Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosures



**Department of Energy Responses to the October 17, 2000, Letter
From the Nuclear Waste Technical Review Board**

The following text addresses the four key examples of the Board's concerns that there may be gaps in data and analyses as was highlighted in the October 17, 2000, letter from the Board:

The Board expressed concern that there is not, as yet, a complete comparison of high- and low-temperature repository designs

As was discussed in its May 30, 2001 letter to the Board, the DOE is preparing a more complete integrated evaluation and comparison of high- and low-temperature operating modes, based on available information. This comparison draws on the postclosure performance analyses in the *Supplemental Science and Performance Analyses (SSPA)* and the preclosure safety analyses in the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation Report*. It also considers economic costs and the timeframe for construction, operation, ventilation, and closure. All of this information exists in various documents and reports that are available to the public. DOE plans to complete this comparison in the January timeframe.

This evaluation builds on previous work that addressed the risk/cost/benefit aspects of repository performance as a function of postclosure thermal conditions. In 1999, the DOE conducted a series of meetings and workshops on the topic culminating in the License Application and Design Selection Report (LADS)(CRWMS M&O 1999¹). Board members and staff attended and contributed to many of those internal meetings. The final report and its supporting documents were transmitted to the Board as they were completed. A number of studies and reports have looked at the design concepts and performance implications of operating the repository in a below boiling configuration. They include:

- Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada and Supplement to the Draft EIS
- License Application Design Selection Report
- Operating a Below-Boiling Repository: Demonstration of Concept
- Natural Ventilation Study: Demonstration of Concept
- Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing
- Yucca Mountain Science and Engineering Report
- Supplemental Science and Performance Analyses Report
- Life Cycle Cost Analysis for Repository Flexible Design Concepts

¹ CRWMS M&O 1999, *License Application Design Selection Report*. B00000000-01717-5705-00131 REV 00. Las Vegas, Nevada.

- December 12, 2000, PORB Position Paper
- July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Each of these documents is briefly summarized with respect to examining cold operating modes in enclosure 2.

The repository design is flexible, and can be constructed and operated in various modes to achieve specific technical objectives, accommodate policy decisions, and address new information. As the Board has noted, the performance assessment results described in the SSPA do not show significant differences over the long term between the lower-temperature operating mode (LTOM) and the higher-temperature operating mode (HTOM). There are, however, measurable differences in performance at the subsystem level. Differences at the subsystem level do not appear at the total system level primarily because the duration of these changes is relatively short-lived (hundreds of years) in comparison to the duration of the regulatory time period (10,000 years) and to the time to calculated peak dose (~1,000,000 years). The degree of uncertainty associated with performance analyses during the first few thousand years may well be greater for the HTOM case than for the LTOM and uncertainty in the risk analysis could vary between different design/operating mode options. However, in either case the performance is well below limits set by the EPA and NRC for public health and safety.

To better understand uncertainties, DOE has conducted numerous tests and analyses, performance assessments, and peer reviews, over the last ten years. This helped to assure that uncertainties are appropriately identified and addressed in documentation supporting any Site Recommendation decision. We have also relied upon the reviews by the NRC, the Board, and other oversight bodies, as well as comments from the public and the State of Nevada as valued input into this process. DOE is confident that the following activities have addressed uncertainties at a level appropriate for the Site Recommendation decision:

- Scientific testing and analysis to quantify the uncertainty
- Iterative performance assessments to assess the significance of uncertainties
- Peer reviews of scientific bases to assess strengths, weaknesses, and the degree of confidence in projections of performance
- Reviews by the Nuclear Regulatory Commission, Nuclear Waste Technical Review Board and other oversight groups
- Comments by the public, Clark and Nye Counties and the State of Nevada

Each of these activities is briefly discussed in enclosure 2.

The DOE is continuing to investigate the sensitivity and uncertainty of performance analyses to design and operating mode decisions and to identify specific activities that will enhance the evaluation of lower temperature operating modes. This work is being done in anticipation of development of a license application and for other research needs,

should the site be designated. Planned work related to uncertainties in thermal conditions, beginning in FY 2002, includes:

- Continued waste package passive film corrosion material testing program to better understand underlying fundamental scientific processes.
- Continued review and modification of the Performance Confirmation Plan to provide for continued performance testing in the preclosure operational phase to better quantify performance uncertainties.
- Continued modeling activities to incorporate multiple lines of evidence for processes that affect long term performance.
- Performance of additional uncertainty and sensitivity analyses to better understand major contributors to long term performance.
- Continued review and validation of parameter ranges and Features, Events and Processes (FEP's) screening to ensure proper insight into total system performance.

Based on preliminary results from the latest evaluation of operating modes and results of all previous work, taken together with comments on the technical basis for Site Recommendation from the Board, USGS, Nye County, and other interested parties regarding the potential benefits of lower temperature postclosure conditions, the DOE is directing our contractor to implement work activities that will supplement information on the low-temperature operating mode. Updated results from the testing program will be used to expand the technical basis for this end of the flexible design for inclusion in a License Application. As was discussed in a recent meeting, DOE will invite the Board to participate in semi-annual meetings to discuss items of mutual interest such as the hot vs. the cold operating options. Updated information about the enhanced cold operating mode analyses is expected to be available to support the first of these meetings in the next several months.

The Board indicated that it still has questions about the contributions of natural and engineered barriers. In particular, the Board noted that it has suggested that the program conduct an alternative analysis in which barriers would be incrementally added to the repository system to determine the contribution of each barrier to overall repository performance.

An analysis was completed to provide some insight into the role of the natural and the engineered barriers, using the neutralization concept (*Figure 3-2, Revision 4 of the Repository Safety Strategy*²) and the TSPA model for Site Recommendation (TSPA-SR). This figure shows the annual dose without the benefit of any repository system barriers along with the annual dose for natural barriers alone, and the annual dose with full contribution of all barriers. The Electric Power Research Institute has used "Hazard Index" analyses to provide rough, quantitative estimates of the importance of important

² CRWMS M&O 2001. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations*. TDR-WIS-RL-000001 REV 04 ICN 01. Two volumes. Las Vegas, Nevada.

features, events, and processes (FEPs) by artificially turning off all FEPs and then adding in successive FEPs to evaluate their contribution to the total reduction in Hazard Index (EPRI 2000³). DOE has begun additional analyses of this type using the TSPA-SR model. As these analyses are completed and reviewed, DOE will share them with the Board.

The Board expressed concern that there is a lack of rationale for going forward in the face of unresolved issues. In particular, the Board expressed concern that the DOE has not presented a clear and persuasive rationale for going forward with a site recommendation before resolving the issue of differences of between volcanism models and the issue of the origin of moisture in the Cross Drift.

As set out in DOE's site suitability guidelines, a site suitability determination requires not a determination by DOE that all issues have been resolved, but rather a determination that a repository sited at Yucca Mountain would likely meet EPA's radiation protection standards and hence be licensable. DOE is continuing the process of determining whether to recommend the Yucca Mountain site for the location of a repository. During this process and in the future, if the site is designated, the DOE will continue to evaluate issues identified from its own ongoing science investigations as well as those identified by the NRC, the Board, and other interested parties. DOE's evaluation of a given issue may include internal technical review, additional testing, additional analyses, or peer review to responsibly address the issue. If DOE finds an issue significant enough to stop the site recommendation or licensing process, the DOE will do so. As noted in the NRC letter⁴ (and its attachment) on sufficiency of site characterization, the NRC has reasonable confidence that, based on the information DOE has obtained or has agreed to obtain, development of an acceptable license application is achievable.

Igneous consequence models

Recent research sponsored by Center for Nuclear Waste Regulatory Analyses (Center) provides an initial attempt to model consequences of dike-drift interactions in more detail. These analyses suggest that more waste packages may be adversely affected than previously documented in performance assessment analyses (see the *Technical Update Impact Letter Report*, Section 4 and Appendices I and L). The Center-sponsored research focused on idealized conceptual models based on a single drift that is not reflective of the repository system. Their analysis did not address the probability of the various cases occurring, the probability distribution of one or more drifts being intercepted, the quantification of the number of packages damaged, or the extent of damage to the packages. To evaluate the potential implications of the Center-sponsored research, the DOE has completed a very rough estimate of the number of waste packages that may be affected, using the Center's idealized conceptual model. If one presumes that all the

³ EPRI 2000. *Evaluation of the Candidate High-Level Radioactive Waste Repository at Yucca Mountain Using Total System Performance Assessment, Phase 5*. 1000802. Palo Alto, California: Electric Power Research Institute.

⁴ Richard A. Meserve to Robert G. Card, letter and attachment dated November 13, 2001.

assumptions and conservatisms contained in the Center's model are valid and incorporates these assumptions into the DOE's supplemental performance model, the

number of damaged waste packages is not expected to increase more than an order of magnitude. The dose, in turn, is also not expected to increase by more than an order of magnitude over the 0.08 mrem/yr dose calculated for the combined probability-weighted mean dose for direct and indirect releases during the regulatory period, reported in the *Preliminary Site Suitability Evaluation*. Therefore the releases would remain below the EPA standard.

The DOE and NRC have reached agreement on a path forward for further analyses of igneous consequences to resolve the differing points of view. Having considered the Center's research, the DOE continues to believe that the technical basis for igneous consequences is sufficient to support evaluations of site suitability. Some observations that support this position include the following:

- Low probability of an event,
- Robustness of the hazard estimate,
- Waning character of volcanism in the region,
- Localization of igneous activity away from Yucca Mountain, and
- Conservatism included in the consequence analyses

Water in the bulkheaded section of the Cross-Drift

Recent observations and test results from the Cross-Drift Bulkhead Moisture Monitoring test are summarized in the *Technical Update Impact Letter Report* (Section 4 and Appendices B and L). Based on the observations of moisture in the most recent bulkhead entry, the DOE has decided not to move the bulkhead at station 17+63 in the cross Drift so that monitoring can continue over the same section of the Cross Drift. Results of analyses to date indicate that water sampled behind the bulkhead is low in chloride and silica, consistent with condensate as the source of the water. The DOE is collecting additional water samples to further evaluate the source of the water. In terms of postclosure performance, it is important to note that condensate water has little effect on waste-package and drip-shield corrosion models. These models assume aqueous conditions at low relative humidities and are not sensitive to the quantities of water present. In addition, there is little effect of seepage or condensation on transport in the unsaturated zone. Condensate might result in more advective releases from waste packages, but the impact of this is not expected to be large, especially considering the range of percolation and seepage included as uncertainty in the analyses. The potential impact on dose is expected to be minor.

Activities DOE has undertaken to examine cold operating modes

While these documents may not have fully addressed the Board's concerns, the following is a brief summary of documents that discuss activities DOE has undertaken to examine cold repository operating modes. For completeness we list all documents that relate to the cold operating mode:

Published Reports

Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada (DOE 1999) and Supplement to the Draft EIS (DOE 2001)

While it contains no new or original evaluations of the operating modes, the Draft EIS does include an evaluation of the environmental impacts of high, intermediate, and low thermal load scenarios. The Supplement to the Draft EIS includes an evaluation of impacts over a range of thermal operating modes from higher-temperature (equivalent to Draft EIS intermediate thermal load) and lower-temperature (equivalent to the range between the Draft EIS low and intermediate thermal loads).

License Application Design Selection Report (CRWMS M&O 1999)

This report evaluated five Enhanced Design Alternatives (EDA) which range in thermal operating modes from "cool" (boiling at the drift wall) to "hot" (above boiling) at the drift wall and throughout the pillar. These five EDAs easily meet postclosure performance (peak dose in 10,000 years) standards. The recommended Design Alternative is known as EDA-II, and its thermal operating mode is characterized by "boiling" at the drift wall and "below boiling" in a portion of the pillar. This design is a moderate thermal load compared to others considered and the Viability Assessment Design.

Operating a Below-Boiling Repository: Demonstration of Concept (CRWMS M&O 2000)

This study demonstrates that the Site Recommendation design can be operated below boiling. The below-boiling repository can be achieved, by various combinations of: staging on the surface, changing the distance between waste packages within the emplacement drifts, and/or adjusting emplacement drift ventilation duration.

Natural Ventilation Study: Demonstration of Concept (CRWMS M&O 2000)

This study concluded that a combination of forced ventilation and natural ventilation is a technically viable option for keeping repository temperatures substantially lower. Certain

combinations of forced air ventilation and natural ventilation would result in below boiling drift wall temperatures.

Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing (CRWMS M&O 2000)

This analysis documents that the Site Recommendation reference design can be modified so that the waste-package surface temperature after closure remains at or below 85°C for the majority of waste packages. Three scenarios were evaluated; these included increasing drift spacing and allowing 300 years of active ventilation; a combination of aging, increasing waste package spacing, and at least 75 years of active ventilation; and increasing the drift spacing and 100 years of active ventilation.

Yucca Mountain Science and Engineering Report (DOE 2001)

This report provides a summary of analyses to assess the performance of a flexible design concept that includes lower- and higher-temperature operating modes.

Supplemental Science and Performance Analyses Report, Volume 1 (BSC 2001)

The effects of a range of thermal operating modes were evaluated. At the process model level, analyses indicate that the thermal operating mode does not significantly influence the natural processes over the long term. Lower temperature operating modes have less impact effects on the processes operating in the thermally perturbed region near emplacement drifts. For the higher temperature operating modes, the effects of coupled processes are generally small, and relatively short-lived. At the repository system level, the maximum differences in annual dose are approximately a factor of 10 while still achieving acceptable performance. The choice of thermal operating mode does not strongly influence overall conclusions from these supplemental analyses.

Life Cycle Cost Analysis for Repository Flexible Design Concepts (BSC 2001)

This report documents a life cycle cost analysis for repository flexible design and operating modes to provide input to the total system life cycle cost estimate for Site Recommendation and the Final Environmental Impact Statement.

YMSCO Internal Documents

December 12, 2000, PORB Position Paper

This position paper defines six scenarios that illustrate combinations of operating parameters to achieve goals for operating the reference repository design in lower-temperature operating modes. It also provides criteria to be met by a potential representative low-temperature operating mode for the Monitored Geologic Repository.

July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Repository thermal operating curves were generated to assess the difference in repository thermal performance for the nominal drift separation of 81 meters and an extended drift separation of 120 meters. These were evaluated for a peak waste package-surface temperature of 85°C.

Activities the Department of Energy has Undertaken to Improve Quantification of Uncertainties in Projections of Post Closure Performance

DOE is constantly seeking to improve the characterization of the Yucca Mountain site and engineered barriers that are potentially important to the assessment of post closure performance. Part of this characterization is to improve the sound scientific basis for the models used to project performance for the 10,000-year regulatory time period and longer. This characterization recognizes that residual uncertainties will remain after each characterization phase and that these uncertainties need to be evaluated to provide a meaningful assessment of risks to decision makers and the public.

To this end, DOE has conducted several activities to assure that uncertainties are appropriately identified and addressed in the development of the Site Recommendation. Each of these activities is briefly discussed below.

Scientific Testing and Analysis to Quantify Uncertainty

The scientific method is one of developing hypotheses and testing those hypotheses and, as additional testing is conducted, modifying hypotheses as necessary. This method includes subjecting scientific bases to reviews by peers. This method has been used for over 20 years of site characterization and engineered materials testing for the Yucca Mountain Project. This testing has formed the basis for models of post closure performance and provided uncertainty distributions in the forms of a) alternative models that explain the observations, b) spatially variable geologic and hydrologic properties that define the range of the environments expected, and c) parameter uncertainty associated with the behavior of the waste packages and waste forms in this range of environments.

Iterative Performance Assessments

DOE has conducted five major performance assessments of the Yucca Mountain site and engineered barriers in the past 10 years. Each of these analyses has used continually refined models based on the most current science available. Each analysis has evaluated the uncertainty in the projected performance through a range of quantitative uncertainty and sensitivity analyses. These analyses have assisted in defining the key components of the repository system and the important uncertainties affecting the performance. These analyses by DOE have been compared to similar analyses conducted over the same time

frame by the NRC and the Electric Power Research Institute (EPRI) that have identified very similar key aspects and uncertainties affecting the performance of a Yucca Mountain repository.

Peer Reviews

An important part of the scientific method is subjecting work to review by peers. Within the Yucca Mountain project, all scientific work is internally reviewed by the contractor staff or staff of the DOE National Laboratories or the US Geological Survey. The work by the National Laboratory staff is also internally reviewed by the management of the labs to assure it is appropriate for the decisions at hand. In addition, DOE has chartered independent external reviews of the scientific activities in a number of crucial areas, including the waste package degradation model and the Total System Performance Assessment model. Also, several external groups, notably the USGS, have provided independent reviews of the science at critical decision points for the Project such as the Viability Assessment and now the Site Recommendation. These peer reviews have identified areas of scientific weakness and the need for additional testing in certain areas to enhance the confidence in the projections of performance.

External Reviews by NRC and NWTRB

The NRC has been reviewing the scientific basis and uncertainty characterization as well as the incorporation of this basis and uncertainty in the Yucca Mountain performance assessment since the development of DOE's Site Characterization Plan in 1987. These reviews benefited from NRC staff's own Iterative Performance Assessment analyses. These reviews culminated in a series of NRC Key Technical Issue Technical Exchanges on the scientific basis for the Site Recommendation models. Additional reviews have been conducted by the Nuclear Waste Technical Review Board. These reviews have resulted in recommendations for the quantification of uncertainty to aid the decision maker in fully exploring the range of possible performance projections.

Comments by the Public and Affected Units of Government

The science developed for the Yucca Mountain Project has been commented on in various forums by local governments and the State of Nevada consultants. Clark County commented on the Viability Assessment and both Nye County and the State of Nevada consultants have commented on the saturated zone modeling in the vicinity of Yucca Mountain. Some of the comments included recommendations for alternative interpretations and models. These alternative interpretations and models have been reviewed by DOE, contractor, and national laboratory staff in their development of the Site Recommendation.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

December 11, 2001

The Honorable Spencer Abraham
Secretary
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary Abraham:

The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress in the Nuclear Waste Policy Amendments Act of 1987. The Board evaluates the technical and scientific validity of the Department of Energy's (DOE) activities associated with characterizing a potential repository site at Yucca Mountain to dispose of high-level radioactive waste and spent nuclear fuel.

Late last month, the Board held a three-day business meeting to review, among other things, the latest round of reports and analyses, which were submitted to it in the week of November 19, 2001, by the Office of Civilian Radioactive Waste Management (OCRWM). On the basis of that review and the results of the Board's ongoing evaluation of the civilian radioactive waste management program, the Board is preparing its comments for you and Congress on the technical and scientific validity of work that will form the basis of your decision on whether to recommend to the President that the Yucca Mountain site be developed for a repository. The Board intends to complete its comments within the next few weeks.

The Board appreciates the DOE's efforts to provide the OCRWM's latest studies so that this important information could be included in the Board's evaluation. The Board hopes that you will find its technical and scientific evaluation helpful in making your recommendation to the President.

Sincerely,

{Signed by}

Jared L. Cohon
Chair



Department of Energy
Washington, DC 20585

DEC 18 2001

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, Virginia 22201-3367

Dear Dr. Cohon:

We appreciate the Nuclear Waste Technical Review Board's letter of December 11, 2001, informing us that the Board intends to complete its comments within the next few weeks.

We continue to value the Board's feedback and look forward to the Board's comments on the documents the Department submitted during the week of November 19, 2001. If you have any questions, please contact me at (202)586-6842.

Sincerely,

A handwritten signature in black ink, appearing to read "Lake H. Barrett".

Lake H. Barrett, Acting Director
Office of Civilian Radioactive
Waste Management



Appendix F

Other U.S. Nuclear Waste Technical Review Board Correspondence

- Letter from Senators Harry Reid and John Ensign to Chairman Jared L. Cohon; November 26, 2001.
Subject: Questions related to the Department of Energy determination of site suitability
- Letter from Chairman Jared L. Cohon to Senator Harry Reid; December 17, 2001.
Subject: Acknowledgement of letter and notice of impending review.
- Letter from Chairman Jared L. Cohon to Senator John Ensign; December 17, 2001.
Subject: Acknowledgement of letter and notice of impending review.
- Letter from Chairman Jared L. Cohon to Senator Harry Reid; January 24, 2002.
Subject: Responses to questions posed in letter of November 26, 2001.
- Letter from Chairman Jared L. Cohon to Senator John Ensign; January 24, 2002.
Subject: Responses to questions posed in letter of November 26, 2001.
- Letter from Congressman John Shimkus to Chairman Jared L. Cohon, December 5, 2001.
Subject: Questions related to the Department of Energy determination of site suitability.
- Letter from Chairman Jared L. Cohon to Congressman John Shimkus; January 24, 2002.
Subject: Responses to questions posed in letter of December 5, 2001.
- Letter from Congressman Joe Barton to Chairman Jared L. Cohon, December 11, 2001.
Subject: Potential health and safety issues at Yucca Mountain.
- Letter from Chairman Jared L. Cohon to Congressman Joe Barton; January 24, 2002.
Subject: Responses to questions posed in letter of November 26, 2001.

United States Senate

WASHINGTON, DC 20510-7012

NOV 29 2001

November 26, 2001

Dr. Jared L. Cohon
Chairman
United States Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

Dear Dr. Cohon:

We are writing in regard to the Department of Energy's (DOE) possible site recommendation for Yucca Mountain, Nevada. The DOE is expected to make a determination by early next year on the suitability of the proposed repository. There are, however, unresolved questions regarding the integrity of DOE's scientific conclusions and procedures for investigating Yucca Mountain. Moving forward with a site recommendation prematurely would threaten Nevadans and would create a hazard for the residents of the 43 states through which the waste will be transported.

As you know, several independent review boards have raised questions about the DOE's investigation of the proposed repository. For example, in your letter of October 16, 2001 to Mr. Lake Barrett, Acting Director of DOE's Office of Civilian Radioactive Waste Management you stated:

"[The Board] believes there are significant problems associated with the technical basis for DOE's base-case repository design, which is a high-temperature design...[T]he Board recommended that the DOE undertake a comparison of the higher- and lower-temperature designs. This comparison does not appear to have been completed."

In addition, the Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste (ACNW) raised concerns about the computer simulation used by the DOE to determine the suitability of the repository. In a September 21, 2001 letter to NRC Chairman Meserve, the ACNW stated:

"The [DOE computer simulation (TSPA-SR)] does not lead to a realistic risk-informed result, and it does not inspire confidence in the TSPA-SR process. In particular, the TSPA-SR reflects the input and results of models and assumptions that are not founded on a realistic assessment of the evidence."

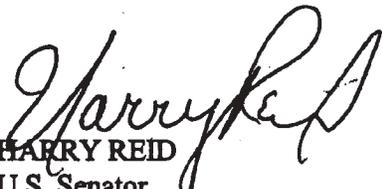
To better understand these and other problems facing the site recommendation process, we would appreciate your responding to the following questions:

1. How strong is the current technical basis for DOE's repository design and for the analysis that support the site recommendation?
2. How confident are you that the current DOE program would lead to a safe repository that protects human health and the environment at Yucca Mountain?
3. Is it premature for the DOE to make a recommendation that the site is suitable for a geologic repository?

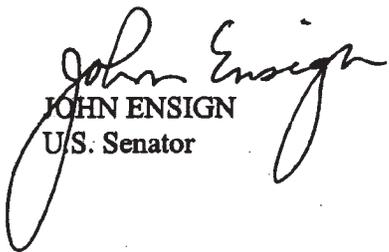
Your response to these questions will help us better identify the problems facing the Yucca Mountain program. Without clear resolution to these problems, the public will lack confidence that a sound scientific process has been followed and that their health and safety have been adequately considered. If you have any questions about our concerns, please contact us.

We appreciate your consideration of our request and look forward to hearing from you.

Sincerely,



HARRY REID
U.S. Senator



JOHN ENSIGN
U.S. Senator

Cc: William D. Barnard

HR:jh



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

December 17, 2001

The Honorable Harry Reid
528 SHOB
Washington, DC 20510-2803

Dear Senator Reid:

Thank you very much for the letter sent by you and Senator John Ensign dated November 26, 2001. Your letter raises several important questions related to the Department of Energy's (DOE) Yucca Mountain site investigation.

As part of its ongoing review of the DOE's site-characterization activities, the Board is evaluating the technical and scientific validity of work that will form the technical basis for a decision by the Secretary of Energy on whether to recommend the Yucca Mountain site for repository development. I have enclosed a copy of a letter sent to Secretary Spencer Abraham indicating that the Board anticipates conveying to him and to Congress the results of the Board's review in the next few weeks. To ensure that all pertinent information is considered in our response, we would like to respond to your letter at the same time.

The Board very much appreciates your continued interest in its ongoing independent technical and scientific review of the Yucca Mountain program. If you have questions, please contact me or have your staff contact William Barnard, the Board's Executive Director.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

December 17, 2001

The Honorable John Ensign
364 SROB
Washington, DC 20510-2805

Dear Senator Ensign:

Thank you very much for the letter sent by you and Senator Harry Reid dated November 26, 2001. Your letter raises several important questions related to the Department of Energy's (DOE) Yucca Mountain site investigation.

As part of its ongoing review of the DOE's site-characterization activities, the Board is evaluating the technical and scientific validity of work that will form the technical basis for a decision by the Secretary of Energy on whether to recommend the Yucca Mountain site for repository development. I have enclosed a copy of a letter sent to Secretary Spencer Abraham indicating that the Board anticipates conveying to him and to Congress the results of the Board's review in the next few weeks. To ensure that all pertinent information is considered in our response, we would like to respond to your letter at the same time.

The Board very much appreciates your continued interest in its ongoing independent technical and scientific review of the Yucca Mountain program. If you have questions, please contact me or have your staff contact William Barnard, the Board's Executive Director.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable Harry Reid
United States Senate
528 SHOB
Washington, DC 20510-2893

Dear Senator Reid:

Enclosed are responses to the questions posed in letter of November 26, 2001 from you and Senator John Ensign. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones, but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
SENATORS HARRY REID AND JOHN ENSIGN
JANUARY 24, 2002

1. How strong is the current technical basis for DOE's repository design and for the analysis that supports the site recommendation?

In evaluating the DOE's technical and scientific work related to individual natural and engineered components of the proposed repository system, the Board finds varying degrees of strength and weakness. Such variability is not surprising, given that the Yucca Mountain project is in many respects a first-of-a-kind, complex undertaking. When the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time. As discussed in the Board's January 24, 2002 letter to Congress and the Secretary of Energy, the Board believes that it is possible to increase confidence in the DOE's projections of repository system performance.

The DOE's estimates of repository performance currently rely heavily on engineered components of the repository system, making corrosion of the waste package very important. High temperatures in the DOE's base-case repository design increase uncertainties and decrease confidence in the performance of waste package materials. Confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.

The Board makes no judgment on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public policy considerations as well as an assessment of how much technical certainty is necessary at various decision points, go beyond the Board's congressionally established mandate.

2. How confident are you that the current DOE program would lead to a safe repository that protects human health and the environment at Yucca Mountain?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. The Board believes, however, that specific activities can and should be pursued to increase confidence in the projections of performance of the proposed repository at Yucca Mountain. Those activities include identifying, quantifying, and communicating clearly the extent of the uncertainty associated with the DOE's performance estimates; comparing and evaluating a low-temperature repository design with the DOE's current base-case high-temperature design; increasing the fundamental understanding of the potential behavior of the proposed repository system; developing multiple lines of evidence; and strengthening arguments about defense-in-depth (or redundancy). The Board also believes that uncertainties related to the performance of waste package materials under high-temperature conditions should be addressed.

The Board's January 24, 2002 letter to Congress and the Secretary of Energy also contains suggestions about new initiatives that the DOE might undertake to increase confidence. Many factors, such as the DOE's ability to improve the integration of scientific and engineering activities, are likely to influence whether those activities can be successfully completed.

3. Is it premature for the DOE to make a recommendation that the site is suitable for a geologic repository?

The timing of a decision on whether the Yucca Mountain site should be recommended or approved for repository development is a judgment involving a number of public policy considerations as well as an assessment of how much technical certainty policy-makers believe is necessary at the time decisions are made. As stated in the answer to question 1, these judgments go beyond the Board's congressionally established mandate.



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable John Ensign
United States Senate
364 SROB
Washington, DC 20510-2805

Dear Senator Ensign:

Enclosed are responses to the questions posed in letter of November 26, 2001 from you and Senator Harry Reid. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
SENATORS HARRY REID AND JOHN ENSIGN
JANUARY 24, 2002

1. How strong is the current technical basis for DOE's repository design and for the analysis that supports the site recommendation?

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3. Is it premature for the DOE to make a recommendation that the site is suitable for a geologic repository?

The timing of a decision on whether the Yucca Mountain site should be recommended or approved for repository development is a judgment involving a number of public policy considerations as well as an assessment of how much technical certainty policy-makers believe is necessary at the time decisions are made. As stated in the answer to question 1, these judgments go beyond the Board's congressionally established mandate.

JOHN M. SHIMKUS
20TH DISTRICT, ILLINOIS

ENERGY AND COMMERCE
COMMITTEE

SUBCOMMITTEES

ENVIRONMENT AND HAZARDOUS
MATERIALS
Vice Chairman

ENERGY AND AIR QUALITY
TELECOMMUNICATIONS

COMMERCE, TRADE, AND CONSUMER
PROTECTION

BALTIC CAUCUS
Co-Chairman

www.house.gov/hshimkus

Congress of the United States
House of Representatives
Washington, DC 20515-1320

513 CANNON BUILDING
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(202) 225-5271

3130 CHATHAM RD., SUITE
SPRINGFIELD, IL 62704
(217) 492-5090

508 WEST MAIN STREET
COLLINGSVILLE, IL 62234
(618) 344-3066

221 EAST BROADWAY, SUITE
CENTRALIA, IL 62801
(618) 552-8676

December 5, 2001

The Honorable Jared L. Cohon
Chair, U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

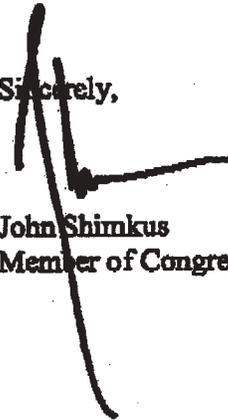
Dear Dr. Cohon:

First, I would like to thank you for the work you have been doing in Nevada to discuss the status of Yucca Mountain site characterization over the last few months. I have had the pleasure of visiting Yucca Mountain in the past and have seen the research and the science that has gone into studying whether this site would be an appropriate nuclear waste repository or not. As you may be aware, I am from the State of Illinois, which is home to the most nuclear power plants in the nation. So this issue is a concern to many in my state.

Second, I have a question that I was hoping you, or your staff, could answer for me. Are you aware of any technical issues or concerns applicable to the site recommendation phase of the Yucca Mountain Project, that directly and negatively impact human health and safety, that could not be mitigated prior to the closure of the repository, which under the current design would occur 100-300 years after its opening?

I look forward to hearing the answer to this question. If should have any questions, please feel free to contact me, or my staff, at your convenience.

Sincerely,



John Shimkus
Member of Congress



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable John Shimkus
Committee on Energy and Commerce
U.S. House of Representatives
Rayburn House Office Building
Washington, DC 20515-1320

Dear Mr. Shimkus:

Enclosed are responses to the questions posed in your letter of December 5, 2001. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
REPRESENTATIVE JOHN SHIMKUS
JANUARY 24, 2002

Are you aware of any technical issues or concerns applicable to the site recommendation phase of the Yucca Mountain Project, that directly and negatively impact human health and safety, that could not be mitigated prior to the closure of the repository, which under current design, would occur 100-300 years after its opening?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. However, the DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model. This is not an assessment of the Board's level of confidence in the Yucca Mountain site.

The Board believes that confidence in performance estimates can be increased. Future scientific investigations may show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. It is impossible to know with absolute certainty whether issues or concerns that cannot be mitigated might arise in the future. This would be the case at any potential repository site.

JOE BARTON
6TH DISTRICT, TEXAS

2284 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-4306
(202) 225-2002

REPUBLICAN STEERING COMMITTEE
REGIONAL REPRESENTATIVE



COMMITTEE ON
ENERGY AND COMMERCE
SUBCOMMITTEES:
CHAIRMAN, ENERGY AND AIR QUALITY
TELECOMMUNICATIONS AND THE INTERNET
HEALTH

COMMITTEE ON SCIENCE
SUBCOMMITTEE:
SPACE AND AERONAUTICS

Congress of the United States
House of Representatives
Washington, DC 20515-4306

December 11, 2001

DEC 18 2001

The Honorable Jared L. Cohon, Ph.D.
Chairman
United States Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Suite 1300
Arlington, Virginia 22201

Dear Dr. Cohon:

As you know, the safe and permanent disposal of high-level nuclear waste is a matter of significant importance for all the citizens of this nation. We noted with great interest the letter you recently received from two of our colleagues in the Senate, Harry Reid and John Ensign of Nevada, asking for the Board's views on certain aspects of the expected Yucca Mountain repository site recommendation decision. The House Energy and Air Quality Subcommittee is also significantly interested in the scientific basis for this decision. We are writing to join Senator's Reid and Ensign in enquiring about the Board's scientific views.

Most of us in Congress have been greatly encouraged by the scientific progress made by the Department of Energy in recent years. We understand that DOE's scientific results have been subject to a significant amount of review by both the public and scientific organizations such as the Board. The preponderance of the scientific information appears to indicate that the proposed repository site is or can be suitable for the protection of public health and safety. A peer review panel of the International Atomic Energy Agency, requested by DOE in consultation with the Board, recently concluded that DOE's approach is "soundly based and has been implemented in a competent manner" and that this approach "provides an adequate basis for supporting a statement on likely compliance within the regulatory period of 10,000 years and, accordingly, for the site recommendation decision."

However, since the Board has raised a number of concerns about DOE's repository development efforts at Yucca Mountain, we would like to join our colleagues from Nevada and, to gain a greater sense of perspective regarding the Board's concerns, ask for the Board's views on two additional questions:

ARLINGTON OFFICE:
805 WASHINGTON DRIVE, SUITE F
ARLINGTON, TX 76011

ENNIS OFFICE:
303 WEST KNOX, SUITE 201
ENNIS, TX 75119-3942
817-543-1000 (main number for all offices)
Homepage: <http://www.house.gov/barton/welcome.html>

FORT WORTH OFFICE:
4521 SOUTH HULEN STREET,
SUITE 210
FORT WORTH, TX 76109

1. Does the Board have any reason to believe that the site currently being studied at Yucca Mountain could not be made suitable for the development of a repository? If so, please explain any such reason(s).
2. What improvements can DOE make in its research and design that would improve the effectiveness of a repository at that location? In keeping with the "step-wise repository development" approach recommended by the National Academy of Sciences, how can such improvements best be phased into the evolving repository design?

In asking these questions we would like to emphasize the importance that the Board's rigorous scientific review plays in this process. DOE's scientific program has been greatly strengthened by the Board's inquiry. If a decision is made to move to the next step in the repository development process at Yucca Mountain, consideration of a NRC license to construct and operate a repository, we expect that the Board will continue to provide an active, highly informed, and politically unbiased review.

We appreciate your consideration of this request and look forward to hearing from you.

Sincerely,



Joe Barton
Member of Congress

JB:sw

c: The Honorable Spencer Abraham
The Honorable Richard Meserve



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable Joe Barton
Chairman
Subcommittee on Energy and Power
Committee on Energy and Commerce
U.S. House of Representatives
Room 2125, Rayburn House Office Building
Washington, DC 20515-6115

Dear Mr. Barton:

Enclosed are responses to the questions posed in your letter of December 11, 2001. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
REPRESENTATIVE JOE BARTON
JANUARY 24, 2002

1. Does the Board have any reason to believe that the site currently being studied at Yucca Mountain could not be made suitable for the development of a repository? If so, please explain any such reason(s)?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. However, the DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model. This is not an assessment of the Board's level of confidence in the Yucca Mountain site.

The Board believes that confidence in performance estimates can be increased. Future scientific investigations may show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. It is impossible to know with absolute certainty whether issues or concerns that cannot be mitigated might arise in the future. This would be the case at any potential repository site.

2. What improvements can DOE make in its research and design that would improve the effectiveness of a repository at that location? In keeping with the "step-wise repository development" approach recommended by the National Academy of Sciences, how can such improvements best be phased into the evolving repository design?

If policy-makers decide to approve the Yucca Mountain site, the Board strongly recommends that in addition to demonstrating regulatory compliance, the DOE continue a vigorous well-integrated scientific investigation to increase its fundamental understanding of the potential behavior of the repository system. The Board believes, in addition, that specific activities can and should be pursued to increase confidence in the projections of performance of the proposed repository at Yucca Mountain. Those activities include systematically integrating new data and analyses produced by ongoing scientific and engineering investigations; identifying, quantifying, and communicating clearly the extent of the uncertainty associated with its performance estimates; comparing and evaluating a low-temperature repository design with the DOE's current base-case high-temperature design; increasing the fundamental understanding of the potential behavior of the proposed repository system; developing multiple lines of evidence; and strengthening arguments about defense-in-depth (or redundancy). The Board also believes that uncertainties related to the performance of waste package materials under high-temperature conditions should be addressed.

The Board has not evaluated the implications of a “step wise” approach to repository development. However, in its January 24, 2002 letter to Congress and the Secretary of Energy, the Board suggests several new actions that should be considered if policy-makers approve the Yucca Mountain site, regardless of the development approach used. The actions include monitoring repository performance before, during, and after waste emplacement; developing a strategy for modifying or stopping repository development if potentially significant unforeseen circumstances are encountered; and continuing external review of the DOE’s technical and scientific activities. The Board notes that the National Academy of Sciences (NAS) is scheduled soon to release a preliminary report describing the advantages and disadvantages of applying a step wise approach specifically to the development of a repository at Yucca Mountain. As part of its ongoing evaluation, the Board will review the technical and scientific validity of any plans that the DOE adopts in response to the NAS report.

Appendix G

U.S. Nuclear Waste Technical Review Board Fiscal Year 2002-2007 Strategic Plan

Statement of the Chairman

The U.S. Nuclear Waste Technical Review Board was established as an independent agency of the United States Government on December 22, 1987, in the Nuclear Waste Policy Amendments Act. Congress charged the Board with evaluating the technical and scientific validity of activities undertaken by the Secretary of Energy, including characterizing a site at Yucca Mountain, Nevada, for its suitability as the location of a permanent repository for civilian spent nuclear fuel and high-level radioactive waste. The Board also reviews activities related to packaging and transporting such waste. In creating the Board, Congress realized that an unbiased technical and scientific evaluation of the credibility of site evaluation and other high-level radioactive waste management activities would be crucial to public acceptance of any approach for disposing of the waste.

The Board strives to provide Congress and the Secretary of Energy with completely independent, credible, and timely technical and scientific program evaluations and recommendations achieved through peer review of the highest quality. The Board's technical and scientific findings and

recommendations are included in reports that are submitted at least twice each year to the Secretary of Energy and Congress. The Board can make recommendations but cannot compel the Department of Energy to comply.

The attached strategic plan includes the Board's goals and objectives for 2002 through 2007. *If* the site is approved for repository development, much important technical and scientific work related to gaining a better understanding of potential repository performance will continue. In addition, the Department of Energy will need to finalize a repository design, establish a program for confirming projections of repository performance, and develop and implement plans for a waste management system, including transportation and packaging of the waste. Because many crucial technical and scientific decisions will be made throughout this period, we believe that the Board's ongoing independent technical and scientific review of these efforts will continue to be critically important.

On behalf of the Board,

Jared L. Cohon
Chairman

Mission

The Board's mission, established in the Nuclear Waste Policy Amendments Act (NWPAA) of 1987 (Public Law 100-203), is to "... evaluate the technical and scientific validity of [high-level radioactive waste management] activities undertaken by the Secretary of Energy, including site-characterization activities; and activities related to the packaging or transportation of high-level radioactive waste and spent nuclear fuel." By law, the Board shall cease to exist not later than one year after the date on which the Secretary begins disposal of high-level radioactive waste or spent nuclear fuel in a repository.

Vision

By performing ongoing technical and scientific review and evaluation of the highest quality, the Board makes a unique and essential contribution to the Secretary of Energy's efforts to implement the Nuclear Waste Policy Act (NWPA). If the recommendation of the site is approved, the Board will continue to perform critical technical and scientific peer review of technical and scientific work related to gaining a basic understanding of the potential performance of the Yucca Mountain site, of performance-confirmation work and repository design efforts, and of activities related to the waste management system, including transportation and packaging of the waste.

Values

To achieve its goals, the Board conducts itself according to the following values:

- The Board strives to ensure that its members and staff have no conflicts of interest—real or perceived—related to the Secretary's efforts to characterize the Yucca Mountain site or to package and transport spent nuclear fuel and high-level radioactive waste.

- The Board members arrive at their conclusions on the basis of objective evaluations of the technical and scientific validity of the Secretary's activities.
- The Board's practices and procedures are open and conducted so that the Board's integrity and objectivity are above reproach.
- The Board's findings and recommendations are technically and scientifically sound and are based on the best available technical analysis and information.
- The Board's findings and recommendations are communicated clearly and in time for them to be most useful to Congress, the Secretary, and the public. The Board encourages public discussion of its findings and recommendations at its meetings.

The NWTRB's General Goals and Strategic Objectives

The national goal for radioactive waste management established by Congress in the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 is safe disposal of civilian spent nuclear fuel and high-level radioactive waste in a permanent geologic repository at a suitable site or sites. In the acts, Congress directed the U.S. Department of Energy (DOE) to characterize a site at Yucca Mountain, Nevada, to determine its suitability as the potential location of a permanent repository for spent nuclear fuel and high-level radioactive waste. Congress charged the U.S. Nuclear Waste Technical Review Board with reviewing the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA, including characterizing the Yucca Mountain site and packaging and transporting the waste. The Board's general goals have been established in accordance with its congressional mandate.*

* In February 2002, the Secretary of Energy and the President recommended the Yucca Mountain site for repository development. If the State of Nevada disapproves the recommendation, Congress will debate a "Resolution of Approval" later this year. The Board's goals and objectives will be revised to reflect the outcome of these deliberations.

General Goals

To accomplish its congressional mandate, the Board has established four general goals.

1. Ensure that technical and scientific activities undertaken by the DOE related to characterizing and analyzing the natural components of a potential Yucca Mountain repository and predicting the performance of a potential repository establish a sound technical basis for a decision on whether to recommend the site for repository development.
2. Ensure that technical and scientific activities undertaken by the DOE related to evaluating and designing the repository and waste packages are well integrated and establish a sound technical basis for designing the repository system, including the engineered barrier system (EBS).
3. Ensure that technical and scientific activities undertaken by the DOE related to packaging, handling, and transporting spent nuclear fuel and high-level radioactive waste to a potential repository are well integrated and establish a sound technical basis for designing and operating a waste management system.
4. Ensure that technical and scientific performance-confirmation activities undertaken by the DOE establish a sound technical basis for operating a repository, reducing uncertainties related to repository performance, and revising repository and waste package designs. (Will apply only if the site recommendation is approved.)

Strategic Objectives

To achieve its general goals, the Board has established the following long-term objectives.

1. Objectives Related to the Natural Components of the Repository System and Predicting Repository Performance

- 1.1. Evaluate the technical and scientific validity of DOE studies, testing, and analyses supporting a decision on whether to recommend the Yucca Mountain site.

- 1.2. Evaluate the analyses and investigations pertaining to hydrologic and other natural processes at the Yucca Mountain site and at related analogue sites that establish the foundation for predicting repository performance.
- 1.3. Review the technical and scientific validity of models used to predict repository performance.
- 1.4. Evaluate the DOE's progress in developing a safety strategy for the Yucca Mountain site.
- 1.5. Monitor progress in completing development of standards and regulatory guidelines for a potential Yucca Mountain repository.
- 1.6. Review the *Record of Decision* and maintain awareness of legal challenges to the final environmental impact statement (EIS) for a potential Yucca Mountain repository.

2. Objectives Related to the Engineered Components of the Repository System

- 2.1. Evaluate repository and waste package designs, including the technical bases for the designs.
- 2.2. Review the progress or results of materials testing being conducted to address uncertainties about waste package performance.
- 2.3. Assess the integration of science and engineering in the DOE program, paying particular attention to the effects of site-characterization studies (e.g., modeling, testing, and analyses of thermal and mechanical effects) on repository and waste package designs.

3. Objectives Related to the Waste Management System

- 3.1. Evaluate the accuracy and reasonableness of analyses, methods, and major assumptions used by the DOE in estimating health and safety risks associated with transporting spent nuclear fuel and high-level radioactive waste.
- 3.2. Review the adequacy of DOE plans for developing the transportation infrastructure and deter-

mine the effort needed to develop a large-scale transportation capability.

- 3.3. Review the adequacy of the DOE's plans for safely handling and packaging spent nuclear fuel and high-level radioactive waste for transport to a permanent repository.
- 3.4. Evaluate the effectiveness of the DOE's efforts to integrate the various components of the waste management system (packaging, handling, transport, storage, and disposal of the waste).
- 3.5. Review the DOE's plans for addressing public safety concerns and for enhancing safety capabilities along transportation corridors. This includes activities related to development of plans (e.g., route selection), coordination, accident prevention (e.g., improved inspections and enforcement), and emergency response.

*4. Objectives Related to Confirmatory Testing
(Will apply only if the site recommendation is approved)*

- 4.1. Monitor performance-confirmation activities, including performance-confirmation planning, undertaken by the DOE that are designed to reduce uncertainties related to repository performance.
- 4.2. Monitor performance-confirmation activities undertaken by the DOE, and evaluate the need to revise repository or waste package designs on the basis of the results of such activities.

Achieving the Goals and Objectives

Congress granted significant investigatory powers to the Board in the NWPAA. In accordance with the NWPAA, the Board may hold such hearings, sit and act at such times and places, take such testimony, and receive such evidence as it considers appropriate. By law, no nominee to the Board is employed by the DOE, the national laboratories, or DOE contractors performing activities related to spent nuclear fuel or high-level radioactive waste. The Board has adopted strong procedures that go even further to ensure that the Board avoids even the appearance of a conflict of interest.

Subject to existing law, the DOE is directed to provide all records, files, papers, data, and information requested by the Board, including drafts of work products and documentation of work in progress. According to the legislative history, in providing this access, Congress expected that the Board would review and comment on DOE decisions, plans, and actions as they occurred, not after the fact. The Board believes that it has adequate powers under current law to achieve its goals and objectives.

Much of the Board's information-gathering is done at open public meetings where the DOE, its contractors, and other program participants present technical information. The Board's five panels meet as needed and are organized around specific issue areas. The full Board meets three or four times each year. The Board also gathers information through field trips to the Yucca Mountain site, visits to contractor laboratories and facilities, and informal meetings with individuals working on the project. Although the Board's information-gathering activities are carried out primarily to further the Board's review, they have the collateral benefit of promoting communication and integration of technical information within the DOE program and facilitating the dissemination of information among interested parties outside the program. Analyses of the information gathered by the Board are performed by its members, the Board's professional staff, and consultants hired to supplement the expertise of the Board and the staff.

In February 2002, the Secretary of Energy recommended the Yucca Mountain site for repository development to the President. The President then recommended the site. The State of Nevada will now decide whether to disapprove the recommendation. If the recommendation is approved, the DOE will eventually apply to the Nuclear Regulatory Commission (NRC) for a license to construct and operate a repository at the site. If the license is approved, the expectation is that testing will continue at the site to increase confidence in predictions of repository performance. The Board has reviewed the analytical processes as well as the technical information used by the DOE in making decisions about site recommendation. The Board also will review the technical and scientific validity of activities related to confirmatory testing and to transportation and

packaging of spent nuclear fuel and high-level radioactive waste. The Board reports the results of its reviews at least twice each year to Congress and the Secretary of Energy. Additional communication occurs as needed. Such communications are available to the public either by request or on the Board's Web site at www.nwtrb.gov.

Crosscutting Functions

Several entities and agencies share responsibility for the ultimate national goal established by Congress of packaging, transporting, and disposing of spent nuclear fuel and high-level radioactive waste in a geologic repository at a suitable site. Although there may be cross-cutting areas of interest, the Board's role is unique among those involved in managing high-level radioactive waste. For example:

- **Congress and the Administration, including the Secretary of Energy**, make policy decisions on what the national goals will be and how they will be implemented. The Board's role in this process is to help ensure that policy-makers receive unbiased and credible technical and scientific analyses and information.
- **State and local governments** comment on and oversee DOE activities. The Board's oversight activities are different in that they are (1) unconstrained by any stake in the outcome of the endeavor besides the credibility of the scientific and technical activities, (2) confined to scientific and technical evaluations, and (3) conducted by individuals nominated by the National Academy of Sciences and expressly chosen by the President for their expertise in the various disciplines represented in the DOE program.
- **Federal agencies** that have roles in achieving a safe waste management program include the DOE, the NRC, the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the United States Geological Survey (USGS). The DOE is responsible for developing and implementing the waste management system and for planning and conducting research activities related to disposal, packaging, and transportation of spent

nuclear fuel and high-level radioactive waste. The NRC is the regulatory body authorized to license the construction and operation of the repository to ensure protection of public health and safety and the environment. The EPA is the agency given the responsibility to issue health-based safety standards. The DOT is responsible for regulating the transportation of the waste. The USGS participates in site-characterization activities at the Yucca Mountain site. The Board's role is unique among these federal agencies: perform ongoing, independent review and oversight of the technical and scientific validity of the Secretary of Energy's activities relating to civilian radioactive waste management, including site characterization and packaging and transportation of spent nuclear fuel and high-level radioactive waste, and communicate its findings and recommendations to Congress, the Secretary of Energy, and the public. The Board's evaluation of the technical and scientific validity of the Secretary's activities related to civilian radioactive waste management complements and enhances the work of other agencies involved in achieving the national goal.

Key External Factors

Some factors that are beyond the Board's control could affect its ability to achieve its goals and objectives. Among them are the following:

- **The Board has no implementing authority.** The Board is by statute a technical and scientific review body that can only make recommendations to the DOE. Congress expected that the DOE would accept the Board's recommendations or indicate why the recommendations could not or should not be implemented. However, the DOE is not legally obligated to accept any of the Board's recommendations.

To increase its effectiveness, the Board has developed procedures for increasing the relevance of its findings and recommendations for Congress, the Secretary, DOE program managers, and the public. The Board's recommendations and the DOE's responses are included in Board reports to Congress and the Secretary. If the DOE does not accept

a Board recommendation, the Board's recourse is to advise Congress or reiterate its recommendation to the DOE, or both.

- Legislation could affect nuclear waste policy. Congress has considered nuclear waste legislation several times in the last few years. The effects of such legislation, if enacted, on the program or the Board's activities are not currently known.

The Board will evaluate the status of these external factors, identify any new factors, and, if warranted, modify the "external factors" section of the strategic plan as part of the annual program evaluation described below.

Evaluating Board Performance

The Board believes that measuring its effectiveness by directly correlating improvements in the DOE program with Board actions and recommendations would be ideal. However, the Board has no implementing authority, so it cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program is, in most cases, (1) subjective and (2) an imprecise indicator of Board performance because implementation of Board recommendations by the DOE is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

- Were the reviews, evaluations, and other activities undertaken under the auspices of the goal completed?

- Were the results of the reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures are met, the Board's performance in meeting the annual goal will be judged effective. If only one measure is met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal.

The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to establish its annual performance objectives and develop its budget request for subsequent years. The results of the Board's performance evaluation are included in its annual summary report.

Congressional and Stakeholder Consultations

In developing its original strategic plan, the Board consulted with the Office of Management and Budget, the DOE, congressional staff, and members of the public and provided a copy of the plan to the NRC and to representatives of state and local governments. The Board solicited public comment and presented its strategic plan at a session held expressly for this purpose during a meeting in Amargosa Valley, Nevada, on January 20, 1998. Copies of the Board's strategic plan and annual performance plans are available on the Board's Web site: www.nwtrb.gov.

Appendix H

U.S. Nuclear Waste Technical Review Board Fiscal Year 2001 Performance Plan and Performance Evaluation

The NWTRB's General Goals and Strategic Objectives

The national goal for radioactive waste management established by Congress in the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 is safe disposal of civilian spent nuclear fuel and high-level radioactive waste in a permanent geologic repository at a suitable site or sites. In the acts, Congress directed the U.S. Department of Energy (DOE) to characterize a site at Yucca Mountain, Nevada, to determine its suitability as the potential location of a permanent repository for spent nuclear fuel and high-level radioactive waste. Congress charged the U.S. Nuclear Waste Technical Review Board with reviewing the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA, including characterizing the Yucca Mountain site and packaging and transporting the waste. The Board's general goals have been established in accordance with its congressional mandate.*

General Goals

To accomplish its congressional mandate, the Board has established four general goals.

1. Ensure that technical and scientific activities undertaken by the DOE related to characterizing and analyzing the natural components of a potential Yucca Mountain repository and predicting the performance of a potential repository establish a sound technical basis for a decision on whether to recommend the site for repository development.
2. Ensure that technical and scientific activities undertaken by the DOE related to evaluating and designing the repository and waste packages are well integrated and establish a sound technical basis for designing the repository system, including the engineered barrier system (EBS).
3. Ensure that technical and scientific activities undertaken by the DOE related to packaging, handling, and transporting spent nuclear fuel and high-level radioactive waste to a potential repository are well integrated and establish a sound technical basis for designing and operating a waste management system.
4. Ensure that technical and scientific performance-confirmation activities undertaken by the DOE establish a sound technical basis for operating a repository, reducing uncertainties related to repository performance, and revising repository

* In February 2002, the Secretary of Energy and the President recommended the Yucca Mountain site for repository development. If the State of Nevada disapproves the recommendation, Congress will debate a "Resolution of Approval" later this year. The Board's goals and objectives will be revised to reflect the outcome of these deliberations.

and waste package designs. (Will apply only if the site recommendation is approved.)

Strategic Objectives

To achieve its general goals, the Board has established the following long-term objectives.

1. Objectives Related to the Natural Components of the Repository System and Predicting Repository Performance

- 1.1. Evaluate the technical and scientific validity of DOE studies, testing, and analyses supporting a decision on whether to recommend the Yucca Mountain site.
- 1.2. Evaluate the analyses and investigations pertaining to hydrologic and other natural processes at the Yucca Mountain site and at related analogue sites that establish the foundation for predicting repository performance.
- 1.3. Review the technical and scientific validity of models used to predict repository performance.
- 1.4. Evaluate the DOE's progress in developing a safety strategy for the Yucca Mountain site.
- 1.5. Monitor progress in completing development of standards and regulatory guidelines for a potential Yucca Mountain repository.
- 1.6. Review the *Record of Decision* and maintain awareness of legal challenges to the final environmental impact statement (EIS) for a potential Yucca Mountain repository.

2. Objectives Related to the Engineered Components of the Repository System

- 2.1. Evaluate repository and waste package designs, including the technical bases for the designs.
- 2.2. Review the progress or results of materials testing being conducted to address uncertainties about waste package performance.

- 2.3. Assess the integration of science and engineering in the DOE program, paying particular attention to the effects of site-characterization studies (e.g., modeling, testing, and analyses of thermal and mechanical effects) on repository and waste package designs.

3. Objectives Related to the Waste Management System

- 3.1. Evaluate the accuracy and reasonableness of analyses, methods, and major assumptions used by the DOE in estimating health and safety risks associated with transporting spent nuclear fuel and high-level radioactive waste.
- 3.2. Review the adequacy of DOE plans for developing the transportation infrastructure and determine the effort needed to develop a large-scale transportation capability.
- 3.3. Review the adequacy of the DOE's plans for safely handling and packaging spent nuclear fuel and high-level radioactive waste for transport to a permanent repository.
- 3.4. Evaluate the effectiveness of the DOE's efforts to integrate the various components of the waste management system (packaging, handling, transport, storage, and disposal of the waste).
- 3.5. Review the DOE's plans for addressing public safety concerns and for enhancing safety capabilities along transportation corridors. This includes activities related to development of plans (e.g., route selection), coordination, accident prevention (e.g., improved inspections and enforcement), and emergency response.

4. Objectives Related to Confirmatory Testing (Will apply only if the site recommendation is approved)

- 4.1. Monitor performance-confirmation activities, including performance-confirmation planning, undertaken by the DOE that are designed to reduce uncertainties related to repository performance.
- 4.2. Monitor performance-confirmation activities undertaken by the DOE, and evaluate the need to revise repository or waste package designs on the basis of the results of such activities.

Performance Goals for FY 2001

The Board's performance goals for FY 2001 have been developed to further the achievement of the Board's general goals and strategic objectives. Because some of the general goals and strategic objectives relate to work and activities that will be undertaken in the future, they may not have corresponding annual performance goals in any given year. For example, the following performance goals for FY 2001 relate primarily to DOE activities supporting a DOE decision on whether to recommend the Yucca Mountain site to the President, the design of a potential repository and waste package, and transportation planning.

1. Performance Goals Related to the Natural Components of the Repository System and Predicting Repository Performance

Performance Goals

- 1.1.1. Review for technical validity the technical and scientific components of the DOE site recommendation report.
- 1.1.2. Review for technical validity the technical and scientific components of the DOE site recommendation "notification document."
- 1.1.3. Review for technical validity the technical components of the DOE site recommendation "consideration document."
- 1.1.4. Evaluate the DOE's use of risk assessment and quantification of uncertainty, and determine whether they are being used appropriately.
- 1.2.1. Monitor the results of flow-and-transport studies being conducted to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.
- 1.2.2. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block (ECRB) at Yucca Mountain.
- 1.2.3. Evaluate results of the fluid inclusion study.
- 1.3.1. Set priorities among and evaluate for technical validity the DOE process model reports that will be used to support a decision on site recommendation.
- 1.3.2. Determine the strengths and weaknesses of the total system performance assessment (TSPA) and recommend additional measures used to strengthen the DOE's repository safety case.
- 1.4.1. Determine the appropriateness of the "principal factors" identified by the DOE in its safety strategy.
- 1.4.2. On the basis of an evaluation of the natural processes at work at the Yucca Mountain site, recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distribution of water seepage into the proposed repository.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, TSPA, and the site recommendation.
- Meeting with contractor's principal investigators on technical issues, including those related to climate change, flow and transport in the unsaturated and saturated zones, seepage, and the biosphere.
- Holding public meetings with the DOE and contractor personnel at least three times a year involving the full Board and several meetings with individual Board panels.
- Visiting and observing ongoing laboratory investigations, including facilities at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratory, and the engineered barrier test facility; observing field investigations, including the niche, alcove, and sealed ECRB studies and Busted Butte.

- Meeting with other entities carrying out research on, or providing input to, scientific and technical issues related to waste disposal, including the Nuclear Regulatory Commission and its contractors, the Southwest Research Institute, The Nye County Early Warning Drilling Program, the University of Nevada at Las Vegas project on fluid inclusions, the Environmental Protection Agency, and the State of Nevada Nuclear Waste Projects Office.

2. Performance Goals Related to the Engineered Repository System and Strategy for Achieving Performance Goals

Performance Goals

- 2.1.1. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.
- 2.1.2 Evaluate the extent to which the DOE is using the technical bases for developing repository and waste package designs.
- 2.1.3. Monitor and evaluate the DOE's progress in developing a technical basis for modified or novel design features.
- 2.2.1. Evaluate the adequacy for a site recommendation decision of corrosion studies on materials being proposed for the EBS.
- 2.3.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package. In particular, monitor the results of ongoing thermal tests and evaluate DOE plans for using the test results to support models of the thermally disturbed region near the repository and to decide on spacing between emplacement drifts, degree of preclosure ventilation, and closure date.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Evaluating the technical bases for the EBS design by reviewing technical documents and databases

(e.g., the controlled design assumption document and the technical database), paying particular attention to the technical bases for making and inspecting final closure welds of the waste package and methods for making drip shield sections. Meetings will be held with project personnel as necessary to obtain clarification and confirmation.

- Evaluating the technical bases for repository design by reviewing federal documents and databases, paying particular attention to design features for promoting drainage, controlling ventilation, and protecting workers in the exhaust end of the ventilation system.
- Evaluating repository and waste package designs to identify which parts (if any) of the designs do not have a technical basis.
- Evaluating the DOE's technical program to fill in the gaps. In addition, where the DOE is working on alternative design features, the Board will evaluate the technical basis of these features.
- After identifying the corrosion mechanisms most important to performance of the overall repository system, reviewing the common database (literature, laboratory, and field data) and judging the adequacy of the database for a site recommendation decision.

3. Performance Goals Related to the Waste Management System and Strategy for Achieving Performance Goals

Performance Goals

- 3.1.1. Evaluate storage cask and container designs to ascertain whether there is a sufficient technical basis for predicting potential problems that could develop during storage and that could affect the performance of the spent fuel during subsequent repository disposal.
- 3.1.2. Evaluate storage cask and container designs to ascertain whether there is a sufficient technical basis for predicting potential problems that could develop during storage and that could affect the performance of the spent fuel during subsequent repository disposal.

- 3.2.1. Evaluate the effects of “off-normal” events at the surface facility and how the events could affect the ability of the facility to receive waste shipments.
- 3.2.2. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.
- 3.3.1. Examine the ability of storage casks and containers, including multipurpose canisters, to serve as disposal casks and containers in a repository.
- 3.4.1. Monitor progress by the railroad industry in implementing new technologies that would enhance the safety of spent-fuel transportation (e.g., electronic braking, wheel-bearing monitoring). Evaluate how well the DOE works with the railroad industry to design an integrated cask-rail and car-train transportation system that would ensure maximum safety and efficiency.
- 3.4.2. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.
- 3.4.3. Evaluate the DOE’s plans for enhancing safety capabilities along transportation corridors and review the DOE’s planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Meeting with the American Association of Railroads (AAR), individual railroad companies, and railroad infrastructure manufacturers to determine the current state of rail infrastructure and noting the effects of a sustained transportation campaign on the railroad industry. The Board will monitor the construction of a short-line rail line currently under construction in Minnesota as an

analogue to a possible rail line in Nevada from a main line to a repository at Yucca Mountain.

- Continuing to meet with the AAR to keep up to date on the work they are doing related to their performance specification for shipping radioactive waste, and meeting with AAR personnel at the AAR Technology Center in Pueblo, Colorado.
- Attending the semiannual DOE-sponsored Transportation External Coordination Working Group meetings to determine how well the DOE is working to implement Section 180 (c) of the Nuclear Waste Policy Act.
- Holding a meeting of the Board’s Panel on the Waste Management System.

4. Performance Goal Related to Performance Confirmation and Strategy for Achieving the Goal

Performance Goal

- 4.1.1. Monitor the DOE’s proposed performance-confirmation plans to help ensure that uncertainties identified as part of the site recommendation process are considered in the formulation of those plans.

Strategy for Achieving Goal

The Board will accomplish its goal by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, TSPA, and the site recommendation.
- Reviewing performance-confirmation plans and meeting with DOE personnel to discuss aspects of the plans.

Board Operations

The Board is composed of 11 members appointed by the President who serve on a part-time basis; are eminent in a relevant field of science or engineering,

including environmental sciences; and are appointed solely on the basis of distinguished service. Because of the comprehensive nature of the program and the part-time availability of the members, Congress authorized the Board to maintain a small professional staff of 10 full-time employees to support the Board's comprehensive review of the DOE program. In addition to the members and professional staff, the Board maintains a small administrative staff that supports its activities.

The full Board meets three or four times each year. The Board has organized itself into panels that meet as needed. The Board also gathers information from field trips to the Yucca Mountain site, visits to contractor laboratories and facilities, and informal meetings with individuals working on the project. The Board has gained insights from visiting other countries to learn about their nuclear waste management programs. On the basis of the information gathered throughout the year, the Board issues its findings in letters and reports.

Evaluating the Board's Performance

The Board believes that measuring its effectiveness by directly correlating improvements in the DOE program with Board actions and recommendations would be ideal. However, the Board has no implementing authority, so it cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program is, in most cases, (1) subjective and (2) an imprecise indicator of Board performance because implementation of Board recommendations by the DOE is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

1. Were the reviews, evaluations, and other activities undertaken under the auspices of the goal completed?
2. Were the results of the reviews, evaluations, and other activities communicated in a timely, under-

standable, and appropriate way to Congress and the Secretary of Energy?

If both measures are met, the Board's performance in meeting the annual goal will be judged effective. If only one measure is met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal.

The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to establish its annual performance objectives and develop its budget request for subsequent years. The results of the Board's performance evaluation are included in its annual summary report.

Performance Evaluation for 2001

On the basis of the following evaluation and consistent with the performance measures described in the previous section, the Board's performance for 2001 related to site investigations and other activities undertaken by the Secretary in preparation for a decision on site recommendation was found effective. However, the Secretary's activities related to transportation and packaging of spent fuel and high-level radioactive waste were extremely limited during 2001. Therefore, the Board's performance goals related to the waste management system are deferred until the Secretary of Energy undertakes technical and scientific work in this area.

1. Performance Goals Related to the Natural Components of the Repository System and Predicting Repository Performance

1.1.1. Review for technical validity the technical and scientific components of the DOE site recommendation report.

- Evaluation of 1.1.1: The Board met in November 2001 to begin a comprehensive review of work conducted by the DOE related to a site recommendation. The Board's

review included the results of the Board's ongoing review of the DOE's Yucca Mountain technical and scientific investigations since the Board's inception; an evaluation of the DOE's work on the natural and engineered components of the proposed repository system, using a list of technical questions identified by the Board; a comprehensive Board review of draft and final documents supplied by the DOE through mid-November 2001; and field observations by Board members at Yucca Mountain and related sites.

1.1.2. Review for technical validity the technical and scientific components of the DOE site recommendation "notification document."

- Evaluation of 1.1.2: All documents supplied to the Board by the DOE before the DOE's notification to the State of Nevada that the Secretary of Energy would recommend the site were reviewed by the Board (see evaluation of 1.1.1).

1.1.3. Review for technical validity the technical components of the DOE site recommendation "consideration document."

- Evaluation of 1.1.3: All documents supplied to the Board by the DOE before the DOE's notification to the State of Nevada that the Secretary of Energy would recommend the site were reviewed by the Board (see evaluation of 1.1.1).

1.1.4. Evaluate the DOE's use of risk assessment and quantification of uncertainty, and determine whether they are being used appropriately.

- Evaluation of 1.1.4: After conducting its comprehensive review, the Board concluded that when the DOE's technical and scientific work is taken as a whole, at this time the technical basis for the DOE's repository performance estimates is weak to moderate. The Board further found that gaps in data and basic understanding cause important uncertainties in the concepts and

assumptions on which the DOE's performance estimates are now based. As part of its evaluation, the Board found that the DOE's efforts to quantify uncertainties had improved but are incomplete and recommended that the DOE implement suggestions proposed in a DOE contractor report titled *Uncertainty Analysis and Strategy*. The Board commented in letters dated March 30, 2001, and July 17, 2001, to the acting director of the Office of Civilian Radioactive Waste Management (OCRWM) on the DOE's progress in identifying and quantifying uncertainties associated with its estimates of repository performance.

1.2.1. Monitor the results of flow-and-transport studies being conducted to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.

- Evaluation of 1.2.1: The Board monitored the DOE's efforts and conducted an evaluation of the results of DOE studies included in *Supplemental Science and Performance Analysis* and *Technical Update Information Letter Report*.

1.2.2. Evaluate geologic, hydrologic, and geochemical information obtained from the ECRB at Yucca Mountain.

- Evaluation of 1.2.2: The Board heard several presentations on studies in the ECRB and commented to the DOE on specific concerns in letters to the acting director of OCRWM dated July 17, 2001, and October 17, 2001.

1.2.3. Evaluate results of the fluid inclusion study.

- Evaluation of 1.2.3: The results of a University of Nevada at Las Vegas fluid inclusion study, which was precipitated by a Board analysis of the hypothesis of hydrothermal upwelling, were presented and discussed at length at a meeting of the Board in Arlington, Virginia, in May 2001.

1.3.1. Set priorities among and evaluate for technical validity the DOE process model reports that will be used to support a decision on site recommendation.

- Evaluation of 1.3.1: The Board provided ongoing comments to the DOE on its process model reports and on its analysis model reports.

1.3.2. Determine the strengths and weaknesses of TSPA and recommend additional measures used to strengthen the DOE's repository safety case.

- Evaluation of 1.3.2: The Board commented extensively on TSPA, including the appropriateness and limits of the methodology, uncertainties related to lack of data and assumptions underlying performance estimates, and the need to supplement TSPA with additional lines of evidence and argument. In January 2001, Board Chairman Jared Cohon identified multiple lines of evidence to supplement TSPA in the DOE's repository safety case as one of the four essential elements of a site recommendation, from the Board's point of view. On April 13, 2001, the Board held a meeting devoted to discussing multiple lines of evidence and commented on the repository safety strategy in letters to the acting director of OCRWM dated March 30, 2001; June 11, 2001; and July 17, 2001. In May, two Board members and staff visited the Peña Blanca radionuclide transport analogue site in Chihuahua, Mexico.

1.4.1. Determine the appropriateness of the "principal factors" identified by the DOE in its safety strategy.

- Evaluation of 1.4.1: See evaluation of item 1.3.2.

1.4.2. On the basis of an evaluation of the natural processes at work at the Yucca Mountain site, recommend additional work needed to address uncertainties, paying particular atten-

tion to estimates of the rate and distribution of water seepage into the proposed repository.

- Evaluation of 1.4.2: The Board urged the DOE several times to reconcile results of different studies on fast water pathways and commented on infiltration studies in its July 17, 2001, letter to the acting director of OCRWM. The Board recommended to the DOE in an October 17, 2001, letter that the DOE obtain data supporting the DOE's contention that moisture discovered in the bulkheaded part of the cross drift is condensation.

2. Performance Goals Related to the Engineered Repository System and Strategy for Achieving Performance Goals

2.1.1. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.

- Evaluation of 2.1.1: In January 2001, the Board identified an evaluation and comparison of the base-case repository design with a low-temperature design as one of four essential elements of any site recommendation. During 2001, the Board evaluated DOE work related to high- and low-temperature operating modes for the DOE's flexible repository design. The Board commented to the DOE on this issue in letters to the acting director of OCRWM dated March 30, 2001; July 17, 2001; and October 17, 2001.

2.1.2. Evaluate the extent to which the DOE is using the technical bases for developing repository and waste package designs.

- Evaluation of 2.1.2: Uncertainties in the technical basis, particularly for higher-temperature designs, were identified. Because of a lack of data, the magnitude of these uncertainties cannot be determined. As stated in the Board's January 24, 2002, letter, because of the uncertainties, the Board has limited confidence in the DOE's performance estimates for high-temperature designs.

2.1.3. Monitor and evaluate the DOE's progress in developing a technical basis for modified or novel design features.

- Evaluation of 2.1.3: The novel design aspect of highest interest to the Board is development of one or more low-temperature designs for an evaluation and a comparison with higher-temperature designs. For example, if low-temperature designs require significantly larger repository footprints, whether the additional area has been adequately characterized and represented in performance estimates will need to be addressed.

2.2.1. Evaluate the adequacy for a site recommendation decision of corrosion studies on materials being proposed for the EBS.

- Evaluation of 2.2.1: In January 2001, the Board identified progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion as one of four essential elements of any site recommendation. The Board monitored DOE activities and commented on the issue in letters to OCRWM's acting director dated March 30, 2001, and July 17, 2001. On July 19 and 20, 2001, the Board hosted an international workshop on issues related to the stability of the passive layer on metals proposed for the waste package and the challenges of extrapolating data obtained from short-term experiments to performance of the waste packages over thousands of years. At the workshop, experts from programs in other countries gave their views on surprises that might be encountered over the very long time periods involved.

2.3.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package. In particular, monitor the results of ongoing thermal tests and evaluate DOE plans for using the test results to support models of the thermally disturbed re-

gion near the repository and to decide on spacing between emplacement drifts, degree of preclosure ventilation, and closure date.

- Evaluation of 2.3.1: In a July 17, 2001, letter to the acting director of OCRWM, the Board commented on the need to complete investigations that connect the near-field natural environment with the engineered repository system. The letter also gave an example of lack of communication among program scientists, engineers, designers and modelers related to repository design and the large hydraulic gradient.

3. Performance Goals Related to the Waste Management System

As noted above, the DOE's efforts related to the waste management system were extremely limited. Therefore, the Board's review in this area was likewise constrained. The expectation is that if the site recommendation is approved, waste management activities, including transportation plans and studies, will become a major area of review for the Board. Therefore, waste management system performance goals have been deferred until FY 2003.

3.1.1. Evaluate storage cask and container designs to ascertain whether there is a sufficient technical basis for predicting potential problems that could develop during storage and that could affect the performance of the spent fuel during subsequent repository disposal.

- Evaluation of 3.1.1: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

3.2.1. Evaluate the effects of "off-normal" events at the surface facility and how the events could affect the ability of the facility to receive waste shipments.

- Evaluation of 3.2.1: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

3.2.2. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.

- Evaluation of 3.2.2: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

3.3.1. Examine the ability of storage casks and containers, including multipurpose canisters, to serve as disposal casks and containers in a repository.

- Evaluation of 3.3.1: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

3.4.1. Monitor progress by the railroad industry in implementing new technologies that would enhance the safety of spent-fuel transportation (e.g., electronic braking, wheel-bearing monitoring). Evaluate how well the DOE works with the railroad industry to design an integrated cask-rail and car-train transportation system that would ensure maximum safety and efficiency.

- Evaluation of 3.4.1: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

3.4.2. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.

- Evaluation of 3.4.2: Because of limited DOE activity in this area, Board work on this spe-

cific goal and related issues was deferred until fiscal year 2003.

3.4.3. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

- Evaluation of 3.4.3: Because of limited DOE activity in this area, Board work on this specific goal and related issues was deferred until fiscal year 2003.

4. Performance Goal Related to Performance Confirmation

4.1.1. Monitor the DOE's proposed performance-confirmation plans to help ensure that uncertainties identified as part of the site recommendation process are considered in the formulation of those plans.

- Evaluation of 4.1.1: Several Board members and staff attended and contributed to a workshop sponsored by the Electric Power Research Institute at which representatives of the DOE, the NRC, the National Academy of Sciences, and Nye County, among others, began a preliminary discussion of the following questions: (1) What is the definition of performance confirmation? (2) How are the elements of a performance-confirmation plan selected? (3) What measurements will be used to confirm performance estimates? (4) How would the program or the repository system be modified according to the results of performance-confirmation studies? (5) How long would the performance-confirmation period continue?

Appendix I

U.S. Nuclear Waste Technical Review Board Fiscal Year 2002 Performance Plan

The NWTRB's General Goals and Strategic Objectives

The national goal for radioactive waste management established by Congress in the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 is safe disposal of civilian spent nuclear fuel and high-level radioactive waste in a permanent geologic repository at a suitable site or sites. In the acts, Congress directed the U.S. Department of Energy (DOE) to characterize a site at Yucca Mountain, Nevada, to determine its suitability as the potential location of a permanent repository for spent nuclear fuel and high-level radioactive waste. Congress charged the U.S. Nuclear Waste Technical Review Board with reviewing the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA, including characterizing the Yucca Mountain site and packaging and transporting the waste. The Board's general goals have been established in accordance with its congressional mandate.*

General Goals

To accomplish its congressional mandate, the Board has established four general goals.

1. Ensure that technical and scientific activities undertaken by the DOE related to characterizing and analyzing the natural components of a potential Yucca Mountain repository and predicting the performance of a potential repository establish a sound technical basis for a decision on whether to recommend the site for repository development.
2. Ensure that technical and scientific activities undertaken by the DOE related to evaluating and designing the repository and waste packages are well integrated and establish a sound technical basis for designing the repository system, including the engineered barrier system (EBS).
3. Ensure that technical and scientific activities undertaken by the DOE related to packaging, handling, and transporting spent nuclear fuel and high-level radioactive waste to a potential repository are well integrated and establish a sound technical basis for designing and operating a waste management system.
4. Ensure that technical and scientific performance-confirmation activities undertaken by the DOE establish a sound technical basis for operating a repository, reducing uncertainties related to repository performance, and revising repository

* In February 2002, the Secretary of Energy and the President recommended the Yucca Mountain site for repository development. If the State of Nevada disapproves the recommendation, Congress will debate a "Resolution of Approval" later this year. The Board's goals and objectives will be revised to reflect the outcome of these deliberations.

and waste package designs. (Will apply only if the site recommendation is approved.)

Strategic Objectives

To achieve its general goals, the Board has established the following long-term objectives.

1. Objectives Related to the Natural Components of the Repository System and Predicting Repository Performance

- 1.1. Evaluate the technical and scientific validity of DOE studies, testing, and analyses supporting a decision on whether to recommend the Yucca Mountain site.
- 1.2. Evaluate the analyses and investigations pertaining to hydrologic and other natural processes at the Yucca Mountain site and at related analogue sites that establish the foundation for predicting repository performance.
- 1.3. Review the technical and scientific validity of models used to predict repository performance.
- 1.4. Evaluate the DOE's progress in developing a safety strategy for the Yucca Mountain site.
- 1.5. Monitor progress in completing development of standards and regulatory guidelines for a potential Yucca Mountain repository.
- 1.6. Review the *Record of Decision* and maintain awareness of legal challenges to the final environmental impact statement (EIS) for a potential Yucca Mountain repository.

2. Objectives Related to the Engineered Components of the Repository System

- 2.1. Evaluate repository and waste package designs, including the technical bases for the designs.
- 2.2. Review the progress or results of materials testing being conducted to address uncertainties about waste package performance.

- 2.3. Assess the integration of science and engineering in the DOE program, paying particular attention to the effects of site-characterization studies (e.g., modeling, testing, and analyses of thermal and mechanical effects) on repository and waste package designs.

3. Objectives Related to the Waste Management System

- 3.1. Evaluate the accuracy and reasonableness of analyses, methods, and major assumptions used by the DOE in estimating health and safety risks associated with transporting spent nuclear fuel and high-level radioactive waste.
- 3.2. Review the adequacy of DOE plans for developing the transportation infrastructure and determine the effort needed to develop a large-scale transportation capability.
- 3.3. Review the adequacy of the DOE's plans for safely handling and packaging spent nuclear fuel and high-level radioactive waste for transport to a permanent repository.
- 3.4. Evaluate the effectiveness of the DOE's efforts to integrate the various components of the waste management system (packaging, handling, transport, storage, and disposal of the waste).
- 3.5. Review the DOE's plans for addressing public safety concerns and for enhancing safety capabilities along transportation corridors. This includes activities related to development of plans (e.g., route selection), coordination, accident prevention (e.g., improved inspections and enforcement), and emergency response.

4. Objectives Related to Confirmatory Testing (Will apply only if the site recommendation is approved)

- 4.1. Monitor performance-confirmation activities, including performance-confirmation planning, undertaken by the DOE that are designed to reduce uncertainties related to repository performance.
- 4.2. Monitor performance-confirmation activities undertaken by the DOE, and evaluate the need

to revise repository or waste package designs on the basis of the results of such activities.

Performance Goals for FY 2002

The Board's performance goals for fiscal year (FY) 2002 have been developed to further the achievement of the Board's general goals and strategic objectives. Because some of the general goals and strategic objectives relate to work and activities that will be undertaken in the future, they may not have corresponding annual performance goals in any given year. For example, the following performance goals for FY 2002 relate primarily to DOE activities supporting a DOE decision on whether to recommend the Yucca Mountain site to the President, the design of a potential repository and waste package, and transportation planning.

1. Performance Goals Related to Site Suitability and Predicting Repository Performance and Strategy for Achieving Performance Goals

Performance Goals

- 1.1.1. Review for technical validity the technical and scientific components of a DOE site recommendation report (if applicable).
- 1.1.2. Monitor the DOE's efforts to quantify uncertainties related to estimates of repository performance.
 - 1.2.1. Monitor the results of flow-and-transport studies being conducted to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.
 - 1.2.2. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block at Yucca Mountain.
- 1.3.1. Determine the strengths and weaknesses of the total system performance assessment (TSPA).
- 1.3.2. On the basis of an evaluation of the natural processes at work at the Yucca Mountain site, recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distribution of water seepage into the proposed repository under proposed repository design conditions.
- 1.3.3. Evaluate the DOE's quantification of uncertainties and conservatisms used in TSPA.
- 1.3.4. Recommend additional measures for strengthening the DOE's repository safety case.
- 1.3.5. Evaluate data from the drift-scale heater test.
 - 1.4.1. Review plans and work carried out on natural and engineered analogues.

Strategy for Achieving Goals

The strategy for achieving performance goals for fiscal year 2002 is similar to that used and proven successful in previous years. The Board will accomplish its goals by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, TSPA for site recommendation, and the site recommendation.
- Meeting with contractor's principal investigators on technical issues, including those related to climate change, flow and transport in the unsaturated and saturated zones, seepage, and the biosphere.
- Holding public meetings with DOE and contractor personnel at least three times a year involving the full Board and holding several meetings with individual Board panels.
- Visiting and observing ongoing laboratory investigations, including the facilities at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratory, and the engineered-barrier test facility. Observing field investigations.
- Meeting with other entities carrying out research on, or providing input to, scientific and technical issues related to waste disposal, including the Nuclear Regulatory Commission and its contractors, the Southwest Research Institute, The Nye

County Early Warning Drilling Program, the Environmental Protection Agency, and the State of Nevada Nuclear Waste Projects Office.

2. Performance Goals Related to the Engineered Repository System and Strategy for Achieving Performance Goals

Performance Goals

- 2.1.1. Monitor the DOE's development of analytical tools for assessing the differences between different repository designs.
- 2.1.2. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.
- 2.1.3. Evaluate the extent to which the DOE is using the technical bases for modifying repository and waste package designs.
- 2.1.4. Monitor and evaluate the DOE's progress in developing a technical basis for modified or novel design features.
- 2.2.1. Evaluate data from studies of corrosion and the waste package environment on the predicted performance of materials being proposed for the EBS.
- 2.3.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package. In particular, monitor the results of ongoing thermal tests and evaluate DOE plans for using the test results to support models of the thermally disturbed region near the repository and for deciding on spacing between emplacement drifts, degree of preclosure ventilation, and closure date of the potential repository.
- 2.3.2. Evaluate the DOE's efforts in identifying natural and engineered analogues.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Evaluating the technical bases for the EBS design by reviewing technical documents and databases (e.g., the controlled design assumption document and the technical database), paying particular attention to the technical bases for making and inspecting final closure welds of the waste package and methods for making sections of the drip shields. Meetings will be held with project personnel as necessary to obtain clarification and confirmation.
- Evaluating the technical bases for repository design by reviewing DOE documents and databases, paying particular attention to design features developed to promote drainage, control ventilation, and protect workers in the exhaust end of the ventilation system.
- Evaluating repository and waste package designs to identify which parts (if any) of the designs do not have a technical basis.
- Evaluating the technical basis for the DOE's work on alternative design features.
- After identifying the corrosion mechanisms most important to performance of the overall repository system, reviewing the common database (literature, laboratory, and field data) and judging the adequacy of the database for a decision on site recommendation.

3. Performance Goals Related to the Waste Management System and Strategy for Achieving Performance Goals

Performance Goals

- 3.1.1. Monitor efforts by the NRC to update estimates of risk associated with transportation of spent nuclear fuel and high-level radioactive waste.
- 3.1.2. Evaluate the operation of the entire repository facility, including the surface and subsurface components.
- 3.2.1. Evaluate the effects of "off-normal" events at the surface facility and how the events could

affect the ability of the facility to receive waste shipments.

- 3.2.2. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.
- 3.3.1. Examine the ability of storage casks and containers, including multipurpose canisters, to serve as disposal casks and containers in a repository.
- 3.3.2. Evaluate effects of human errors on risks associated with packaging and transporting spent nuclear fuel.
- 3.4.1. Evaluate logistics capabilities of the transportation system.
- 3.4.2. Monitor progress in implementing new technologies for improving transportation safety for spent fuel (e.g., electronic braking, wheel-bearing monitoring).
- 3.4.3. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.
- 3.4.4. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors, and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Meeting with the American Association of Railroads, individual railroad companies, and railroad infrastructure manufacturers to determine the current state of rail infrastructure, and noting the effects of a sustained transportation campaign on the railroad industry.

- Attending meetings of the DOE-sponsored Transportation External Working Group to determine how well the DOE is working to implement Section 180(c) of the Nuclear Waste Policy Act.

- Holding meetings of the Board's Panel on the Waste Management System, as appropriate.

4. Performance Goals Related to Long-Term Activities and Strategy for Achieving Performance Goals (Will apply only if the site is found suitable and a site recommendation is ratified.)

Performance Goals

- 4.1.1. Monitor the DOE's proposed plans for performance confirmation to help ensure that uncertainties identified as part of the site recommendation process are addressed.
- 4.1.2. Monitor design modification activities undertaken by the DOE.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, TSPA for site recommendation, and the site recommendation.
- Reviewing performance-confirmation plans and meeting with DOE personnel to discuss aspects of the plans.

Evaluating the Board's Performance

The Board believes that measuring its effectiveness by directly correlating improvements in the DOE program with Board actions and recommendations would be ideal. However, the Board has no implementing authority, so it cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program is, in

most cases, (1) subjective and (2) an imprecise indicator of Board performance because implementation of Board recommendations by the DOE is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each annual performance goal, the Board considers the following.

1. Were the reviews, evaluations, and other activities undertaken under the auspices of the goal completed?
2. Were the results of the reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures are met, the Board's performance in meeting the annual goal will be judged effective. If only one measure is met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal.

The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to establish its annual

performance objectives and develop its budget request for subsequent years. The results of the Board's performance evaluation are included in the Board's annual summary report to Congress and the Secretary.

Board Operations

The Board is composed of 11 members appointed by the President who serve on a part-time basis; are eminent in a relevant field of science or engineering, including environmental sciences; and are appointed solely on the basis of distinguished service. Because of the comprehensive nature of the program and the part-time availability of the members, Congress authorized the Board to maintain a small professional staff of 10 full-time employees to support the Board's comprehensive review of the DOE program. In addition to the members and professional staff, the Board maintains a small administrative staff that supports its activities.

The full Board meets three or four times each year. The Board has organized itself into panels that meet as needed. The Board also gathers information from field trips to the Yucca Mountain site, visits to contractor laboratories and facilities, and informal meetings with individuals working on the project. On the basis of the information gathered throughout the year, the Board issues its findings in letters and reports.

Appendix J

U.S. Nuclear Waste Technical Review Board Fiscal Year 2003 Performance Plan

The NWTRB's General Goals and Strategic Objectives

The national goal for radioactive waste management established by Congress in the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 is safe disposal of civilian spent nuclear fuel and high-level radioactive waste in a permanent geologic repository at a suitable site or sites. In the acts, Congress directed the U.S. Department of Energy (DOE) to characterize a site at Yucca Mountain, Nevada, to determine its suitability as the potential location of a permanent repository for spent nuclear fuel and high-level radioactive waste. Congress charged the U.S. Nuclear Waste Technical Review Board with reviewing the technical and scientific validity of the Secretary of Energy's activities associated with implementing the NWPA, including characterizing the Yucca Mountain site and packaging and transporting the waste. The Board's general goals have been established in accordance with its congressional mandate.*

General Goals

To accomplish its congressional mandate, the Board has established four general goals.

1. Ensure that technical and scientific activities undertaken by the DOE related to characterizing and analyzing the natural components of a potential Yucca Mountain repository and predicting the performance of a potential repository establish a sound technical basis for a decision on whether to recommend the site for repository development.
2. Ensure that technical and scientific activities undertaken by the DOE related to evaluating and designing the repository and waste packages are well integrated and establish a sound technical basis for designing the repository system, including the engineered barrier system (EBS).
3. Ensure that technical and scientific activities undertaken by the DOE related to packaging, handling, and transporting spent nuclear fuel and high-level radioactive waste to a potential repository are well integrated and establish a sound technical basis for designing and operating a waste management system.
4. Ensure that technical and scientific performance-confirmation activities undertaken by the DOE establish a sound technical basis for operating a repository, reducing uncertainties related to repository performance, and revising repository and waste package designs. (Will apply only if the site recommendation is approved.)

* In February 2002, the Secretary of Energy and the President recommended the Yucca Mountain site for repository development. If the State of Nevada disapproves the recommendation, Congress will debate a "Resolution of Approval" later this year. The Board's goals and objectives will be revised to reflect the outcome of these deliberations.

Strategic Objectives

To achieve its general goals, the Board has established the following long-term objectives.

1. Objectives Related to the Natural Components of the Repository System and Predicting Repository Performance

- 1.1. Evaluate the technical and scientific validity of DOE studies, testing, and analyses supporting a decision on whether to recommend the Yucca Mountain site.
- 1.2. Evaluate the analyses and investigations pertaining to hydrologic and other natural processes at the Yucca Mountain site and at related analogue sites that establish the foundation for predicting repository performance.
- 1.3. Review the technical and scientific validity of models used to predict repository performance.
- 1.4. Evaluate the DOE's progress in developing a safety strategy for the Yucca Mountain site.
- 1.5. Monitor progress in completing development of standards and regulatory guidelines for a potential Yucca Mountain repository.
- 1.6. Review the *Record of Decision* and maintain awareness of legal challenges to the final environmental impact statement (EIS) for a potential Yucca Mountain repository.

2. Objectives Related to the Engineered Components of the Repository System

- 2.1. Evaluate repository and waste package designs, including the technical bases for the designs.
- 2.2. Review the progress or results of materials testing being conducted to address uncertainties about waste package performance.
- 2.3. Assess the integration of science and engineering in the DOE program, paying particular attention to the effects of site-characterization studies (e.g., modeling, testing, and analyses of thermal and

mechanical effects) on repository and waste package designs.

3. Objectives Related to the Waste Management System

- 3.1. Evaluate the accuracy and reasonableness of analyses, methods, and major assumptions used by the DOE in estimating health and safety risks associated with transporting spent nuclear fuel and high-level radioactive waste.
- 3.2. Review the adequacy of DOE plans for developing the transportation infrastructure and determine the effort needed to develop a large-scale transportation capability.
- 3.3. Review the adequacy of the DOE's plans for safely handling and packaging spent nuclear fuel and high-level radioactive waste for transport to a permanent repository.
- 3.4. Evaluate the effectiveness of the DOE's efforts to integrate the various components of the waste management system (packaging, handling, transport, storage, and disposal of the waste).
- 3.5. Review the DOE's plans for addressing public safety concerns and for enhancing safety capabilities along transportation corridors. This includes activities related to development of plans (e.g., route selection), coordination, accident prevention (e.g., improved inspections and enforcement), and emergency response.

4. Objectives Related to Confirmatory Testing (Will apply only if the site recommendation is approved)

- 4.1. Monitor performance-confirmation activities, including performance-confirmation planning, undertaken by the DOE that are designed to reduce uncertainties related to repository performance.
- 4.2. Monitor performance-confirmation activities undertaken by the DOE, and evaluate the need to revise repository or waste package designs on the basis of the results of such activities.

Performance Goals for FY 2003

The Board's performance goals for fiscal year (FY) 2003 have been developed to further the achievement of the Board's general goals and strategic objectives. Because some of the general goals and strategic objectives relate to work and activities that will be undertaken in the future, they may not have corresponding annual performance goals in any given year.

1. Performance Goals Related to Site Suitability and Predicting Repository Performance and Strategy for Achieving Performance Goals

Performance Goals

- 1.1.1 Review for technical validity the technical and scientific components of the DOE's on-going site investigations (if applicable).
- 1.1.2. Monitor the DOE's efforts to quantify uncertainties related to estimates of repository performance.
 - 1.2.1. Monitor the results of flow-and-transport studies being conducted to obtain information on the potential performance of the saturated zone as a natural barrier in the repository system.
 - 1.2.2. Evaluate geologic, hydrologic, and geochemical information obtained from the enhanced characterization of the repository block at Yucca Mountain.
 - 1.3.1. Determine the strengths and weaknesses of the total system performance assessment (TSPA).
 - 1.3.2. On the basis of an evaluation of the natural processes at work at the Yucca Mountain site, recommend additional work needed to address uncertainties, paying particular attention to estimates of the rate and distribution of water seepage into the proposed repository under proposed repository design conditions.

- 1.3.3. Evaluate the DOE's quantification of uncertainties and conservatisms used in TSPA.
- 1.3.4. Recommend additional measures for strengthening the DOE's repository safety case.
- 1.3.5. Evaluate data from the drift-scale heater test.
 - 1.4.1. Review plans and work carried out on natural and engineered analogues to the repository system.

Strategy for Achieving Goals

The strategy for achieving performance goals for fiscal year 2003 is similar to that used and proven successful in previous years. The Board will accomplish its goals by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.
- Meeting with contractor's principal investigators on technical issues, including those related to climate change, flow and transport in the unsaturated and saturated zones, seepage, and the biosphere.
- Holding public meetings with DOE and contractor personnel at least three times a year involving the full Board and holding several meetings with individual Board panels.
- Visiting and observing ongoing laboratory investigations, including the facilities at Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratory, and the engineered-barrier test facility. Observing field investigations.
- Meeting with other entities carrying out research on, or providing input to, scientific and technical issues related to waste disposal, including the Nuclear Regulatory Commission and its contractors, the Southwest Research Institute, The Nye County Early Warning Drilling Program, the Environmental Protection Agency, and the State of Nevada Nuclear Waste Projects Office.

2. Performance Goals Related to the Engineered Repository System and Strategy for Achieving Performance Goals

Performance Goals

- 2.1.1. Monitor the DOE's development of analytical tools for assessing the differences between different repository designs.
- 2.1.2. Evaluate the accuracy and completeness of the technical bases for repository and waste package designs.
- 2.1.3. Evaluate the extent to which the DOE is using the technical bases for modifying repository and waste package designs.
- 2.1.4. Monitor and evaluate the DOE's progress in developing a technical basis for modified or novel design features.
- 2.2.1. Evaluate data from studies of corrosion and the waste package environment on the predicted performance of materials being proposed for the engineered barrier system.
- 2.3.1. Assess the integration of scientific studies with engineering designs for the repository and the waste package. In particular, monitor the results of ongoing thermal tests and evaluate DOE plans for using the test results to support models of the thermally disturbed region near the repository and for deciding on spacing between emplacement drifts, degree of preclosure ventilation, and closure date of the potential repository.
- 2.3.2. Evaluate the DOE's efforts in identifying natural and engineered analogues (see also 1.4.1.).

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Evaluating the technical bases for the EBS design by reviewing technical documents and databases (e.g., the controlled design assumption document and the technical database), paying particular

attention to the technical bases for making and inspecting final closure welds of the waste package and methods for making sections of the drip shields. Meetings will be held with project personnel as necessary to obtain clarification and confirmation.

- Evaluating the technical bases for repository design by reviewing DOE documents and databases, paying particular attention to design features developed to promote drainage, control ventilation, and protect workers in the exhaust end of the ventilation system.
- Evaluating repository and waste package designs to identify which parts (if any) of the designs do not have a technical basis.
- Evaluating the technical basis for the DOE's work on alternative design features.
- After identifying the corrosion mechanisms most important to performance of the overall repository system, reviewing the common database (literature, laboratory, and field data) and judging the adequacy of the database for a decision on repository development.

3. Performance Goals Related to the Waste Management System and Strategy for Achieving Performance Goals

Performance Goals

- 3.1.1. Monitor efforts by the NRC to update estimates of risk associated with transportation of spent nuclear fuel and high-level radioactive waste.
- 3.1.2. Evaluate the operation of the entire repository facility, including the surface and subsurface components.
- 3.2.1. Evaluate the effects of "off-normal" events at the surface facility and how the events could affect the ability of the facility to receive waste shipments.
- 3.2.2. Evaluate the effects of reduced receiving capacity at the repository surface facility on the nationwide transportation system.

- 3.3.1. Examine the ability of storage casks and containers, including multipurpose canisters, to serve as disposal casks and containers in a repository.
- 3.3.2. Evaluate effects of human errors in risks associated with packaging and transporting spent nuclear fuel.
- 3.4.1. Evaluate logistics capabilities of the transportation system.
- 3.4.2. Monitor progress in implementing new technologies for improving transportation safety for spent fuel (e.g., electronic braking, wheel-bearing monitoring).
- 3.4.3. Review criteria for waste acceptance for storage to ensure that accepted material has been suitably characterized for subsequent disposal.
- 3.4.4. Evaluate the DOE's plans for enhancing safety capabilities along transportation corridors, and review the DOE's planning and coordination activities (e.g., route selection), accident prevention activities (e.g., improved inspections and enforcement), and emergency response activities.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Meeting with the American Association of Railroads, individual railroad companies, and railroad infrastructure manufacturers to determine the current state of rail infrastructure, and noting the effects of a sustained transportation campaign on the railroad industry.
- Attending meetings of the DOE-sponsored Transportation External Coordination Working Group to determine how well the DOE is working to implement Section 180(c) of the Nuclear Waste Policy Act.

- Holding meetings of the Board's Panel on the Waste Management System, as appropriate.

4. Performance Goals Related to Long-Term Activities and Strategy for Achieving Performance Goals (Will apply only if the site is found suitable and a site recommendation is ratified.)

Performance Goals

- 4.1.1. Monitor the DOE's proposed plans for performance confirmation to help ensure that uncertainties identified as part of the site recommendation process are addressed.
- 4.1.2. Monitor design modification activities undertaken by the DOE.

Strategy for Achieving Goals

The Board will accomplish its goals by doing the following.

- Reviewing critical documents provided by the DOE and its contractors, including contractor reports, process model reports, and TSPA.
- Reviewing performance-confirmation plans and meeting with DOE personnel to discuss aspects of the plans.

Evaluating the Board's Performance

The Board believes that measuring its effectiveness by directly correlating improvements in the DOE program with Board actions and recommendations would be ideal. However, the Board has no implementing authority, so it cannot compel the DOE to comply with its recommendations. Consequently, a judgment about whether a specific recommendation had a positive outcome for the DOE program is, in most cases, (1) subjective and (2) an imprecise indicator of Board performance because implementation of Board recommendations by the DOE is outside the Board's direct control. Therefore, to measure its performance in a given year, the Board has developed performance measures. For each

annual performance goal, the Board considers the following:

1. Were the reviews, evaluations, and other activities undertaken under the auspices of the goal completed?
2. Were the results of the reviews, evaluations, and other activities communicated in a timely, understandable, and appropriate way to Congress and the Secretary of Energy?

If both measures are met, the Board's performance in meeting the annual goal will be judged effective. If only one measure is met, the performance of the Board in achieving that goal will be judged minimally effective. Failing to meet both performance measures without sufficient and compelling explanation will result in a judgment that the Board has been ineffective in achieving that performance goal.

The Board will use its evaluation of its own performance from the current year, together with its assessment of current or potential key issues of concern related to the DOE program, to establish its annual performance objectives and develop its budget request for subsequent years. The results of the Board's performance evaluation are included in the

Board's annual summary report to Congress and the Secretary.

Board Operations

The Board is composed of 11 members appointed by the President who serve on a part-time basis; are eminent in a relevant field of science or engineering, including environmental sciences; and are appointed solely on the basis of distinguished service. Because of the comprehensive nature of the program and the part-time availability of the members, Congress authorized the Board to maintain a small professional staff of 10 full-time employees to support the Board's comprehensive review of the DOE program. In addition to the members and professional staff, the Board maintains a small administrative staff that supports its activities.

The full Board meets three or four times each year. The Board has organized itself into panels that meet as needed. The Board also gathers information from field trips to the Yucca Mountain site, visits to contractor laboratories and facilities, and informal meetings with individuals working on the project. On the basis of the information gathered throughout the year, the Board issues its findings in letters and reports.