presumption of the proposed action that Yucca Mountain is found suitable for the repository and that a license authorizing construction is issued sometime in 2005.

The nuclear utilities have been placed in a bind by the delay in waste acceptance. Many have already had to make investments to expand reactor site storage that should not have been necessary if DOE had met the 1998 milestone or had taken other steps to move spent fuel per the waste acceptance schedule to other DOE-managed sites on a temporary basis. As a consequence, many utilities expanded their on-site storage capacity and others will need to before waste acceptance begins in 2010 or later. Many utilities have entered into litigation seeking waste removal and cost recovery for damages from DOE's breach of contract.

We raise this question in the context of the need to move the spent fuel from reactor sites in a timely fashion as move spent fuel accumulates. This must be a priority regardless of whether the lower or higher temperature-operating mode is the one selected. Therefore, the aging facility needs to be sized accordingly if the lower-temperature mode is adopted.

Response
As discussed in Section 2.2.2.2.2 of the Supplement to the Draft EIS, commercial spent nuclear fuel would be the major contributor of heat in the repository. It would have a wide range of thermal outputs. The thermal output of the waste packages could, however, be reduced by varying waste package loading. Commercial spent nuclear fuel waste package loading could be varied by (1) placing low-heat-output (older) fuel with high-heat-output (younger) fuel in the same waste package (fuel blending), (2) limiting the number of spent nuclear fuel assemblies to less than the waste package design capacity (derating), (3) using smaller waste packages, or (4) placing younger fuel in a surface aging area to allow its heat output to dissipate so it could meet thermal goals for later emplacement. Section 2.3.2.1 of the Supplement to the Draft EIS describes the fuel blending process further. Reducing the thermal output of the waste package through any of these means would achieve lower waste package and drift wall temperatures. DOE would consider aging as much as 40,000 metric tons of heavy metal of commercial spent nuclear fuel during a 50-year period.

The flexible design for the repository allows flexibility in the types of commercial spent nuclear fuel that DOE would be receive. However, the estimated receipts are based on DOE projections of actions that would be taken by utilities to deliver spent nuclear fuel for disposal and are independent of the repository design. Instead, they are based on the terms of DOE's Standard Contract for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste contained in 10 CFR Part 961 and the generation and storage characteristics of each generator site (see discussion of CALVIN computer code in Section J.1.1.1 of the EIS). Therefore, DOE believes that the flexible design, including the blending facility, would accommodate fuel that would be shipped to a Yucca Mountain repository based on the terms of the Standard Contract.

7.3 Repository Long-Term Performance

7.3 (7)
Comment - 24 comments summarized
Commenters said that Total System Performance Assessment evaluations are close to the status required for licensing reviews. However, improvements needed for licensing would include revision or refinement of model details, revision of parameter values as a result of data additions, and improvement of quality assurance basis for models, computer codes, and data. One commenter said that the long-term consequences in the Draft EIS suffer from the shortcomings that they are a snapshot in an evolutionary process. Commenters felt that the Viability Assessment provided only a limited description of the methodology, assumptions, and use of information in the Total System Performance Assessment (DIRS 101779-DOE 1998).

Response
DOE has continued technical development of the Total System Performance Assessment since publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. Chapter 5 and Appendix I of the Final EIS reports on the modified assumptions and methodologies utilized. DOE agrees that the process requires continual refinement and improvement.

A peer review of the Total System Performance Assessment noted: "For cases in which it is feasible to improve either the component models or their underlying data, the Panel recommends that primary attention be directed to those changes that will affect the overall assessment of the proposed repository. Where conservative bounding analyses do not result in an unduly pessimistic estimate of total system performance, it may not be cost-effective to refine the assessment in an attempt to make it more realistic. For those systems and events for which, by virtue of their complexity, it is not feasible to produce realistic models supported by data, the Panel recommends that, if possible, a combination of bounding analyses and design changes be applied." (DIRS 102726-Budnitz et al. 1999). DOE concurs with these approaches. They are consistent with the Department's strategy for developing a preclosure safety case for the potential Site Recommendation and License Application, with the ongoing design selection process, and with its efforts to prioritize future work for the Site Recommendation and License Application.

With regard to the statements about Total System Performance Assessment sufficiency and the fact it is evolutionary, DOE did not intend for the assessment to provide a precise projection of the probable behavior of the repository system. Rather, the Total System Performance Assessment provides the probable behavior within the range of results given the available information and analyses.

DOE continues to evaluate the sufficiency of its approach to uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should Yucca Mountain be recommended as a suitable site for a geologic repository.

7.3 (71)
Comment - 4 comments summarized
Several commenters questioned the location of the maximally exposed individual, indicating that there is no rationale provided in the EIS for the location and that the location is not conservative. Other commenters suggested the individual should be an age- and gender-weighted subsistence farmer located at the repository operations area boundary.

One commenter noted that the definition of the maximally exposed individual in the EIS is not the same as the reasonably maximally exposed individual used by the Environmental Protection Agency.

Response
Environmental Protection Agency rules (40 CFR Part 197) and Nuclear Regulatory Commission rules (10 CFR Part 63) specify protection of the reasonably maximally exposed individual as the standard of safety for the proposed Yucca Mountain Repository.

DOE accepts the definition of the Reasonably Maximally Exposed Individual (RMEI) at 40 CFR 197.21, which defines the individual as a hypothetical person who could meet the following criteria:

1. Has a diet and living style representative of the people who are now residing in the Town of Amargosa Valley, Nevada. DOE must use the most accurate projections, which might be based upon surveys of the people residing in the Town of Amargosa Valley, Nevada, to determine their current diets and living styles and use the mean values in the assessments conducted for 40 CFR 197.20 and 197.25.

2. Drinks 2 liters (0.5 gallon) of water per day from wells drilled into the groundwater at the location where the RMEI lives.

The location of the RMEI described in 40 CFR Part 197 would be where the predominant groundwater flowpath crosses the southern boundary of the Nevada Test Site, which coincides with the southern boundary of the controlled area as defined in the regulation. This point is approximately 18 kilometers (11 miles) from the proposed repository. DOE has concluded that it is not necessary to analyze in the Final EIS a hypothetical individual at locations closer

than approximately 18 kilometers (11 miles) to the repository because it is unreasonable to assume that anyone would reside in this area, for these reasons:

- An individual would need to install and operate a water well in volcanic rock more than 360 meters (1,200 feet) deep to reach the water table, at costs significantly (and likely prohibitively) above those that would be incurred several kilometers farther south of the repository where the water tables lies less than 60 meters (200 feet) beneath the surface through sand and gravel.

- Locations closer than 18 kilometers (11 miles) are within the controlled area defined in the Environmental Protection Agency individual protection standard (40 CFR 197.20) for a Yucca Mountain Repository and, therefore, not in the postclosure accessible environment defined by the Agency.

The updated analysis in the Final EIS estimates potential impacts to a member of the public reported for the location prescribed in 40 CFR 197.21 [approximately 18 kilometers (11 miles) from the proposed repository]. As part of a comprehensive presentation of impacts, this EIS is charged with providing groundwater impacts for two other important downgradient locations. These are 30 kilometers (18 miles), where most of the current population in the groundwater path is located, and 60 kilometers (37 miles) where the aquifer discharges to the surface (this location is also known as Franklin Lake Playa). The doses for these other locations were assessed for an individual with the same characteristics as the RMEI with the exception of the location. This analysis indicates that for the first 10,000 years there would be only very limited releases, attributable to a small number of early waste package failures (zero to three, and possibly as many as five) due to waste package manufacturing defects, with very small radiological consequences (see Table 5-6). For the first 10,000 years after repository closure, the mean peak annual individual dose would be thousands of times less than the Environmental Protection Agency individual protection standard (40 CFR 197.20), which allows up to 15-millirem-per-year dose rates during the first 10,000 years. The peaks would be even smaller at greater distances.

DOE has revised the definitions of the maximally exposed individual and RMEI in the Final EIS. Chapters 4, 6, and 7 now use the term "maximally exposed individual," and Chapter 5 uses "individual" for distances other than 18 kilometers (11 miles). The "individual" is the same as the "reasonably maximally exposed individual" defined in 40 CFR Part 197 with the exception of the location.

7.3 (94)
Comment - 10 comments summarized
Several commenters cited or referred to a report by two DOE scientists at the Los Alamos National Laboratory, Drs. Bowman and Venneri, which concluded that an explosive nuclear criticality was credible and suggested that the impacts of such an event should be analyzed in the EIS. Commenters also suggested that these analyses should be quantitative in nature and that all assumptions and results should be in the Final EIS. One commenter wanted to know why impacts from an external criticality event could not be determined by experiment.

One commenter suggested that enhanced material migration resulting from natural (earthquake, volcanism) or manmade (intrusion) external events could increase the likelihood of a criticality event. Other commenters were concerned about the lack of any consensus among DOE's own scientists on the subject. One commenter stated that the Nuclear Regulatory Commission position is that DOE does not have sufficient data to support the conclusion that criticality is not a significant issue.

One commenter noted that "there is no chance" of criticality accident, with the words in quotes taken from the Draft EIS. Another commenter stated that regardless of the conclusion that an explosive criticality is not credible, the DOE must show the impacts of such an event because it is considered credible by some critics of Yucca Mountain.

Response
To evaluate criticality safety, DOE analyzed a comprehensive collection of all features, events, and processes that could conceivably affect the potential for criticality, including those postulated by Drs. Bowman and Venneri in their report, *Underground Autocatalytic Criticality from Plutonium and Other Fissile Materials* (DIRS 152123-Bowman and Venneri 1995), as well as those postulated to occur as a result of natural (earthquake, volcanism) or manmade (intrusion) external events. In addition, DOE updated the analysis to consider the flexible design repository and waste package designs.

In performing the analysis, DOE used the most current information on the facility design and site properties, known physical processes regarding nuclear criticality, and industry-accepted methods to evaluate nuclear criticality scenarios. In addition, the Department believes there is adequate experimental data available from operating commercial and research reactors as well as empirical data gathered from natural analogs (for example, the Oklo natural reactors in Gabon, Africa) to predict the likely behavior of these systems without the need for conducting additional criticality experiments.

These exhaustive, quantitative analyses demonstrate that nuclear criticality is not likely at the Yucca Mountain Repository. While a highly unlikely criticality within a waste package could occur, it would result in an inconsequential increase in heat load and radioactivity. It would not result in mechanical disruption of the engineered systems. Criticalities outside a waste package were deemed not credible. Therefore, an explosive nuclear criticality is not considered a reasonably foreseeable event. The Draft EIS references the source of the information supporting the conclusions (DIRS 101779-DOE 1998) and the Final EIS references sources of information supporting similar conclusions for the enhanced design (DIRS 153849-DOE 2001).

Information related to the criticality analyses performed for the Final EIS waste package designs has been provided in Chapter 5 and Appendix I of the Final EIS. Because of space considerations, it would have been impractical to include all the information from supporting documents. Therefore, the information is summarized with appropriate reference citations. Supporting information including the scientific bases regarding nuclear criticality can be found in the Science and Engineering Report (DIRS 153849-DOE 2001) and referenced supporting documents. DOE has made information about these and more than 600 other Final EIS reference documents available to the public on the Internet (*www.ymp.gov*) and at reading rooms across the Nation (see Appendix D.)

DOE continues to provide the results of updated criticality analyses and other requested information to the Nuclear Regulatory Commission as part of an ongoing technical exchange. This information exchange will continue as the repository design evolves, and the Department expects to be able to address adequately any issues that might arise in the future.

The comment noting that "there is no chance" of a criticality is taken out of context. The complete phrase from the Draft EIS is "...there is no chance that a criticality would cause a mechanical disruption of the waste package and engineered barrier system." A reference is provided for that conclusion. The comment that DOE must show the impacts of an explosive criticality event regardless of the probability of the event is incorrect. Consistent with Council of Environmental Quality regulations (40 CFR 1502.22) for implementing the National Environmental Policy Act, DOE analyzes reasonably foreseeable significant adverse impacts, including impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason. However, as explained above, DOE has taken a hard look at this issue and has determined that an explosive nuclear criticality is not a credible event (that is, not reasonably foreseeable). Thus, DOE believes that analysis of the impacts of such an event is not required under the National Environmental Policy Act and would not provide useful information to decisionmakers.

7.3 (110)
Comment - 6 comments summarized
Commenters questioned DOE's reliance on computer modeling, in lieu of actual testing and use of real data, to demonstrate the safety of a Yucca Mountain Repository. Several commenters pointed out that the Department does not accept modeling as an accurate predictor of the behavior of nuclear weapons and questioned why such modeling should be considered acceptable for the proposed repository.

Response
A much larger amount of nuclear weapons testing would have been necessary had there not been good models for prediction of weapons effects. Modeling in support of weapons testing has been very highly developed. The significant difference between modeling the behavior of nuclear weapons and a geologic repository is that it is possible to test a weapon that operates over a period of fractions of a second with data gathering, interpretation, and analysis over a few months. In the case of a geologic repository the test duration would be at least 10,000 years. In the case of weapons, the testing provided a much higher degree of certainty in the results of modeling of weapons effects.

For the proposed repository, DOE does not have the option of a 10,000-year test and must accept some uncertainty in predictions of long-term repository performance. DOE deals with this uncertainty in two ways. First, where it is necessary to make assumptions, either due to uncertainty or to make mathematical modeling practicable, DOE chooses conservative assumptions that tend to result in overestimates of impacts. Second, models are used to simulate behavior statistically using large ranges of values for parameters about which there is uncertainty. In addition, note that it is expected that the final decision to close the repository would not be made for at least 50 years and possibly up to 300 years after final emplacement. The sophistication of modeling tools probably would have advanced significantly during the intervening years and DOE would have obtained much more comprehensive data on repository during construction, operation, and associated investigations and monitoring. Thus, the final decision to close the repository would benefit from more analyses than are possible now.

The Federal Government, therefore, would maintain stewardship of the repository site for generations to come, if the site is selected for a repository. These stewardship activities will entail site protection, confirmatory scientific work, and a postclosure monitoring program, as required by Nuclear Regulatory Commission rules governing the disposal of high-level radioactive waste in a geologic repository (10 CFR 63.51). The decision to close the repository (and thus give up active control) would come after the approval of a license amendment supported by what will be new and likely more advanced analyses utilizing future data and modeling tools.

7.3 (206)
Comment - 20 comments summarized
Commenters generally expressed concern about the repository site conditions and consequences to future generations or societies. One commenter suggested that "both should be projected at least several thousand years into the future." Other commenters acknowledged that "predicting societal change over the long term was impossible" but that there was still a need to assess the long-term socioeconomic and health impacts. Another commenter suggested that the biosphere would change and, therefore, the human population and pathways of potential importance would change over 10,000 years as the climate changed. There also was worry expressed over the legacy left to future generations.

Commenters stated that nuclear waste would be with us for an extremely long time, and one commenter asked what would happen if some future society had a change in language and could not read warnings we might post or no longer retain the knowledge of radiation. Another commenter asked what would happen if a few hundred years from now someone somehow "taps into" the repository. One commenter said that there would be no institutional controls that last as long as the waste is toxic. Similarly, a concern was expressed that there would be no accountability, the engineering errors of this time would not require an accounting because of failure until long after the current generations are gone.

Several commenters expressed concern over long-term consequences. Commenters expressed concern over the ability of the Federal Government to maintain support in terms of oversight and funding for the required number of decades.

Response
As described in Chapter 1 of the EIS, Congress has determined through the passage of the Nuclear Waste Policy Act of 1982 that the Federal Government has the responsibility to permanently dispose of spent nuclear fuel and high-level radioactive waste to protect the public health and safety and the environment. The Act states that the Federal Government needs to take precautions to ensure that these materials do not adversely affect this and future generations. DOE believes that our elected representatives, having directed the Federal Government to embark on this project, would continue to fund it adequately to protect the public's health and welfare.

Given the current state of technology, it is virtually impossible to design and construct a geologic repository that would provide a reasonable expectation that there would never be any releases of radioactive materials. DOE would design, construct, operate and monitor, and eventually close a repository that would meet public health and safety radiation protection standards and criteria established by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC). Congress, in the Energy Policy Act of 1992, directed the EPA to develop public health and safety standards for the protection of the public from releases of radioactive materials stored or disposed of in a repository at the Yucca Mountain site. Congress also directed the NRC to publish criteria for licensing the repository that would be consistent with the radiation protection standards established by the EPA. In

part, the EPA standards (40 CFR Part 197) and NRC criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, must be designed not to exceed during a 10,000-year period after closure.

In the EIS, DOE has evaluated the ability of the natural and engineered barrier system to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to exceed the prescribed radiation exposure limits during the 10,000-year period after closure. Further, DOE estimates that the average peak dose to a hypothetical individual from the repository would be less than the dose received from natural background radiation.

DOE recognizes, as one commenter noted, that predicting societal change over the long term is not credible. As a consequence, the Department has structured conservative assumptions and scenarios taking into account the regulatory guidance provided by the EPA and NRC, as well as other scientific authorities that have provided reviews. These assumptions and scenarios attempt to reasonably accommodate the inherent uncertainties with estimating long-term repository performance.

DOE confidence in the robustness of its analyses is enhanced by the safety margin and the defense-in-depth provided by the multiple natural and engineered barriers at Yucca Mountain. Nevertheless, the EPA, NRC, and DOE have all recognized that some uncertainty about repository performance would remain. As a consequence, DOE has established performance, monitoring, and site stewardship programs that would accomplish multiple goals related to DOE's obligation to protect the public health and safety and the environment (DIRS 153849-DOE 2001).

After closure, DOE would be responsible for maintaining institutional control over the proposed repository, as required by the Energy Policy Act of 1992. Neither the extent nor the length of this regulatory requirement is well defined at present. However, DOE would maintain appropriate institutional control for as long as required (DIRS 153849-DOE 2001).

To maintain flexibility and an ability to respond to changing conditions and technologies, Section 122 of the NWPA requires retrievability at a geologic repository. Federal regulations (10 CFR Part 63) require that the repository design preserve the option of retrieval on a reasonable schedule for as long as 50 years after the start of waste emplacement. Consistent with these requirements, the operational plan for the Yucca Mountain Repository allows the flexibility to preserve options for modifying emplacement and retrieving waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years, in the event of a decision to retrieve the waste either to protect the public health and safety or the environment, or to recover resources from spent nuclear fuel. During this period, the repository would remain accessible for continued testing and monitoring while providing flexibility to future generations, who would ultimately determine the timing and methods of repository closure.

Once the repository was closed, DOE would implement a postclosure monitoring program pursuant to 10 CFR Part 63. This program would include monitoring activities around the repository after the facility was closed and sealed. The program would include continued oversight to prevent any activity at the site that would pose an unreasonable risk of breaching the repository's geologic or engineered barriers or increasing the radiation beyond allowable limits, as discussed in Section 2.1.2.3 of the EIS. The details of this program would be defined during the processing of the license amendment for closure.

While DOE cannot speculate on future society's ability to read today's warnings or on its retention of knowledge about nuclear materials, it would have an obligation to notify future potential intruders that the repository exists. As a consequence, monuments designed and fabricated to be as permanent as practicable would identify the repository. The monuments would allow intruders the option to make informed decisions regarding the use of the surface and subsurface areas for habitation or other activities.

DOE has considered questions about human intrusion and acknowledged this as an important issue because the future behaviors of humans cannot be predicted. The NRC and the EPA have specified the way to analyze human intrusion in their respective regulations for Yucca Mountain. The regulations describe a stylized calculation that attempts to address why humans would intrude into the proposed repository. DOE also incorporated the advice

provided by the National Academy of Sciences, through a National Research Council report requested by Congress on the *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995).

7.3 (208)
Comment - 11 comments summarized
Commenters cited a report issued by the Peer Review Panel (the Panel) that was, in the view of the commenters, critical of the scientific work underlying the Total System Performance Assessment. The report was offered as an indication that DOE cannot sufficiently assess the long-term performance of the repository because the assessment is based upon approaches that are "fraught" with uncertainty and "flanked" by lack of data. For example, several commenters cited the final report of the Panel, which states "…the panel finds that at the present time an assessment of the future probable behavior of the proposed repository may be beyond the analytical capabilities of any scientific and engineering team. This is due to the complexity of the system and the nature of the data that now exists or that could be obtained within a reasonable time and at a reasonable cost."

One commenter questioned the meaning of the term "reasonable assurance." Another noted that DOE indicates in Chapter 5 of the EIS general agreement with the Panel's advice. However, the commenter wants to know what DOE does not agree with and why.

Response
DOE welcomed the reviews and suggestions provided by the Peer Review Panel (DIRS 102726-Budnitz et al. 1999). The panel was formed to provide a formal, independent evaluation and critique of Total System Performance Assessment carried out for the Viability Assessment (DIRS 101779-DOE 1998). The objectives of the panel are to describe the technical strengths and weaknesses of the Total System Performance Assessment and to provide suggestions for its improvement.

DOE acknowledges the difficulties associated with assessing the performance of the repository over the long periods involved. Section 5.2.4 of the EIS discusses uncertainty in the assessment process. The Peer Review Panel recognized the complexity of the system and nature of the data that now exist or that could be obtained within a reasonable time and at a reasonable cost. The Panel's concerns are provided within that context. The Panel also noted that while serious questions remain as to the adequacy and acceptability of some portions of the analysis, parts of the study were well done. In addition, the Panel noted that the overall performance assessment framework and the approach used in developing the assessment were sound and followed accepted methods.

As presented in the Supplement to the Draft EIS and in the Final EIS, DOE modified its performance assessment in several key areas in response to the Peer Review Panel's critique. Two of the more notable examples are:

1. In the Draft EIS, DOE based cladding failure rates on expert judgment. The Final EIS based cladding failure rates on experimental data.

2. The Panel expressed concern that a hot repository introduced too many uncertainties to model the reasonable long-term performance of the repository, given the current state of knowledge. Major concerns are associated with the ability to model complex coupled processes with the rock in a higher-temperature (above-boiling) state. As a consequence, DOE evaluated a lower-temperature operating mode in the Final EIS. This lower-temperature operating mode would result in lower repository operating temperatures over the long-term life of the repository.

The assessments presented in the Draft EIS were not meant to be definitive predictions of probable repository behavior as used in the Peer Review Report. Work continues to address the higher-priority issues identified in the report and would continue if a decision was made to recommend the site. The purpose of the ongoing work is to ensure that as future decisions need to be made, the basis for the performance calculations will be more and more complete where possible and where important to demonstrate long-term performance.

In its review, the Peer Review Panel does not imply that implementing all their recommendations would result in the ability to calculate probable behavior. The Panel's position is that the recommendations could result in a determination of "whether it can be shown with reasonable assurance that the repository will comply with the applicable regulatory limits."

"Reasonable assurance" is the standard applied in the licensing of commercial nuclear facilities. DOE believes it can perform projections of long-term behavior that are consistent with the regulatory goals of providing reasonable expectation of compliance with dose-based standards.

With regard to the request for an accounting of what DOE did not agree with in the Peer Review Report, the Department does not agree with the Panel's position that "it is unlikely that the [Total System Performance Assessment-Viability Assessment], taken as a whole, describes the long-term probable behavior of the proposed repository (DIRS 102726-Budnitz et al. 1999). The DOE responses to the Peer Review Report are in CRWMS M&O (DIRS 153111-1999).

7.3 (209)
Comment - 26 comments summarized
The term "isolation" was interpreted by many commenters to mean "absolute containment forever". Based on this interpretation, the commenters stated that the Proposed Action would not meet the criteria of "isolation." One commenter added that the concept of "disposal" is not possible because this would require the same idea of absolute containment forever.

Response
The goal of geologic disposal is to concentrate and isolate spent nuclear fuel and high-level radioactive waste in a relatively small area for a very long time. DOE intends to achieve isolation of the wastes in the proposed repository by using a system of engineered barriers and by locating the repository in the geologic setting of Yucca Mountain. However, it is always possible to conceive of circumstances (both manmade and natural) that, given the inherent uncertainties associated with long-term projections, could result in the release of radioactive materials to the accessible environment. It is also likely that eventual release of some material is inevitable because all systems will degrade given sufficient time.

The Environmental Protection Agency standards (40 CFR Part 197) recognize that, with the current state of technology, it is impossible to provide a reasonable expectation that there would be no releases over a 10,000-year or longer time frame. Therefore, the Agency has established public health protection standards that the Agency believes would protect human health and safety. These standards do not require complete isolation of the wastes over the compliance period (that is, 10,000 years) or the period of geologic stability (1 million years). The goal of a performance assessment for Yucca Mountain is to evaluate whether the repository would be likely to meet these standards and thus provide protection of human safety and the environment.

7.3 (210)
Comment - 16 comments summarized
Many comments expressed concern about designing a system that would operate for 10,000 years and longer. Commenters cited the short experience of engineering practices compared to these time frames, along with comparisons between recorded history and the necessary period of performance. One commenter expressed concern about the potential for early cask failures due to manufacturing defects.

Response
DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. The EIS provides the Department's best estimate of the impacts that could occur when the containment system inevitably degraded. The EIS confirms that the Proposed Action would be likely to result in release of radioactive contamination to the environment after repository closure. However, the EIS also shows that these releases under the Proposed Action would not exceed environmental protection standards (40 CFR Part 197) within the 10,000-year compliance period for the repository, standards specifically enacted to ensure the safety of future generations.

In addition to the 10,000-year compliance period, DOE has evaluated potential impacts for the period of geologic stability at the repository (that is, 1 million years). This evaluation was performed consistent with 40 CFR Part 197 to gain insight into the long-term performance of the repository and thus provide information for the decisionmakers in making both design and licensing decisions. These results show a mean peak dose rate that is much lower than background levels (see Section 5.4.2 for details).

With regard to the potential for manufacturing defects, as part of the waste package performance analysis DOE conducted a comprehensive evaluation of fabrication processes that indicated that, for the current design and with a strong quality assurance program, the Department anticipates a very small number of early failures. The DOE long-term performance model represents the number of early package failures statistically as a probability distribution of between zero and five failures. The results show releases during the first 10,000 years that are more than 100,000 times less than the 40 CFR Part 197 individual protection standard of 15 millirem per year. A strong quality assurance program would ensure proper fabrication, stress relief, and testing of the waste packages before emplacement.

7.3 (220)
Comment - 32 comments summarized
A number of comments reflected worry or fear over the potential for catastrophic repository failure from earth motion and volcanism. Several commenters suggested the containers would be vulnerable to earthquake motion, and especially to a penetrating volcanic dike. Among the concerns were: that damage could consist of ready access to the waste, as well as accelerated waste package failures and releases to the water table and the environment; that earthquake damage calculations in the Draft EIS did not include an uncertainty discussion or impacts on downgradient springs; and whether any of the impact analyses would change with the new design that was forecast in the Draft EIS. Potential impacts were said to be missing from a volcanic intrusion with an eruption, and the potential impacts as far away as White Pine County were requested. The adequacy of the rockfall analysis was questioned.

One commenter questioned the impact of a future generation not being able to predict earthquakes, while another questioned the inability to provide a correct future response in case of a disaster. Two commenters questioned the wisdom of siting a repository where there was even the remotest chance of a severe earthquake or a volcanic event. One of those suggested there was a political consideration in the siting process that overruled what would have been an obviously bad choice to an engineer.

Response
The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probabilities and effects of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

One change in the Final EIS is that now there is an aerial pathway release from an eruptive scenario that is analyzed. The dose rates for this scenario are reported in Section 5.7.2 and are well below the 40 CFR Part 197 individual protection standard of 15 millirem per year.

For probabilistic analyses such as that performed to evaluate potential impacts from igneous disruption events in the EIS, a Monte Carlo method was used whereby a number of realizations using different sets of input parameters are added together to give the total probability-weighted dose. For the Final EIS, 5,000 realizations were completed and the results are provided graphically in the Section 5.7.2. The results are presented as a group of curves that display probability-weighted annual dose rates calculated using different sets of statistically sampled values for uncertain input parameters in the model. The range of results shown by these individual curves displays the uncertainty in the calculated dose history resulting from uncertainty in parameter values.

The dose history for the igneous activity scenario in Figure 5-7 of the Final EIS is presented as a probability-weighted annual dose resulting from events occurring at uncertain times throughout the period of simulation. This approach to calculating and displaying the probability-weighted annual doses is consistent with the approach specified by 40 CFR Part 197 and is required for determination of the overall expected annual dose. However, displays of the probability-weighted annual dose do not allow direct interpretation of the conditional annual dose, which is the annual dose an individual would receive if a volcanic event occurred at a specified time. For conditional analyses, the probability of the event is set equal to one, and the time of the event is specified. Conditional results do not provide a meaningful estimate of the overall risk associated with igneous activity at Yucca Mountain, but they provide insights into the magnitude of possible consequences for specific sets of assumptions. A sensitivity calculation was performed to provide results for this conditional case, and conditional

mean annual dose histories were calculated for eruptive events at 100, 500, 1,000, and 5,000 years. The conditional mean dose in the first year after an eruptive event at 100 years after repository closure is approximately 13 rem. The conditional dose in the first year after an eruption decreases to approximately one-half this level for an eruption 500 years after closure, and is approximately 10 percent of this value for an eruption 5,000 years after closure. This calculation was made with a previous TSPA model that has some differences from the model used elsewhere in this EIS for long-term performance. The differences that affect the analysis described above are that dose factors were revised to conform to 40 CFR Part 197 and the distance analyzed is 18 kilometers (11 miles) rather than 20 kilometers (12 miles) from the repository. These changes would be expected to increase the dose values at 100 years and 500 years by a factor of between 2 and 3. The results at the later times would increase by about 20 percent.

As discussed in Section 5.2.3.5 of the Draft EIS, the major effect of an earthquake at Yucca Mountain would be ground motion (shaking) rather than direct offset along a fault. The *Disruptive Events Process Model Report* (DIRS 151968-CRWMS M&O 2000) discusses the effect of offset along a fault. Past movement has been along existing faults, and the probability of new faults forming is low. DOE would not emplace waste packages near existing faults, so the probability of shearing a waste package would be very low.

The rockfall analysis discussed in the *Waste Package Degradation Process Model Report* (DIRS 138396-CRWMS M&O 2000) that supports the Total System Performance Assessment (DIRS 151968-CRWMS M&O 2000) and the Final EIS is much more detailed than that in the Draft EIS. DOE based the analysis of the probability of rocks of various sizes falling and damaging waste packages on the rock properties in the repository. Analyses of this new design (DIRS 114171-CRWMS M&O 1999), which includes a drip shield, show that the waste package could withstand the largest potential rockfall. Adding strong drip shields above the waste packages provides a very robust design that would be able to withstand any credible rockfall. Therefore, the effects of rockfall are not part of the Total System Performance Assessment calculations for the Final EIS.

The analysis for the million-year period extended the screening of seismic damage to waste packages throughout that time. This was an analytical assumption based on using the best data and models available for the Final EIS. No quantitative analysis was performed to determine when a waste package might degrade to the point where it could be damaged by a seismic event. However, it is reasonable to expect that peak dose estimates would likely have been higher (by an unknown amount) if the analysis accounted for potential seismic damage of degraded waste packages hundreds of thousands of years in the future.

Computer technology is being used to assess the impacts on the environment and human population that would result from seismic and volcanic activity, but not to predict the occurrence and magnitude of these natural events. Computer simulation allows the integration of scientific knowledge about earthquakes and volcanism frequencies, and their effects, together with repository design and other data to predict what damage could result from volcanic events. These are the type of results reported in the Final EIS.

Seismic occurrences around Goldfield, Nevada, are similar to those expected for much of the Yucca Mountain setting and earthquakes of the general magnitude and frequency experienced in the Goldfield vicinity are a part of what analysts have termed the “expected case” for Yucca Mountain for purposes of calculating long-term performance assessment for the proposed repository at Yucca Mountain. The 10,000-year results in the Final EIS were obtained using models that were updated with this new information.

DOE has evaluated the long-term geologic stability of Yucca Mountain, including the potential for volcanoes. Volcanic activity has been waning in the recent geologic past; the probability of a volcano that could disturb the repository is very low (see EIS Section 3.1.3.1). Nevertheless, DOE presents an analysis of the effects of both a volcanic eruption, which could release volcanic ash and entrained wastes into the atmosphere, and the intrusion of magma into the emplacement drifts, which could damage waste packages and contaminate the underlying aquifer. DOE estimated potential impacts on the nearest population to the south, conservatively assuming wind in that direction. Impacts in White Pine County would be a small fraction of nearby impacts such as those calculated. Sensitivity studies for the Total System Performance Assessment suggest that the probability-adjusted dose from a volcanic, eruptive event at 20 kilometers (12 miles) in the direction of wind transport of an ash plume peaks at a few hundredth of a millirem per year. Therefore, given that White Pine County is considerably farther from the source, doses would be much lower than the very small doses calculated at 20 kilometers.

DOE's analyses also continue to include water pathways in its analyses of health risks of the proposed repository. The people of Amargosa Valley are most at risk because groundwater in the saturated zone beneath Yucca Mountain flows in a generally southerly direction. They use water acquired primarily from local wells for household purposes, agriculture, dairy and catfish farms, horticulture, and animal husbandry.

With respect to comments regarding potential impacts on Death Valley, the DOE acknowledges in Chapter 3 of the EIS that a small amount of groundwater may move beyond the primary groundwater discharge point at Alkali Flat (Franklin Lake Playa) and continue toward Death Valley through the areas of Tecopa and Shoshone. Some of the groundwater in the Amargosa Desert might move through the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. However, even if this were the case, any impacts on the Furnace Creek area would be even less than the low impacts shown in Chapter 5 of the EIS for the discharge location (Franklin Lake Playa) because the impacts would decline with distance from the repository.

7.3 (221)
Comment - 5 comments summarized
Commenters were dissatisfied that only nine "dominant" radionuclides (carbon-14, selenium-79, technetium-99, iodine-129, protactinium-231, uranium-234, neptunium-237, and plutonium-239 and -242) were selected for the detailed analysis of repository performance. Commenters requested revisions to provide specific information on why a number of long half-lived radionuclides present in the wastes were excluded from the evaluation. The commenters questioned the method used to account for ingrowth of decay products. One commenter also questioned if classified radionuclides had been included in the analysis.

Response
DOE agrees with the concerns raised in these comments. As a consequence, DOE has reevaluated and enhanced the radionuclide screening analysis and inventory abstraction for the analysis of long-term performance for the Final EIS. It should be noted that information provided in the Final EIS is summary in nature because of space limitations. However, the reference documents cited in Final EIS Chapter 5 and Appendix I provide the detailed information necessary to trace important information and to independently verify the results.

The radionuclide screening analyses now encompass the nominal release scenario, disruptive event and human intrusion scenarios, and time periods of 100 to 10,000 years and 1 million years after repository closure. The radionuclide inventory abstraction includes commercial, defense, and naval spent nuclear fuel; defense high-level radioactive waste; and DOE plutonium waste (DIRS 152218-CRWMS M&O 2000). The screening procedure considered factors such as relative contribution to annual dose, radionuclide longevity (that is, decay and production), elemental solubility, transport affinity, release scenario, and containment time (for example, 10,000 years and 1 million years). This screening procedure produced an initial list of radionuclides that was then augmented to account for ingrowth of the actinide decay chains (DIRS 153246-CRWMS M&O 2000). The combined list of radionuclides for the three waste allocation categories was screened to identify the specific ones that could make significant contributions to the calculation of expected annual dose. The results of the radionuclide screening identified the following important radionuclides for various scenarios and time periods:

- Nominal Scenario (and Indirect Release for Volcanism Scenario), 10,000 Years–actinium-227; americium-241 and -243; carbon-14, iodine-129; neptunium-237; protactinium-231; lead-210; plutonium-238, -239, and -240; radium-228; technetium-99; thorium-229 and -232; and uranium-232, -233, -234, -235, -236, and -238.

- Nominal Scenario (and Indirect Release for Volcanism Scenario), 1,000,000 Years–The nominal scenario set for 10,000 years, plutonium-242, radium-226, and thorium-230, less americium-241, carbon-14, plutonium-238, and uranium-232.

- Volcanism Scenario with Direct Release, 10,000 Years–actinium-227; americium-241 and -243; cesium-137, protactinium-231; lead-210; plutonium-238, -239, and -240; radium-232; strontium-90; thorium-229, and uranium-232, -233, -234, and -235.

- Volcanism Scenario with Direct Release, 1 Million Years–Volcanism scenario with direct release for 10,000 years, plus neptunium-237, plutonium-242, radium-226, thorium-230, uranium-236 and -238, less americium-241, carbon-14, plutonium-238, strontium-90, and uranium-232.

- Human Intrusion Scenario, 1 Million Years–Same as nominal scenario for 1 million years.

DOE agrees that the discussion in Section 5.1 of the Draft EIS related to allowance for ingrowth is somewhat confusing. However, the updated analysis in the Final EIS does not require the predecay of relatively short-lived radionuclides because the analysis includes a transport model for chains of radionuclides (that is, parents and their decay products). This enhanced model therefore accounts for release estimates of short-lived radionuclides in the event of early waste package failure from possible disruptive events such as inadvertent human intrusion.

With regard to the human intrusion scenario, for periods of 1 million years, uranium-235 was added to the list because it is a source for actinium-227, which was considered potentially important to dose. In addition, certain radionuclides were added because of their relevance to the groundwater protection standard (40 CFR Part 197). This standard specifies concentration limits for radium-226 and radium-228. As a consequence, radium-228 and its precursor, thorium-232, were added to the list for the case of the nominal scenario. These adjustments expanded the list to a total of 26 radionuclides.

With regard to classified radionuclides/materials in Yucca Mountain, Appendix A provides an inventory of all candidate materials and radionuclides for disposal in the repository. All waste accepted for disposal would be required to meet the repository waste acceptance criteria as well as the packaging requirements regardless of the classification of the materials. These waste form, radionuclide quantity, and packaging requirements were developed to enhance the long-term performance of the repository.

7.3 (222)
Comment - 15 comments summarized
Commenters stated that DOE is designing the repository to leak, and charged that the Department is relying on the natural environment to dilute the contamination. Commenters took the position that DOE could not stop the repository from leaking, citing past failures and leaks at DOE and commercial facilities. Some commenters were concerned that DOE is underestimating the rate at which leaks would occur.

Response
The repository performance assessment does not begin with the assumption the repository will leak. Rather, the assessment assigns probability-of-occurrence values (referred to as probability distributions) to various parameter and process features that include consideration of the uncertainty associated with that parameter or process. When multiple simulations of repository performance (realizations) are computed, the results indicate which of the various outcomes are more likely to occur (mean values). However, in addition to the most likely outcome, the distributions also show extreme cases referred to as the 5th- and 95th-percentile values, which provide a measure of the uncertainty associated with a particular outcome. In response to the observation that the analysis appears to assume, *a priori*, that the repository will leak, it should be noted that, although not likely, there were a number of realizations (outcomes of computer models) that produced no leakage for extremely long times. In the new analyses for the Final EIS, the releases in the first 10,000 years would be extremely small [more than 100,000 times less than the standard set by the Environmental Protection Agency (EPA)] and would be due to the very unlikely event of between zero and five packages failing due to manufacturing defects.

The goal of geologic disposal is to concentrate and isolate high-level radioactive wastes in a relatively small area for a very long time. The Department intends to achieve isolation of the wastes in the proposed repository by using a system of engineered barriers and by locating the repository in the geologic setting of Yucca Mountain. However, it is always possible to conceive of circumstances (both manmade and natural) that, given the inherent uncertainties associated with long-term projections, could result in the release of radioactive materials to the accessible environment. In other words, the eventual release of some material is inevitable because all systems will degrade given sufficient time.

Given the current state of technology, it is virtually impossible to design and construct a geologic repository that would provide a reasonable expectation that there would never be any releases of radioactive materials. DOE would

design, construct, operate and monitor, and eventually close a repository that would meet public health and safety radiation protection standards and criteria established by the EPA and the Nuclear Regulatory Commission (NRC). Congress, in the Energy Policy Act of 1992, directed the EPA to develop public health and safety standards for the protection of the public from releases of radioactive materials stored or disposed of in a repository at the Yucca Mountain site. Congress also directed the NRC to publish criteria for licensing the repository that would be consistent with the radiation protection standards established by the EPA. EPA standards (40 CFR Part 197) and NRC criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, must be designed not to exceed during a 10,000-year period after closure.

In the EIS, DOE has evaluated the ability of the natural and engineered barrier system to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to exceed the prescribed radiation exposure limits during the 10,000-year period after closure. Further, DOE estimates that the average peak dose to a hypothetical individual from the repository would be less than the dose received from natural background radiation.

In terms of contamination at other DOE sites, the Yucca Mountain Repository would be different from other facilities in several important aspects. The system under consideration would allow relatively little water to contact the barriers to waste migration and the materials selected for those barriers would be highly immune to degradation in the anticipated subsurface environment.

DOE believes that it has incorporated much knowledge and data from incidents at other DOE sites into the Yucca Mountain design and performance assessment. To ensure safety, DOE has used conservative (that is, pessimistic) calculations of the potential impacts of this system to estimate the risks of the repository. There has been no effort to minimize these risks.

In addition, in the last 5 years there has been considerable study by DOE, with coordination across locales and programs, of the poorly predicted or unpredicted radionuclide transport phenomena alluded to at other Department facilities. As a result, DOE now has a better understanding of transport processes and has improved its modeling ability. For example, DOE better understands the potential transport of actinides by colloid-sized mineral particles, and has incorporated conservative estimates of such actinide transport mechanisms into the modeling of the proposed Yucca Mountain Repository reported in this EIS (see Chapter 5).

7.3 (232)
Comment - 7 comments summarized
Several comments suggested that climate change should be incorporated into the long-term performance analysis. Several others acknowledged that climate change had been addressed, but not in sufficient detail to allow impacts from climate change to be properly evaluated. Commenters suggested, for example, that the increased flux in the unsaturated zone had not been properly incorporated; another suggested that extreme precipitation events had not been properly evaluated.

Response
The Draft EIS included an evaluation of climate change and its effects on long-term performance. These effects included increased infiltration, increased flux at depth, increased radioactive material transport at depth after waste package failure, and a shortened path to the water table because of changes in water table elevation.

The Draft EIS performance assessment considered three climate scenarios: present day, long-term average (wetter than the present-day climate), and superpluvial (Draft EIS Section I.4.2.4). These climate scenarios were assumed to occur at short-duration, fixed intervals on a periodic basis during the 1,000,000-year period after waste emplacement. However, the modeling of climate states was changed for the Final EIS based on the latest research of the U.S. Geological Survey and the Desert Research Institute. As a consequence of this work, pluvial states were expanded to allow short-duration states within them resembling the previously modeled superpluvial states. Superpluvial states are no longer included as separate states based on the results of this continued research.

Models of future climates caused by global warming from increased atmospheric carbon dioxide are speculative, though they are supported by some global climate modeling and the general increase in global temperature noted in the 20th Century. At Yucca Mountain the estimated effect of global warming would increase average precipitation

to a level similar to the long-term average climate of the Draft EIS, which resembles the glacial-transition climate in the Final EIS. This estimate, which is based on atmospheric model input, resembles near-continuous El Niño conditions and the near doubling of the precipitation that accompanies these conditions. In other words, DOE considers global warming impacts on future climates to be within the bounds of predicted climate ranges used in the assessment of long-term performance. Chapter 5 of the Final EIS incorporates such climate impacts in the estimates of the environmental consequences of long-term repository performance. These impacts include the effects of global warming and future climate change in general.

Extreme precipitation events were mentioned in Section 3.1.2.2, but do not greatly influence the infiltration rates discussed and used for modeling purposes in Chapter 5 and Appendix I. This is because the subsurface tends to "damp" the extreme events (particularly in the Paintbrush nonwelded stratigraphic unit) to produce a nearly uniform infiltration rate with time at depth. If anything, extreme precipitation events are more closely associated with surface runoff events. Locality-based infiltration rates were used (not whole-mountain averages) to derive infiltration rates for repository zones modeled in the performance analysis. The approach to discretizing the repository (dividing it into discrete zones) for performance analysis calculations, and the areal infiltration rate applicable to each modeled zone, has been updated for the calculation results reported in the Final EIS (Section 5.4).

7.3 (238)
Comment - 2 comments summarized
Commenters stated, "The analysis is very detailed discussing the latent cancer fatalities with respect to a chosen scenario. For the undisturbed case DOE states '...that it is mostly likely that no person would die due to groundwater contamination by radiological material in the 10,000 year period....'" Commenters requested "the worst case scenario using a pregnant woman and young children to establish the dose rate, and don't use the new dose rate that you guys are trying to put into the record. Use the EPA rate."

Response
The EIS does not present a worst-case scenario for dose-to-receptor analysis and calculations because no matter what worst-case choice was presented, it would be always possible for someone to develop a worse scenario. This is consistent with the Council on Environmental Quality regulations that implement the National Environmental Policy Act. These regulations do not require a worst-case analysis. In addition, problems related to worst-case analyses were recognized as a potential issue by the Environmental Protection Agency (EPA), which settled the issue by prescribing a biosphere modeling approach and identifying the potential dose recipients to be evaluated in the analyses as part of the Yucca Mountain environmental protection standards (40 CFR Part 197).

With regard to estimating dose to special groups within the general population (for example, children, pregnant women, and the fetus), the Department recognizes that metabolic weighting factors (such as those described in ICRP (DIRS 101836-1991) are constantly under study and refinement. This research will continue. For this reason, DOE has decided to use the methodology specified by the regulatory standards for the Yucca Mountain Repository promulgated by the EPA (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63). This method of dosimetry is fully described in ICRP (DIRS 101075-1977) and the dose conversion factors derived from this methodology and used in the EIS are provided in Federal Guidance Reports 11 and 12 (DIRS 101069-Eckerman, Wolbarst and Richardson 1988 and DIRS 107684-Eckerman and Ryman 1993, respectively). In addition, the EIS has incorporated the reasonably maximally exposed individual concept described in the preamble to 40 CFR Part 197 to project potential doses for long periods.

DOE will continue to monitor the future developments in the field of dosimetry and will refine its dose factors as necessary to ensure capture of generally accepted scientific principles, recommendations by national and international scientific advisory groups and, where appropriate, regulatory requirements.

With regard to use of the recently published EPA age-specific risk factor of 5.75 chances in 10 million per millirem for fatal cancer (DIRS 153733-EPA 2000), DOE currently uses the value of 5.0 and 4.0 chances in 10 million per millirem for fatal cancer for members of the public and workers, respectively, as recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991). When recommending these risk factors, the International Commission on Radiological Protection also expressed the desirability, for purposes of radiation protection, to use the same nominal risk factors for both men and women and for a representative population with wide ranges in age. The Commission stated that although there are differences between the sexes and populations of

different age-specific mortality rates, these differences are not so large as to necessitate the use of different nominal risk factors. However, the higher risk factor for members of the public compared to that recommended for workers accounts for the fact that children comprise a relatively large part of the population and are more sensitive to the effects of radiation (cancer induction) than adults. Although the embryo-fetus is more radiosensitive (with a radiation risk factor about two times that for the whole population) it is protected by the body of the mother and comprises a small part of the overall population. Pregnant women are not particularly radiosensitive, especially to low levels of radiation.

Both the EPA and DOE recognize that there are large uncertainties associated with these risk factors, as expressed by the National Council on Radiation Protection and Measurements comment on the result of their uncertainty analysis in the risk coefficients that "... show a range (90 percent confidence intervals) of uncertainty values for the lifetime risk for both a population of all ages and an adult worker population from about a factor of 2.5 to 3 below and above the 50th percentile value" (DIRS 101884-NCRP 1997). DOE believes that the 15-percent difference in these risk factors is well within other uncertainties and would provide little additional information to the decisionmaking process that this document informs. In the Final EIS, DOE used risk factors recommended by the International Commission on Radiological Protection.

7.3 (239)
Comment - 13 comments summarized
Several commenters expressed concern that there was undue reliance on the integrity of the waste form to contain radioactive materials. Comments focused on the issue of whether the cladding on spent nuclear fuel would provide any containment and whether any credit should be taken for cladding containment in the long-term performance assessment. Commenters expressed concern that the high-level radioactive waste glass form would not maintain integrity over long periods and skepticism that the current models being used for neptunium solubility were appropriate for assessment of release of neptunium-237 from the waste forms. Commenters expressed concern about degradation of storage casks and waste forms while they are in dry storage.

Response
DOE has conducted considerable research on the various waste form materials. This information has been used to develop models of how these materials would perform over long periods in the repository environment. For example, models of commercial spent nuclear fuel dissolution are based on experimental tests where actual reactor fuel has been used. The models for borosilicate glass and the plutonium ceramic are also based on extensive testing. Dissolution and degradation models for borosilicate glass have been under development for over 25 years, and there has been extensive testing of plutonium ceramic degradation for several years to support the Yucca Mountain Project. While all these waste forms eventually degrade and dissolve, the process is extremely slow, being characteristic of reactions of water on glass and ceramic materials where time scales are in the hundreds of thousands of years (DIRS 153246-CRWMS M&O 2000, Section 3.5.3).

The dissolution models used in the Total System Performance Assessment are described in the Final EIS. Details about these models are contained in supporting documents referenced in Section I.2.5.

Since the publication of the Draft EIS, research has continued on solubility of neptunium, with considerable focus on formation of secondary phases. Recent data, incorporated in the analysis presented in Chapter 5 of the Final EIS, show that the lower solubility results in considerably lower peak doses than found in the analysis in the Draft EIS.

The updated zirconium alloy cladding failure models used for the Final EIS analyses include representations of cladding behavior that are extremely conservative, which resulted in highly conservative values of failure rates (DIRS 153246-CRWMS M&O 2000, Section 3.5.4). In addition, no barrier credit was taken for either stainless-steel packaging or cladding, or cladding on DOE spent nuclear fuel.

The cladding degradation model used for the Final EIS is much more rigorous than that for the Draft EIS. The model is based on empirical data and includes localized corrosion and unzipping effects. This model results in greatly reduced reliance on cladding than was the case for the Draft EIS (see Section I.2.5). The Final EIS analysis also includes seismic effects on the cladding, so the occurrence of seismic activity was modeled as damaging the cladding within the waste packages. Nevertheless, the peak doses in the Final EIS would be lower than those in the Draft EIS.

7.3 (252)
Comment - 7 comments summarized
Some commenters expressed concern that microbes could conceivably contribute significantly to degradation of materials, especially in waste packages or drip shields.

Response
Microbes would not directly attack the materials; rather they would be responsible for biofilms (layers of dead organisms and waste products) that would alter the chemistry on the surface of the material. The modeling of corrosion of the Alloy-22 includes enhancement factors for microbial-induced corrosion. Very conservative values are used to account for this possibility, even though research to date has not identified significant effects of biofilms on the material. The research indicates no tendency for the titanium drip shields to be affected in any way by such films, so no enhancement factors were used (DIRS 153246-CRWMS M&O 2000). This is also discussed in Section I.2.4 of the EIS and referenced supporting documents.

7.3 (253)
Comment - 7 comments summarized
Commenters expressed concern that deficiencies found in the DOE quality assurance program and the large number of errors identified by the Nuclear Regulatory Commission cast significant doubt on the validity of the TSPA-SR long-term performance estimates. Several commenters suggested that the deficiencies were so great that the Supplement to the Draft EIS and the Science and Engineering Report should be withdrawn and resubmitted pending resolution of all the quality assurance findings and the calculational errors.

Response
DOE has an ongoing program to address Nuclear Regulatory Commission (NRC) comments on technical issues, largely as they have been translated into its comprehensive listing of scientific modeling issues in the Commission's Issue Resolution Status Reports (see, for example, DIRS 135160-Bell 1996; DIRS 154605-NRC 2000). Not all technical issues raised by the NRC are closed, but DOE has made and will continue to make a good faith effort to address each issue to the extent practicable. As reported in the Final EIS, DOE has made a number of modifications to the design of the repository and to the Total System Performance Assessment that address NRC concerns. As of September 1, 2001, the Key Technical Issues had all been declared "Closed-Pending" by the NRC.

DOE has made a similar best effort to address the status of model validation and quality assurance findings. The Department recognizes that it needs to apply a rigorous and effective quality assurance program, and that doing so will be crucial to demonstrating the validity of findings and analyses in any License Application. In response to previous NRC comments in this area, the Department has established a schedule for achieving quality assurance goals by the time of the License Application, if Yucca Mountain is found suitable and approved for development of a repository. DOE has met interim quality assurance goals for the Site Recommendation phase.

DOE has taken action to correct the deficiencies and ensure that similar deficiencies do not recur. On September 6, 2001, DOE provided transition plans for the respective quality assurance programs that would support becoming a licensee. Implementation of these transition plans is periodically reviewed by the NRC.

DOE has also evaluated the effects of the identified deficiencies on the performance analysis performed and determined that they did not affect long term performance estimates.

7.3 (256)
Comment - 9 comments summarized
Commenters expressed concern that the human intrusion scenario was inadequate, unrealistic, or too constrained and that additional effects such as atmospheric release and direct exposure of the drilling crew should have been considered. Commenters were not satisfied with only one occurrence or with the assumed timing of the occurrence and also suggested the scenario evaluated in the EIS was inadequate because it relied on the integrity of waste packages and the continuing use of current drilling technology. Commenters stated that the risk would increase over time, because peak doses increase over time. Commenters also expressed concern with the possibility of sabotage or terrorism over the next 10,000 years. Commenters suggested that the human intrusion scenario should factor in the potential presence of mineral deposits and other natural resources as well as the potential for people to explore for

these resources in the future. Commenters expressed concern related to the statement by the State of Nevada that "drilling could occur not long after closure of the repository."

Response

The estimation of impacts from human intrusion into the repository is an analytical issue because the future behavior of humans cannot be accurately predicted. The Nuclear Regulatory Commission and Environmental Protection Agency have provided guidance to analyze human intrusion in their regulations for Yucca Mountain. The regulations describe a stylized calculation that attempts to minimize speculation as to why humans would intrude into the repository.

In formulating the regulatory approach to the human intrusion scenario, the Environmental Protection Agency and Nuclear Regulatory Commission paid attention to the advice given by *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995). That report suggests there are three types of intrusions: inadvertent and the intruder does not recognize that a hazard has been created, inadvertent and the driller recognizes the hazard and takes corrective action, and intentional (DIRS 100018-National Research Council 1995). The last category would include terrorists or saboteurs, but it could also include a society needing to access the material for its energy content. The members of the National Research Council committee decided to recommend that only the first category be addressed, because the second category, if corrective measures are ineffective, would have the same consequences as the first. The third category was an imponderable given the unpredictability of future human society. There is no way to absolutely ensure that if a future society wished to re-enter a repository, it would not be able to do so.

The members of the committee then assessed the types of consequences from the first category of intrusion. There would be drill cuttings brought to the surface, and these would present a hazard to the drillers and subsequent visitors to the site. It was suggested these types of consequences not be considered because they are the consequences of an intrusion that would apply no matter where the repository was located and, therefore, would not provide useful information about the safety of any particular location. The consequence recommended for evaluation was the dose to the same critical population group addressed in the long-term performance of the undisturbed repository. Therefore, the important thing is how the intrusion event affects safety by potentially degrading the engineered and natural barriers in a given location.

With regard to evaluating multiple intrusion events, the National Research Council (DIRS 100018-1995) concluded that one borehole was a good test of system resiliency, and going further was so speculative that it served no purpose useful in judging the robustness of a system. The Council also recommended the assumption of the use of current drilling technology to avoid speculation over future advances in drilling technology. The emphasis was recommended to be on the analysis of the creation of enhanced environmental transport pathways.

These conclusions and recommendations have been endorsed by the Environmental Protection Agency (40 CFR 197.26). DOE recognizes the efforts made by the National Research Council and agrees with the conclusions to which they came. The Department also recognizes that there are other viewpoints and opinions of merit, but agrees with the National Research Council and the Environmental Protection Agency that the amount of speculation required to implement other approaches to defining human intrusion consequences would make the results of such analyses arguably meaningless.

For the Draft EIS, the intrusion event was assumed to occur 10,000 years after closure of the repository. This time was chosen because it is the earliest time that waste packages (under the Draft EIS design) would have probably degraded to the extent necessary to allow penetration without the use of specialized drill bits. However, for the analysis presented in the Final EIS, DOE chose intrusion at 30,000 years to simulate an intrusion at a time when the intruder might not detect the waste package because of its weakened state. Over time, as more waste packages failed (and potential doses rose toward a peak dose from the overall system), intrusion would become less, not more, meaningful. This is because the more waste packages have failed, the less the additional waste package failure from drilling would contribute to the overall risk.

Section 5.7.1 of the Final EIS discusses the human intrusion scenario analysis and results.

As discussed in Section 3.1.3.4 of the EIS, site characterization activities have found no economic deposits of base or precious metals, industrial rocks or minerals, or energy resources based on present use, extraction technology, and economic value. The operating gold and silver mines visible from the mountain are in a different type of rock than Yucca Mountain. Those rocks formed deep in the Earth, and uplift has exposed them. Yucca Mountain was formed by ash flow and ash fall from volcanic events. Thus, DOE believes that the potential for intrusion resulting from resource recovery would be minimal.

7.3 (491)
Comment - EIS000120 / 0005
The fact that any groundwater at all comes in contact with these containers to me is not acceptable.

Response
One of the key attributes of the Yucca Mountain repository safety strategy is minimizing the amount of water that contacts the waste packages. However, this does not imply precluding such contact. The waste packages would be fabricated with a highly corrosion-resistant barrier that would result in very long waste package lifetimes even in the presence of water. In addition, DOE has modified the repository design to include a titanium drip shield with the purpose of diverting any seeping water away from the waste packages. Analyses conducted in support of the Site Recommendation process and the Final EIS include these drip shields. Such analyses also assess the effects of any water contacting the wastes in the evaluation of risk to the public and the demonstration of safety in accordance with regulatory requirements. The Final EIS documents the revised repository design and the long-term performance assessment analyses based on this design.

7.3 (600)
Comment - EIS000127 / 0017
When they do their comparisons here, they got a nice little pretty map here comparing the two no action scenarios, the one that assumes that for the 10,000 years, we're going to keep rebuilding this thing every hundred years, as least, effective institutional control for 10,000 years, and the another one that assumes that we'll lose that control in about a hundred years.

What they don't talk about is as soon as they put those things in the mountain and close the hole, they've lost institutional control. They have no way to deal with it if it's leaking, and yet that's not considered in the Environmental Impact Statement.

Response
The scientific community has long recognized that absolute confinement forever is not practical in any system. What is practical is to work to standards that can be agreed upon as providing sufficient protection of human health and the environment. The Environmental Protection Agency has set such standards (40 CFR Part 197), and the Nuclear Regulatory Commission is guiding the planning and development of the proposed repository (10 CFR Part 63).

DOE's plan for the repository includes the ability to retrieve the waste for 50 to 300 years after the start of emplacement. Part of the reason for this feature is to ensure the public health and safety and the protection of the environment should the proposed repository not perform as expected. Throughout the licensing, construction, operation, and maintenance of the repository, DOE would conduct performance confirmation activities to evaluate the adequacy of the information used to demonstrate compliance that the repository would meet long-term performance objectives. If the data determined that actual conditions differed from those predicted, the NRC would be notified and remedial measures would be undertaken to address any such condition. Nuclear Regulatory Commission regulations [10 CFR 63.51 (a)(1) and (2)] require a license amendment for permanent closure of the repository. This amendment must specifically provide an update of the assessment for the repository's performance for the period after permanent closure, which would include institutional control.

After closure, DOE would have the responsibility of maintaining institutional control over the repository, as required by the Energy Policy Act of 1992. The methods, extent, and length of this regulatory requirement are not well defined at present. However, DOE would maintain appropriate institutional control for as long as required. DOE and NRC would define the details of this program during the processing of the license amendment for permanent

closure. Deferring a description of this program until closure would allow for the identification of appropriate technology, including technology that might become available in the future.

7.3 (951)
Comment - EIS000259 / 0003
On a related topic, we are concerned that all the design alternatives considered in the EIS lead, ultimately, to a repository that leaks. DOE must have as its goal complete and permanent isolation of radioactive material from humans. In our estimation, the only way to meet this goal is to have a permanently open and thoroughly monitored facility.

Backfilling and closing the repository complicates close monitoring of the waste packages for structural integrity and increases the difficulty and cost of retrieving the waste should a radioactive release occur or new findings and technologies emerge which provide for safer forms of storage or reuse of the nuclear material.

With a closed repository, groundwater contamination will not be noticed until radioactive material shows up in monitoring wells, by which time a contaminant plume is probably already well developed and beyond mitigation.

Leaving the repository open and ventilated also has the potential to drive out heat and moisture which would otherwise build up in the facility, possibly slowing or eliminating movement of water through the facility into the groundwater. The EIS should include, as a mitigation measure, a commitment to leave the repository open and ventilated indefinitely, with the decision to close the facility left up to future generations.

In closing, we believe that the project should incorporate a zero-tolerance approach to radioactive releases from the repository. The project and the EIS should not anticipate a closure date for the repository, and, in order to mitigate the many uncertainties associated with repository performance, to allow flexibility in future decision-making, and to safeguard the residents and users of Amargosa Valley and Death Valley, the facility should be kept open and monitored on an indefinite basis.

Response
The goal of geologic disposal is to concentrate and isolate high-level radioactive wastes in a relatively small area for a very long time. DOE intends to achieve isolation by using a system of engineered barriers and by locating the repository in the geologic setting of Yucca Mountain. However, it is always possible to conceive of circumstances (both manmade and natural) that, given the inherent uncertainties associated with long-term projections, could result in the release of radioactive materials to the accessible environment. It is also likely that eventual release of some material is inevitable because all systems will degrade given sufficient time.

The Environmental Protection Agency, in promulgating the Yucca Mountain environmental protection standards (40 CFR Part 197), recognized that with the current state of technology it is impossible to provide a reasonable expectation that there would be no releases over 10,000 years or longer. Therefore, the Agency established standards that it believes provide comparable protections to those of other activities related to radioactive and nonradioactive wastes. These standards do not require complete isolation of the wastes over the compliance period (10,000 years) or the period of geologic stability (1 million years). The goal of a performance assessment such as the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000) performed for Yucca Mountain, is to evaluate whether the repository is likely to meet these standards.

A postclosure monitoring program is required by 10 CFR Part 63. This program would include the monitoring activities around the repository after the facility was closed and sealed. At 10 CFR 63.51(a)(1) and (2), the rule requires that a license amendment be submitted for permanent closure of the repository. This amendment must specifically provide an update of the assessment for the repository's performance for the period after permanent closure, as well as a description of the program for postclosure monitoring. This program would include continued oversight to prevent any activity at the site that would pose an unreasonable risk of breaching the geologic repository's engineered or geologic barriers; or increasing the exposure of individual members of the public to radiation beyond allowable limits. The details of this program would be defined during the processing of the license amendment for permanent closure. Deferring a description of this program until the closure period allows for the identification of appropriate technology including technology that might become available in the future.

Section 122 of the NWPA requires retrievability at a repository. Federal regulations (10 CFR Part 60 and 10 CFR Part 63) require that the repository be designed to preserve the option of waste retrieval on a reasonable schedule for as long as 50 years after the start of waste emplacement. Consistent with these requirements, the operational plan for the proposed Yucca Mountain Repository provides for a design and management approach that isolates wastes from the public in the future while allowing flexibility to preserve options for modifying emplacement and retrieving the waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. During this period, the repository would remain accessible for scientists to continue testing and monitoring while providing more flexibility for future generations of scientists and engineers to continue evaluating repository performance and the methods of repository closure.

DOE recognized in the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review of the repository by the Nuclear Regulatory Commission. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS.

The Supplement to the Draft EIS and the Final EIS evaluate the environmental impacts of the higher-temperature repository operating mode, which is the design focus of Section 2.1.5 of the Science and Engineering Report (DIRS 153849-DOE 2001). In addition, the Supplement to the Draft EIS and the Final EIS evaluate the impacts for the lower-temperature repository operating mode (which embraces a range of operational parameters including 300 years of extended ventilation). The differences between these modes deal with the highest postclosure temperatures of the waste package surfaces, the temperature of the emplacement drift rock walls, and the overall temperature of the repository rock. Section 2.3 of the Supplement and Section 2.1.2.2.4 of the EIS describes the design modifications including the addition of drip shields and refined waste packages. DOE is not currently considering backfill in the emplacement drifts as part of the repository design.

7.3 (1153)
Comment - EIS001912 / 0108
Section 9.2, Groundwater -- this section has nothing to do with mitigation. None of the discussion has to do with mitigation. Some level of contingency plans should be included in this section. Appropriate mitigation should also include long-term monitoring procedures for areas aquifers. A discussion of possible adverse impacts and human health impacts should be included in the EIS.

Response
Chapter 5 of the EIS contains a full discussion of the potential for adverse long-term groundwater impacts; Section 4.1.3.3 addresses the potential for adverse impacts to groundwater anticipated from repository construction and operation. These discussions also address potential human health impacts.

DOE is considering a range of additional mitigation measures aimed at reducing the effects of the proposed repository project. These measures would complement the physical features, procedures, and safeguards already incorporated into the project plan and design to reduce environmental consequences. Chapter 9 of the EIS, which provides the Department's initial list of commitments, identifies DOE-determined impact reduction features, procedures and safeguards, and mitigation measures under consideration for inclusion in the project plan and design. Chapter 9 also identifies ongoing studies that could influence mitigation measures related to the project plan and design. For example, Section 9.2 discusses mitigation measures DOE would implement or consider to reduce potential impacts from the construction, operation and monitoring, and eventual closure of the proposed repository. Section 9.2.3.2 enumerates mitigating actions related to groundwater. Similarly, Section 9.3 discusses mitigation measures to reduce potential impacts from the national transportation of spent nuclear fuel and high-level radioactive waste.

The Proposed Action includes a lengthy program of performance monitoring and testing. Testing and performance confirmation would continue for perhaps as long as 300 years after the end of emplacement, through closure of the repository (see Section 2.1.2.3 of the EIS). It would provide data to future decisionmakers on the performance of the repository and on closing the repository or retrieving the wastes. The details of the postclosure monitoring program would be defined during the processing of the license amendment for permanent closure, but the types of

monitoring that DOE would consider are discussed in Section 2.1.2.3. Deferring a description of this program until the closure period would enable the identification of appropriate technology, including technology that could become available in the future.

7.3 (1341)
Comment - EIS000424 / 0001
My first concern is about the drinking water of the surrounding communities whose water comes from Yucca Mountain. These people do not just live in Nevada, but California as well. If the nuclear waste leaked into the water system then the cancer rate would rise by dramatic levels.

If the cancer levels rose and people died due to the cancer which was caused by a project by the US government you could be looking at many large lawsuits in the future. You would be responsible for the mutation of genes in these communities and will have to put more money for more research on cancer.

Response
Prior to recommendation of the Yucca Mountain site for development of a geologic repository, DOE will have to provide reasonable expectation that the repository can meet environmental protections standards (40 CFR Part 197) developed by the Environmental Protection Agency to protect human health and the environment. The estimated dose from long-term repository performance (see Section 5.4) represents a small fraction of the environmental protection standards. Therefore, the Department believes that the occurrence of adverse health effects would be highly unlikely for all potentially exposed populations, including those in Death Valley.

7.3 (1404)
Comment - EIS000434 / 0003
I would like to know how Yucca Mountain would be evaluated and determined as a safe place to store the nuclear waste. In case of a leak in the canisters, the gases could leak, through a possible crack in the mountain.

Response
Section 5.5 of the Draft EIS evaluated the potential for release of radioactive gases (carbon-14) from the repository. The potential impacts to the surrounding population would be a very small fraction of the applicable environmental protection standards (40 CFR Part 197). Thus, DOE believes that the occurrence of adverse health effects from these releases would be highly unlikely.

The Final EIS considers (see Section I.7.3) the gas radon-222 that is formed as part of the radionuclide decay chain resulting from emplacing uranium-234 in the repository. This gas is expected to decay before reaching the ground surface because it has a half-life of about 3.8 days.

7.3 (1436)
Comment - EIS001888 / 0088
In Section 5.6, the DEIS presented consequences from chemically toxic materials. One of the elements considered in this analysis is chromium. The amount of chromium considered has been grossly underestimated since the design that the DOE is currently contemplating as the license application design uses stainless steel, instead of carbon steel as one of the barriers. In view of this, we feel DOE must consider whether RCRA [Resource Conservation and Recovery Act] regulations apply to the repository. If DOE feels that such regulations do not apply, they must provide rationale to support this position.

Response
The quantities of chromium reported in the Final EIS are accurate for the updated design. Revised evaluations for chromium have been conducted. These evaluations indicate that impacts would be lower than the Maximum Contaminant Level Goal for chromium.

Because the analysis shows extremely low levels of chromium in wells, the Resource Conservation and Recovery Act of 1976 would not apply. Furthermore, while chromium+6 is regulated as a waste under the Act, it would not be a chromium+6 solution or salt that would be placed in the repository, but rather chromium as a part of an alloy used in waste package construction. The corrosion of the chromium would lead to some soluble form, which has

been very conservatively assumed to be chromium+6 (evidence indicates it would probably be chromium+3, a nontoxic, low-solubility form of chromium that is a nutrient).

7.3 (1481)
Comment - EIS001521 / 0019
Page 3-12, 3.1.2.2 Climate, first paragraph--Have these extreme precipitation events been used in determining Yucca Mountain infiltration (recharge) rates as discussed later in this chapter? Applying a range of locality-based infiltration rates would be much more realistic than using a whole-mountain average.

Response
Extreme precipitation events were mentioned in Section 3.1.2.2, but do not greatly influence the infiltration rates discussed and used for modeling purposes in Chapter 5 and Appendix I. This is because the subsurface tends to "damp" the extreme events (particularly in the Paintbrush nonwelded stratigraphic unit) to produce a nearly uniform infiltration rate with time at depth. If anything, extreme precipitation events are more closely associated with surface runoff events. Locality-based infiltration rates were used (not whole-mountain averages) to derive infiltration rates for repository zones modeled in the performance analysis. The approach to discretizing (dividing the repository into discrete zones) the repository for performance analysis calculations, and the areal infiltration rate applicable to each modeled zone, has been updated for the calculation results reported in the Final EIS (Section 5.4).

7.3 (1811)
Comment - EIS000332 / 0010
Key aspects of the risk assessments presented in the DEIS are based on estimated values rather than actual data. The NWTRB's [Nuclear Waste Technical Review Board] experts have severely criticized the results of the models that are used as the basis for the DOE's risk assessments. Additionally, results of the models indicate chemical toxicity may pose greater risk to Nye County residents than releases of radiation from the repository. Only now are data being collected and tests being planned to provide the information needed to do meaningful risk assessments. Coupled with inappropriate assumptions and inaccurate data, these assessments result in artificially low risk values for Nye County residents.

The evaluation of impacts associated with the performance confirmation program, as described in the EIS, does not contemplate the remedy(ies) that DOE would implement should conditions occur that suggest that repository performance could fall below those predicted. Nor does the EIS provide an analysis of the impacts that would occur should the repository not perform as predicted or planned.

Response
The EIS shows some likelihood of chemical contamination but, similar to radiological contamination, DOE must establish a reasonable expectation that the levels of contaminants where persons would be likely to use the groundwater would meet health and safety targets set by the Environmental Protection Agency.

The Nuclear Waste Technical Review Board and other reviewers have been critical of the work done for and prior to the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). In the 2 years since DOE published the Viability Assessment, many of the criticisms received have led to activities that have improved the modeling and its bases.

In relation to underestimating potential risk to Nye County residents, DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. However, confidence in the disposal techniques is based on a defense-in-depth that, for example, would place drip shields over waste packages to account for uncertainties. DOE has adopted an analysis approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment

2. Consideration of features, events and processes that could affect repository performance over the long term

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as

changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low-probability events such as volcanoes, earthquakes, and nuclear criticality

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario

5. Parameter distributions that represent the possible change of the system over the long term

6. Use of conservative assessments that lead to an overestimation of impacts

7. Performance of sensitivity analyses

8. Use of peer review and oversight

DOE is confident that its approach to long-term performance analysis addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

DOE designed activities associated with the performance confirmation program to ensure that the repository would meet specific regulatory requirements [10 CFR 63.102(m) and 10 CFR 63 Subpart F]. As defined, the program consists of tests, experiments, and analyses to evaluate the adequacy of the information used to demonstrate compliance that the repository would meet the postclosure objective. The description of the performance confirmation program is documented in "Performance Confirmation Plan" (DIRS 146976-CRWMS M&O 2000).

The performance confirmation program would monitor and test key geologic, hydrologic, geomechanical, and other physical processes or factors (and related parameters) throughout construction, emplacement, and operation to detect significant changes from baseline conditions. DOE would use these data to confirm that subsurface conditions were consistent with the assumptions used in performance analyses and that barrier systems and components operated as expected.

Consistent with Federal regulations (10 CFR Part 963), the operational plan for the Yucca Mountain Repository provides a design and management approach that isolates wastes from the public in the future while allowing flexibility to preserve options for modifying emplacement and retrieving the waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years after the end of waste emplacement in the event of a decision to retrieve the waste to protect the public health and safety or the environment or to recover resources from spent nuclear fuel.

Because retrieval is not anticipated, DOE did not include it as part of the Proposed Action. However, the EIS evaluates retrieval as a contingency action and describes potential impacts if it occurred (see Section 4.2). DOE evaluated only actions that could be predicted with any certainty (that is, removal of the emplaced waste materials and subsequent onsite storage). Because any future actions regarding the management and disposition of these materials following retrieval would be at the direction of Congress and highly speculative, DOE believes it would be inappropriate to attempt to evaluate impacts that could result from these actions.

If the integrity of the repository was compromised, mitigation activities would be funded under the Price-Anderson Act. The Act provides liability coverage for commercial activities operating under a license from the Nuclear Regulatory Commission and for DOE activities by establishing a system of private insurance and Federal indemnification that generally ensures that as much as $9.43 billion is available to compensate for damages suffered by the public from a "nuclear incident," regardless of who causes the damage. Payment would be from Federal funds or, if public liability arose from nuclear waste activities funded by the Nuclear Waste Fund (for example, activities at a geologic repository), from the Nuclear Waste Fund (see Section M.8).

7.3 (1880)
Comment - EIS000443 / 0012
The ground water from the site currently is used for agriculture in the regions. DEIS does not fully address consequences of contamination of the ground water and its impact on regional uses. It also incorrectly assumes

dilution will reduce the consequence of radiation and that will be an acceptable way to reduce concentration. Given the longevity of the container and the mountain barrier has not been determined, assumptions of contamination are premature at best and woefully under estimated at worst.

Response
Sections 3.1.1.1 and 3.1.4.2.1 of the Draft EIS provide information on current land and groundwater use, respectively, which includes various agricultural activities (for example, farming and dairy operations). The potential long-term (10,000-year) consequences for the three thermal load scenarios are presented in Section 5.4 of the Draft EIS and include estimated groundwater concentrations of radionuclides (Tables 5-7, 5-11, and 5-15). In addition, potential consequences (radiation dose) and human health impacts (latent cancer fatalities) resulting from of food and consumption and irrigation of feed crops are presented (Tables 5-4, 5-5, 5-8, 5-9, 5-12 and 5-13) for both reasonably maximally exposed individuals and populations for the three thermal load scenarios. These estimated consequences are a small fraction of the environmental protection standards promulgated by the Environmental Protection Agency (40 CFR Part 197) for the proposed Yucca Mountain Repository to ensure protection of the environment and human health. Therefore, DOE expects no adverse radiation-related health impacts of any kind to the population around Yucca Mountain within 10,000 years of repository closure. In addition, whereas the repository design evaluated in the Draft EIS projected small releases within the 10,000-year compliance period, the flexible design evaluated in the Final EIS projects that the Proposed Action probably would result in even smaller releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197). Therefore, DOE believes that the occurrence of adverse impacts would be highly unlikely within 10,000 years after closure with the flexible design.

With regard to the use of dilution factors, DOE does not believe that dilution, in and of itself, is an acceptable method to meet environmental protection standards. However, the Environmental Protection Agency has specified the location of the reasonably maximally exposed individual for compliance purposes (40 CFR 197.21). DOE has used the best available information and generally accepted methods, which include credit for dilution, to estimate potential impacts to this hypothetically exposed individual at this location.

With regard to uncertainties related to engineered and natural barrier protection, DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency, and Nuclear Regulatory Commission also recognize the difficulty of understanding the behavior of complex systems over long periods. In 10 CFR Part 63, the Commission acknowledged that "absolute proof is not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." Similarly, the Environmental Protection Agency established "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time (40 CFR Part 197). Consistent with National Academy of Science observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events.

DOE confidence in the disposal techniques is based on a defense-in-depth that, for example, places drip shields over waste packages to account for uncertainties. DOE has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components.

DOE believes this process results in a representative estimation of impacts and is sufficient for comparing the relative merits of the various repository scenarios, including the preferred alternative.

DOE continues to evaluate the sufficiency of its approach of dealing with uncertainty at the process level (scientific) as well as at the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

7.3 (1921)
Comment - EIS000477 / 0001
My main issue is the future quality of life for southern [Nevadans] and Californians who are going to live within the nuclear waste repository impacted zone. With this storage facility located near a populated area (Las Vegas), how

can the Department of Energy guarantee that residents and visitors will not be unduly affected by radiation leakage? Presently, monitoring sites have been located in various locations of Tonopah, Rachel, and Las Vegas to measure the effects of past atomic explosions and studies have shown that local residents suffer higher rates of cancers. Is this acceptable? I don't think so. Would you want to live near this facility, raise your family, and watch your future generations die from various cancers or leukemia? Is the EIS correctly addressing the groundwater contamination concerns? Water that will eventually be consumed by the human and animal population of the region?

I wonder about possible groundwater contamination with Lake Mead/Colorado River water supplying Los Angeles, San Diego, Phoenix areas. This facility is only 100 miles away from this source and any geologic shifting from earthquakes can release harmful radioactive materials in the potable water supply.

Response

DOE can provide reasonable expectation, not a guarantee, that the proposed system of multiple engineered and natural barriers, working together, would protect public health and the natural environment for the hazardous life of the waste. In 10 CFR Part 63, the Nuclear Regulatory Commission acknowledges that "absolute proof is not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." Similarly, in 40 CFR Part 197, the Environmental Protection Agency has proposed "reasonable expectation" as a test of compliance, with diminished "weight of evidence" over time.

In *Rethinking High-Level Radioactive Waste Disposal* (DIRS 100061-National Research Council 1990), a panel of the National Academy of Sciences observed: "Confidence in the disposal techniques must come from a combination of remoteness, engineering design, mathematical modeling, performance assessment, natural analogues and the possibility of remedial action in the event of unforeseen events". As stated in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998), DOE is taking this combined approach to provide assurance that the proposed repository would comply with regulatory requirements.

The *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996) examines current and future DOE activities in southern Nevada at the Nevada Test Site, Tonopah Test Range, and sites DOE previously operated. With regard to the potential effects of past atmospheric testing at the Test Site, in 1997 the National Cancer Institute published a report entitled *Calculation of the Estimated Lifetime Risk of Radiation-Related Thyroid Cancer in the United States from the Nevada Test Site Fallout* (DIRS 152469-Institute of Medicine and National Research Council 1999, Appendix C). In 1999 the National Academy of Sciences published *Exposure of the American People to Iodine-131 from Nevada Nuclear-Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications* (DIRS 152469-Institute of Medicine and National Research Council 1999). While discussion of potential health effects of the Nevada Test Site is beyond the scope of this EIS, these sources provide additional information.

The issue of radiation exposure and its relationship to cancer is very pertinent and important. DOE used risk factors recommended by the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection to estimate potential risks to the public and workers from Yucca Mountain activities. The Department is committed to protecting the public and workers from unnecessary radiation exposure and to keeping potential radiation risks as low as reasonably achievable. DOE expects no adverse radiation-related health effects from activities at the Yucca Mountain Repository.

Chapter 8 of the EIS evaluates the cumulative environmental impacts of the proposed repository and other Federal, non-Federal, and private activities, including activities at the Nevada Test Site. Estimates of health effects indicate that the number of latent cancer fatalities attributable to the Test Site is insignificant in comparison to the incidence of cancer in the general population.

Repository-related contamination of Lake Mead or the Colorado River that could affect the Los Angeles, San Diego, and Phoenix areas is not credible. DOE has conducted an extensive site characterization program, including the hydrologic conditions in the Yucca Mountain region (Section 3.1.4 of the EIS). The proposed repository would be in a closed hydrologic basin, so its surface water and groundwater would leave only by evaporation from the soil and transpiration from plants. Therefore, the watershed of the Colorado River would not be at risk.

7.3 (2003)
Comment - EIS000526 / 0004
I am also concerned about the long-term safety of the Yucca Mountain site. Page 2-37 of the EIS states, "DOE would use institutional controls, including land records and warning systems, to limit or prevent intentional and unintentional activities in and around the closed repository." It is my understanding, for example, that plutonium-239, an irradiated fuel, has a half-life of 24,400 years and that it remains dangerous for a quarter million years, or 12,000 human generations. Furthermore, as it decays, uranium-235 is generated which has a half-life of 710,000 years. Thus, the hazard of irradiated fuel will continue for millions of years. Therefore, this material must be isolated from contaminating or irradiating living things for this long. Considering the evidence provided by all of the known history of civilization, does the DOE expect the political stability of this country (which is only one issue pertaining to the long-term safe disposition of this material) to have a duration that would even remotely approach that necessary to ensure the continued application of "institutional controls" for safe disposal of this material?

Response
DOE understands that ensuring public safety requires continued stewardship and has developed components for the postclosure safety case, including site stewardship programs. These programs would include, but are not limited to, long-term monitoring of the site and maintaining the integrity and security of the repository.

After closure, DOE would have the responsibility of maintaining institutional control over the repository, as required by the Energy Policy Act of 1992. Neither the extent nor the length of this regulatory requirement is well defined at present. However, the Department would maintain appropriate institutional controls for as long as required.

A postclosure monitoring program is required by 10 CFR Part 63. This program would include monitoring activities around the repository after the facility has been closed and sealed. In addition, 10 CFR 63.51 (a) (1) and (2) require that a license amendment be submitted for permanent closure of the repository. This amendment must specifically provide an update of the assessment of repository performance for the period after closure, as well as a description of the program for postclosure monitoring. The details of this program, such as the types of active and passive controls, would be defined during the processing of the license amendment for permanent closure. Deferring a description of this program until the closure period allows for the identification of appropriate technology, including technology that might become available in the future.

For impact analysis purposes only, the EIS assumes that passive institutional controls would be applied after repository closure, as described in Section 2.1.2.3. DOE chose to analyze passive institutional controls for the postclosure period based on recommendations by the National Research Council of the National Academy of Sciences (required by the Energy Policy Act of 1992).

DOE believes that passive institutional controls (such as the land records and warning systems used for postclosure impact analysis) are commensurate with the recommendation of the National Research Council.

The last paragraph of Section 2.1.2.3 now clarifies that passive institutional controls were applied for analytical purposes, but that additional controls and monitoring could be applied if deemed necessary in the future.

7.3 (2242)
Comment - EIS000742 / 0001
First off, I am neutral toward the Yucca [Mountain] project. I believe that the US [should] be using and developing [nuclear] energy. [Fossil] fuel waste is more hazardous than [nuclear] waste ever could be. My main concern about the site is the geologic instability in the Goldfield area. [Rarely] a day goes by when a small [magnitude] quake isn't recorded in that area. Just a couple of months ago, a moderate quake hit that area (http://www.seismo.unr.edu/Catalog/fing.html).

How is it that this area can be called safe for a repository that has to remain intact for 100,000 years? It seems to me that the [decision] to place the site at Yucca [Mountain] was based more on politics than on science. As an engineer, I find that to be more than a bit unnerving.

Response
Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future earthquake activity, DOE believes that a repository at Yucca Mountain would operate safely (that is, in compliance with the Environmental Radiation Protection Standards in 40 CFR Part 197).

In addition, Section 4.1.8 describes the likely impacts from accidents caused by earthquakes during operation of the repository. As listed in Table 4-37, the maximum reasonably foreseeable accident is an earthquake-initiated event estimated to result in 0.0073 additional latent cancer fatality in the affected population.

With regard to the concern over politics possibly having more weight than science in the original decision in the NWPA to characterize only Yucca Mountain as a possible site for a geologic repository, DOE is extremely sensitive to this issue. DOE is committed to performing objective site suitability assessments based on the best science practicable given the information available. DOE's recommendation to the President and his (upon acceptance) subsequent recommendation to the U.S. Congress will be based on the site suitability investigations. The ultimate decisions will be based on a weighing and balancing of the facts by the Nation's political leaders. DOE is confident that the final decision will be in the best interest of the United States and its citizens.

7.3 (2321)
Comment - EIS000571 / 0005
Gaseous pathways for radionuclides. The volcanic tufts [tuffs] of Yucca Mountain are highly fractured and faulted already, presenting the pathway for gaseous nuclides to escape into the environment. Such fracture conductivity to the surface has already been documented at the Yucca site. So we're already finding cracks at this site and stuff. So what happens if we put these containers under the ground and they get cracked somehow and once again it gets out to the environment and it contaminates?

Response
Section 5.5 of the Draft EIS evaluated the potential impacts of atmospheric release of gas-phase radionuclides from the proposed repository. These consequences were a function of the inventory and release rate of gas-phase radionuclides (most notably carbon-14). The reported impacts to the local population from gas-phase atmospheric releases were exceedingly low (average lifetime population dose of 1.1×10^{-6} person rem over a 70-year lifetime at the peak release rate, corresponding to 5.3×10^{-10} latent cancer fatality). This represents a negligibly small risk, which was also the opinion of a National Research Council panel that reported its own investigation of this issue (DIRS 100018-National Research Council 1995). The National Research Council advised the Environmental Protection Agency not to bother controlling such a tiny potential release. The Environmental Protection Agency also calculated the risk, and agreed with the National Academy that this risk was too low to regulate.

7.3 (2527)
Comment - EIS000772 / 0005
Geological disposal was proposed in the act for waste isolation, yet the DEIS discusses facility design based on delayed release of radioactivity by means of Engineered Barriers, so the site will leak. Yet no discussion was offered stating how much leakage or when the leakage will occur.

Response
The goal of geologic disposal is to concentrate and isolate radioactive wastes in a relatively small area for a very long time. DOE intends to achieve isolation of the wastes in the proposed repository by using a system of engineered barriers and by locating the repository in the geologic setting of Yucca Mountain. However, it is always possible to conceive of circumstances (both manmade and natural) that, given the inherent uncertainties associated with long-term projections, could result in the release of radioactive materials to the accessible environment.

The Environmental Protection Agency recognized in its Yucca Mountain environmental protection standards (40 CFR Part 197) that with the current state of technology it is impossible to provide a reasonable expectation that there would be no releases over 10,000 years or longer. Therefore, standards have been established by the Agency that it believes provides comparable protections to those of other activities related to radioactive and nonradioactive wastes. These standards do not require complete isolation of the wastes over the compliance period (that is

10,000 years) or the period of geologic stability (1 million years). The goal of a performance assessment such as that performed for Yucca Mountain is to evaluate whether the repository is likely to meet these standards.

The EIS provides DOE's best estimate of the impacts that could occur when the containment system inevitably degrades. The updated analysis in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197) and are due to the very unlikely event of between zero and five packages failing due to manufacturing defects.

In addition to the 10,000-year compliance period, DOE has evaluated potential impacts for the period of geologic stability at the repository (that is, 1 million years). DOE performed this evaluation, consistent with 40 CFR Part 197, to gain insight into the very long-term performance of the repository and thus provide information for decisionmakers in making both design and licensing decisions. These results show a mean peak dose rate that would be much lower than background levels (see Chapter 5 for details).

7.3 (2598)
Comment - EIS000802 / 0002
What about the ground water contamination has already been established and yet they build on.

Response
In 1996 DOE published the Nevada Test Site Final Environmental Impact Statement (DIRS 101811-DOE 1996). This document provides an estimate of the underground testing radionuclide source term that is the best available, unclassified, source term information. This data was used in a simplified calculation to provide a reasonable estimate of potential long-term cumulative impacts resulting from the underground testing activities at the Test Site. Because of ongoing studies and the current uncertainty surrounding groundwater transport models, DOE did not attempt to estimate actual groundwater transport characteristics for the Test Site. Rather, the estimates of potential Test Site groundwater impacts provided in Section 8.3 of the Draft EIS for Yucca Mountain were based simply on the ratio of inventories of radionuclides available for transport at the repository to the Test Site source term.

For the Final EIS, DOE has refined the Nevada Test Site groundwater impact analysis to consider not only the total inventories of radionuclides but also the relative source term radionuclide concentrations and dilution factors for the repository and the Test Site. However, because of the large uncertainties remaining, the refined analysis did not attempt to model actual groundwater transport at the Test Site. Rather, the refined analysis assumed that the radionuclide constituents in the groundwater at the Test Site would be transported in an identical manner to those from the repository (that is, the repository groundwater transport model was applied to the Test Site source term). Therefore, DOE believes that the resulting estimates of the potential cumulative impacts from underground testing activities at the Nevada Test Site represent a reasonable estimate of the maximum impacts. Section 8.3.2.1.1 describes the results.

7.3 (2619)
Comment - EIS000708 / 0002
Jessica Matthews, Senior Fellow at the Council on Foreign Relations, wrote about the Yucca Mountain Project for the Wall Street Journal that "The (DOE) plan is to dispose of nuclear wastes once and forever in a deep hole in the ground. A repository would be built, filled and sealed. This difficult, new technology must work perfectly the first time, protecting the waste for 10,000 years. There can be no pilot project, no improving of the technology, no learning curve; yet there must be public confidence that it will work."

FACT: There is NO PUBLIC CONFIDENCE that it will work. Repeatedly DOE technological discoveries about the site reveal weaknesses such as geologic instability, water penetration, heat accumulation, radioactive leakage, etc. Repeatedly the DOE response to these inherent site flaws has been to weaken the standards to accommodate the problem.

Response
DOE recognizes that that there is uncertainty in both predictive capability and in the likelihood and nature of human error. Therefore, a defense-in-depth approach is being used that, for example, places a drip shield over waste packages to account for uncertainties in the locations and rates of water seeps into the repository. DOE has adopted

this defense-in-depth design philosophy and also a performance assessment methodology that accounts for the variability inherent in natural processes, limits to our knowledge and information, differing views of experts, unpredictability of some phenomena, and uncertainty in system behavior. The methodology is widely accepted nationally and internationally. It is based on recommendations of the National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission. It conforms to international practices in other countries, including Member States of the Organisation for Economic Co-operation and Development Nuclear Energy Agency and the United Nations International Atomic Energy Agency.

In addition, because it is generally recognized that with time, our knowledge of and ability to predict future performance of both engineered and natural systems will improve, Section 122 of the NWPA and Federal regulations [10 CFR Part 60 and 10 CFR Part 63] require that the repository be designed to preserve the option of waste retrieval on a reasonable schedule starting at any time up to 50 years after the start of waste emplacement. Consistent with these requirements, the operational plan for the proposed Yucca Mountain Repository provides for a design and management approach that isolates wastes from the public in the future while allowing flexibility to preserve options for modifying emplacement and retrieving the waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel.

Section 112(a) of the Nuclear Waste Policy Act of 1982 requires the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed characterization. DOE issued these guidelines in 1984 (10 CFR Part 960), describing policies that were applicable to the three sequential stages of the siting process in the Act (preliminary site screening, nomination of sites, and site selection for recommendation to the President).

DOE published proposed amendments to the guidelines in 1996 to reflect the prevailing scientific view on how to evaluate the suitability of the Yucca Mountain site for the development of a nuclear waste repository (61 *FR* 66158, December 16, 1996). Because Congress had by this time required DOE to focus only on Yucca Mountain, the proposed DOE amendments dealt with provisions of the guidelines that were applicable to the site recommendation stage. In November 1999, DOE revised its 1996 proposal (64 *FR* 67054, November 30, 1999) to focus on the criteria and methodology to be used for evaluating geologic and related aspects of the Yucca Mountain site.

DOE revised its proposal for three reasons. First, in response to comments received on the 1996 proposal, DOE sought to provide more specificity in the guidelines and to expand the explanation of the factual and legal bases for them. Second, in December 1998, DOE issued the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) pursuant to Congressional direction. The Viability Assessment sets forth the bases for the site suitability criteria that DOE is proposing to use and the methodology for applying the criteria to a design for a proposed repository at the Yucca Mountain site. Third, the Nuclear Regulatory Commission proposed to issue site-specific licensing requirements for the Yucca Mountain site in February 1999. The details of this new proposal suggest the need to make conforming changes to the December 1996 DOE proposal to establish the requirements for carrying out a Total System Performance Assessment as the method for applying the site suitability criteria to the data developed during characterization of the Yucca Mountain site. DOE is not proposing to revise its guidelines due to any condition found at the Yucca Mountain site.

7.3 (2827)
Comment - EIS000955 / 0003
It is the opinion of the [Mendocino] Environment Center that shipping nuclear waste to Yucca Mountain on the Shoshone Reservation is … irresponsible in that [it] is less safe than an above ground repository.

Response
Yucca Mountain is not part of any Native American reservation, although DOE recognizes that claims exist that the location is a part of Western Shoshone land. This is an issue for Congress to consider as it decides whether to withdraw the land for the repository. In terms of transportation, while some potential routes cross Federally recognized Native American lands (see Chapter 6 of the Final EIS), DOE believes that the impacts would be small and would present no more risk to Native Americans than to any other community along those routes.

DOE does not agree with the second part of the comment. The Draft EIS, in a comparison of the Proposed Action and No-Action Alternative, suggests that although there could be little risk from above-ground storage for some time, eventually there would be either very large investments or sizable risks, some to populations and some to environmentally sensitive locales such as land adjacent to lakes, rivers, or oceans. To do nothing would be to invite disaster at some future time. To act as proposed would present some risk over a short period to those on or adjacent to transportation routes, but it would remove future risks from 77 other locales. In addition, the reduced risk of an unauthorized diversion of materials from these 77 locales, materials that could be used as tools of terrorism is important. The repository would be an important part of this Nation's commitment to nuclear nonproliferation. DOE believes the potential long-term benefits far outweigh the short-term risks from a national perspective and from the perspectives of those currently residing near spent nuclear fuel storage areas.

7.3 (2907)
Comment - EIS001009 / 0002
In the report titled "Geochemical Behavior of Long-Lived Radioactive Wastes" (ORNL-TM-4481) compiled by Ferruccio Gera for the Oak Ridge National Laboratory (1975), Gera notes in the introduction, "It is clear that these wastes will have to be contained for time periods well in excess of the recorded history of mankind." He states that it is necessary to "design a disposal facility in such a manner that it will withstand at least a few hundred thousand years of geologic change. It is known, however, that the longest-lived nuclides in the waste will present some radiological hazard for millions of years and it is not possible to absolutely guarantee that waste will be contained for such long periods of time."

To the taxpayer, the assumption made by Gera and promoted by our federal government and the nuclear power industry that the integrity of containers and the stability of the environment will permit no release of contamination for upwards of thousands of years is lunacy.

Unanticipated man-made events -- such as war or terrorist activity or environmental degradation -- or events occurring in nature -- such as geologic changes caused by earthquakes or volcanic activity or even impacts by asteroids, or the inevitable deterioration of containers -- make such long-term predictions ludicrous.

Response
The goal of geologic disposal is to concentrate and isolate spent nuclear fuel and high-level radioactive waste in a relatively small area for a very long time. DOE intends to achieve isolation of the wastes in the proposed repository by using a system of engineered barriers and by locating the repository in the geologic setting of Yucca Mountain. However, it is always possible to conceive of circumstances (both manmade and natural) that, given the inherent uncertainties associated with long-term projections, could result in the release of radioactive materials to the accessible environment. In other words, the eventual release of some material is inevitable because all systems will degrade given sufficient time. However, based on the results in Chapter 5 of the EIS concerning long-term performance, which considered the effects of earthquakes and volcanic activity as well as the uncertainties related to future human behavior, DOE believes that the repository at Yucca Mountain would operate safely.

DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. This EIS provides DOE's best estimate of the impacts that could occur when the containment system degraded. The updated analysis in the Final EIS projects that the Proposed Action probably would result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197), which would be due to the very unlikely event of between zero and five waste packages failing due to manufacturing defects.

In addition to the 10,000-year compliance period, DOE has evaluated potential impacts for the period of geologic stability at the repository (that is, 1 million years). DOE performed this evaluation, consistent with 40 CFR Part 197, to gain insight into the very long-term performance of the repository and thus provide information for decisionmakers in making both design and licensing decisions. These results show a mean peak dose rate that would be much lower than background levels (see Chapter 5 for details).

7.3 (3001)
Comment - EIS001066 / 0001
From what I have read, there are major concerns about the geologic suitability of Yucca Mountain to be a repository for nuclear waste. It is not water or air tight.

Response
Regarding the question of whether or not Yucca Mountain is "water or air tight," no natural geologic system is water or air tight because all natural geologic environments have a finite permeability to air and water. In choosing Yucca Mountain as a potential disposal site, DOE has selected a site with air and water permeability characteristics that, with the long-term climate in the area, the depth of the water table, and the robust engineering design of the proposed facility, ensures that future impacts to natural systems would be minimal.

The EIS evaluates the impacts of the proposed Yucca Mountain Repository and concludes that potential impacts to natural systems would be well within regulatory standards established by the Environmental Protection Agency and the Nuclear Regulatory Commission. Consistent with Section 122 of the NWPA and Commission regulations (10 CFR Part 63), DOE has designed the repository to maintain the capability to retrieve the waste if there were indications of unacceptable threats to public health and safety or to the environment, or to retrieve resources from spent nuclear fuel.

7.3 (3221)
Comment - EIS000957 / 0003
The risks to health and life are unacceptable due to the possible contamination of the groundwater and our environment will result in approx. 18 latent deaths a year. Any number of deaths per year related to this disposal of nuclear waste is completely unacceptable.

Response
Concerns about the risks to health and life are important and relevant to the proposed Yucca Mountain repository. The people of Amargosa Valley, the closest population center, are most at risk to groundwater contamination because the water beneath Yucca Mountain flows in a generally southerly direction.

DOE's estimate of the health risks due to the possible contamination of the groundwater does not agree with this comment. Section 5.10 of the EIS clearly indicates that no person would be likely to contract a fatal cancer from potential repository releases during the first 10,000 years after closure.

7.3 (3234)
Comment - EIS000998 / 0002
Some of this high-level nuclear waste will be toxic for 150 million years. No responsible person can assure us that any container will be designed which will contain that waste for that period of time, even under the best conditions. Further, major unanswered questions remain about the geologic predictability and long-term stability of Yucca Mountain site, raising further doubts about the safety of this proposal.

Response
DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. The Draft EIS provides the Department's best estimate of the impacts that would occur when the containment system inevitably degraded. The Draft EIS confirms that the Proposed Action would be expected to result in release of radioactive contamination to the environment beginning as early as a few thousand years after repository closure. However, the Draft EIS also shows that these releases under the Proposed Action would not exceed Environmental Protection Agency Standards (40 CFR Part 197) within 10,000 years of repository closure, standards specifically enacted to ensure the safety of future generations.

The EIS contains analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probability and effect of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicate the potential risk, as reported in the EIS.

7.3 (3454)
Comment - EIS000546 / 0001
I really challenge all the scientific evidence to be looked at. There is a lot of very brilliant minds that are coming up with scientific facts and figures, but ultimately I think if you really look at it, we have to admit that it's all speculation and all hypothetical, because we really don't know what's going to happen. We don't know what's going to happen geologically in the next 500 years, in the next 50 years really. It's all speculation. Some very intelligent speculation but none all the same speculation.

We don't know what's going to happen with our environment.

Earlier, it was suggested that posing questions as comments. I'm going to reverse this and pose my question as a commenter. I'm sorry, I'm getting confused. Anyhow.

I'd really like anybody involved in the upper echelons of Yucca Mountain, I'm talking about anybody involved in the facts, the figures, in the decisions being made, whether you're a scientist, whether you are a bureaucrat, an administrator, whether you are a congressman, congresswoman. I'd like to ask you if you would live in the area? This isn't a question of aesthetics but about whether you want to live in southern Nevada, wherever Yucca Mountain happens to be. Would you want to live in the area and raise your family in that area, the next three, four generations of your family? Do you feel that the guarantees are reasonable enough and the risk is reasonable enough to want to raise your family there?

Response
DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency (EPA), and Nuclear Regulatory Commission (NRC) also recognize the difficulty of understanding the behavior of complex systems over long periods. In 10 CFR Part 63, the NRC acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." In 40 CFR Part 197, the EPA establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. The EPA also recognizes the need for expert judgement in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Science observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events. DOE continues to evaluate the sufficiency of its approach to dealing with uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

The choice of where an individual lives is a personal decision based on many factors (such as, lifestyle, cost of living, distance to work, educational opportunities, etc.). Nevertheless, the vast majority of scientists, engineers, and administrators directly involved with the Yucca Mountain project have chosen to reside within the region of influence. Before it could recommend the Yucca Mountain site for development of a geologic repository, DOE would have to provide a reasonable expectation that the repository would meet the EPA standards (40 CFR Part 197) for protecting human health and the environment. The Department believes that the occurrence of adverse health effects would be highly unlikely for all potentially exposed populations in the region of influence.

7.3 (3472)
Comment - EIS000722 / 0008
Like most power plants, Diablo Canyon lately operates with enriched fuel allowing longer stay of the fuel rods in the reactor. Since there is no empirical evidence for the rate of cladding failure in these spent fuel rods with higher burn-up, all risk assessments and analyses for accident and sabotage/terrorists scenarios are conjecture. In addition, calculations about thermal loads for casks and permanent repository may also be effected [affected]. The Draft EIS does not address this important aspect and is therefore seriously flawed.

Response
Section A.2.1.5 of the Draft EIS provides the basis for selecting "typical" pressurized-water reactor and boiling-water reactor fuel assemblies. Specifically, the typical assemblies were chosen to be representative of the average of the fuels to be received at the repository and to provide a realistic inventory and post-irradiation elemental distribution estimate for long-term performance analysis. The typical commercial assemblies specified are representative of an assembly type used in the more recently built reactors. This results in physical characteristics that are slightly higher than average (size and uranium per assembly).

In addition to the typical fuel, however, the Final EIS includes a new "representative" commercial fuel for purposes of calculating impacts of repository and transportation accidents (including accidents resulting from sabotage). The representative fuel (see Appendix A, Tables A-12 and A-13) is based on a hazard index approach that considers the relative hazard for all commercial fuel to be received at the repository. This fuel is younger and has higher burnup than the typical commercial fuels used in the Draft EIS. Use of a "most dangerous" conservative fuel (maximum burnup and minimum cooling) is not appropriate for transportation accidents because transportation casks, to ensure compliance with thermal and direct radiation exposure limits, would not be filled with such fuel. Such loading would require that casks contain fewer spent nuclear fuel assemblies than the large-capacity casks assumed for the EIS. Furthermore, such a fuel represents a very small fraction of the waste inventory. Thus, a reasonably foreseeable accident that could involve shipment of this fuel would be much less severe than the maximum reasonably foreseeable accident in the EIS because of the lower quantity of the material available for release from an affected cask.

Similarly, for the maximum reasonably foreseeable repository accidents, exclusive involvement of younger fuel would not be realistic because of the nature of the activities in the Waste Handling Building. Routine blending operations in the Waste Handling Building would include both younger and older spent nuclear fuel at any given time. Therefore, the Waste Handling Building would contain a mixture of younger, high-burnup and older, low-burnup fuel assemblies that would be equally affected in the event of an accident. The Final EIS defines the parameters of the "representative" commercial fuel and the rationale for developing this new type for use in accident analysis for the Final EIS.

This comment is correct in that whatever has happened to nuclear fuel at operating reactors would have an impact on the future behavior of the repository. For instance, the time the fuel spends in the reactor (the burnup) has a direct impact on the inventory of waste elements (radionuclides) and the heat output. These aspects are considered in design and modeling activities. DOE is evaluating certain aspects of dry cask storage related to the performance of commercial spent nuclear fuel cladding. This is necessary because dry cask storage results in much higher cladding temperatures than at-reactor pool storage. Such information was used to develop a refined clad performance model that is included in the Total System Performance Assessment analyses that support both the Site Recommendation process and the Final EIS. Models of commercial spent nuclear fuel dissolution are based on experimental tests where actual reactor fuel was used. In addition, models of waste package material performance are based on continuing long-term corrosion tests. Details regarding the models used for the Draft EIS are in Chapter 5 of the Draft EIS and of the Viability Assessment (DIRS 101779-DOE 1998). Descriptions of refined models can be found in documentation that supports both the Site Recommendation process and the Final EIS.

7.3 (3549)
Comment - 010114 / 0008
The lower temperature scenario assumes use of an area that hasn't been studied yet and what the fault lines are in that area that we're not aware of. These are things that need to be taken a look at.

Response
The waste inventory for the lower-temperature operating mode would be wholly contained in an area that has been studied during site characterization. Extended inventories (such as Modules 1 and 2) use some unstudied space in the "lower block." These inventories are not part of the Proposed Action, but are considered in the cumulative impacts as a reasonably foreseeable future action. If these additional waste inventories were authorized for disposal in the proposed repository, DOE would be required to characterize additional areas at Yucca Mountain.

7.3 (3599)
Comment - EIS000715 / 0009
In conclusion, I wish to make clear that the only things that the human race has learned about nuclear waste disposal is:

a. No human designed waste container has not leaked.

b. Nuclear waste always works its way lower into the earth carried by underground water.

So, 98% of the waste deposited in Yucca Mountain will end up, percolated and bubbling, beneath Death Valley National Park. It is true that only 2 percent will permanently poison the Las Vegas, acquifer.

Response
DOE acknowledges that it cannot build a containment system that would provide perfect containment forever. The Draft EIS provides the Department's best estimate of the impacts that would occur when the containment system degraded. DOE does confirm in the Draft EIS that the Proposed Action would be expected to result in a release of radioactive contamination to the environment beginning as early as a few thousand years after repository closure. However, the Draft EIS shows that these releases would not exceed environmental protection standards (40 CFR Part 197) within 10,000 years of repository closure, standards specifically enacted to ensure the safety of future generations. In addition, whereas the repository design evaluated in the Draft EIS projected small releases within the 10,000-year compliance period, the enhanced design evaluated in the Final EIS projects that the Proposed Action probably would result in even smaller releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197).

With regard to potential flow of contaminants to Death Valley and as described in Section 3.1.4 of the EIS, DOE has conducted an extensive program to characterize the direction and nature of groundwater flow and transport from the Yucca Mountain site. The general path of water that percolates through Yucca Mountain is southward toward the Town of Amargosa Valley, then beneath the area around Death Valley Junction in the southern Amargosa Desert. The groundwater beneath Yucca Mountain merges and mixes with groundwater beneath Fortymile Wash. This groundwater then flows toward, and mixes with, the large groundwater reservoir in the Amargosa Desert. The natural discharge point of this groundwater occurs farther south in Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume might flow south toward Tecopa into the southern Death Valley area. A fraction of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. Potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. This divide would limit discharge from the shallow flow system, but would not necessarily affect the flow from the deeper carbonate aquifer that might contribute discharge to springs in the Furnace Creek area (DIRS 100465-Luckey et al. 1996).

Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and from deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). Groundwater in the northwestern Amargosa Desert originates in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend southward from Yucca Mountain. Even if part of the flow from Yucca Mountain mixes with the carbonate pathway that supplies the springs in Furnace Creek, it would be too little to noticeably affect the water quality of these springs. Considering the small amount of water that would infiltrate though the repository footprint compared to the total amount of water flowing through the basin (about 0.2 percent), and the large distances involved [more than 60 kilometers (37 miles) from the source], any component of flow from Yucca Mountain that traveled along this long and complicated flow path would be diluted to such an extent that it would be indistinguishable.

As described in Chapter 5 of the EIS, modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep the release of radionuclides well below the regulatory limits in 40 CFR Part 197. If, after more than 10,000 years, some contaminated groundwater flowed past Franklin Lake Playa and discharged at the springs in the Furnace Creek area of Death Valley, the mean

peak dose would be less than the dose calculated at Franklin Lake Playa. See Section 5.4 of the EIS for additional information.

With regard to potential contamination of the Las Vegas aquifer, Sections 3.1.3 and 3.1.4 of the EIS describe the geologic and hydrologic settings of Yucca Mountain and the surrounding region in great detail. Estimated releases to the accessible environment after 10,000 years would be limited geographically to the groundwater flow system described in Section 3.1.4.2 of the EIS. Therefore, contaminants from the repository could not reach the Las Vegas Valley.

7.3 (3616)
Comment - EIS001031 / 0022
Isn't it risky, storing all this waste in one place?

Response
Chapter 5 of the EIS describes the environmental consequences of disposing of radioactive materials in one place. There are risks, but the purpose of this EIS is to present these risks to decisionmakers so they can make informed choices.

The risk of disposing of these materials in multiple locations has not been evaluated. However, the costs and risks of leaving the materials where they presently are have been evaluated in this EIS, and both long-term costs and risks would be lower if the Proposed Action was selected rather than either the 10,000-year maintenance and replacement of existing storage locations, or the abandonment of existing locations after 100 years. Neither alternative is likely to be the course the Nation would follow if the Proposed Action was not taken, but the analyses show the range of potential impacts if No Action was selected.

7.3 (3633)
Comment - EIS001179 / 0002
The recent findings at LANL (Haschke, et al.) regarding oxides of Pu [plutonium] do not seem (to me) to be of show-stopping concern. I believe that mobility and outgassing has been adequately addressed.

Response
Thank you for the comment.

7.3 (3777)
Comment - 010388 / 0003
Continue in-depth evaluations of priority issues as raised by NWTRB [Nuclear Waste Technical Review Board] to lay the scientific foundation for a positive Yucca Mountain site recommendation.

Incorporate a surface aging area for commercial spent nuclear fuel into the surface facilities plan for Yucca Mountain.

Conduct an in-depth investigation of a low temperature repository design, as an operating mode with optimum flexibility.

Response
The effects of thermal loading on the long-term performance of the proposed repository have been a subject of intense study and empirical data gathering for several years. Since the publication of the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance and improve operational safety and efficiency. The design evolution process has resulted in the development of the flexible design (see Chapter 2 of the Final EIS). In developing the flexible design, DOE considered the concerns expressed by the Nuclear Waste Technical Review Board about difficulties in reducing large uncertainties regarding waste package and repository performance related to high (above the boiling point of water) repository rock temperatures associated with the preliminary design in the Viability Assessment (DIRS 152574-Cohon 2000). The Board suggested that it might be possible to reduce such uncertainties by developing an adequate technical basis for a lower-temperature repository design.

The flexible design includes the ability to operate the repository in a range of operating modes that address higher and lower temperatures and associated humidity conditions. Higher-temperature means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96ºC (205ºF)]. The lower-temperature operating mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperatures would not exceed 85ºC (185ºF). To ensure the impact analysis covered the full range of potential impacts, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85ºC.

As discussed in Section 2.2.2.2.2 of the Supplement to the Draft EIS, the thermal output of the waste packages could be reduced by (1) placing low-heat-output (older) fuel with high-heat-output (younger) fuel in the same waste package (fuel blending), (2) limiting the number of spent nuclear fuel assemblies to less than the waste package design capacity (derating), (3) using smaller waste packages, or (4) placing younger fuel in a surface aging area to allow its heat output to dissipate so it could meet thermal goals for later emplacement. Chapter 4 of the Final EIS includes an evaluation of surface aging as much as 40,000 metric tons of heavy metal of commercial spent nuclear fuel during a 50-year period.

7.3 (4042)
Comment - EIS001524 / 0002
The Draft Environment Impact Statement is incomplete with regard to the definition of the "maximally exposed individual." The definition did not take into account differences in age, gender, and physical characteristics and also assumed that current lifestyles in the exposed area would remain consistent over the next 10,000 years. First of all, if the intent of the study is to determine protection for future generations, the maximally exposed individual should not be a person of mean or average lifestyle because it automatically results in some people (namely the old, young, sick, etc.) being less protected. In addition, while it is certainly not possible to know future lifestyle patterns, one cannot assume that characteristic conditions today will remain intact for thousands of years in the future. Therefore, the DEIS is wrong to rely on current averages to determine future levels of safety from the repository (DEIS, p. 5-26).

Response
DOE, the National Academy of Sciences, the Nuclear Regulatory Commission, and the Environmental Protection Agency all concur that "it is not possible to know future lifestyle patterns." In its report, *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995), a National Academy of Sciences committee concluded that there is no scientific basis for predicting future human behavior. The Committee recommended the use of default (or reference) scenarios to incorporate future human actions in compliance assessments.

DOE has followed this recommendation and used the concept of a reasonably maximally exposed individual (RMEI), as discussed by the Environmental Protection Agency in the preamble to 40 CFR Part 197, to project potential doses for long periods. The agency stated:

" … that the RMEI approach is sufficiently conservative and that it is fully protective of the general population (including women and children, the very young, the elderly, and the infirm). The risk factor upon which the dose level was established is very small, 5 chances in 10,000,000 per mrem [millirem] for fatal cancer. The lifetime risk then is this factor multiplied by the total dose received in each year of the individual's lifetime. We believe that the risk prior to birth is very similar to this risk level; however, relative to the rest of that individual's lifetime, the difference is small."

In addition, the Environmental Protection Agency defines the reasonably maximally exposed individual as an individual that has the food and water intake rates, diet, and physiology similar to those individuals currently living in communities in the downgradient direction of flow of the groundwater passing under Yucca Mountain. Thus, in estimating the risks to humans, DOE chooses factors typical of individuals living in the Yucca Mountain region of influence (for example, lifestyle, diet, water usage, farming and agricultural practices, and environmental parameters) that would lead to the highest exposures.

7.3 (4064)
Comment - EIS001181 / 0002
The N.Y. Times ran an extensive article about water flow, calcite crystals and their potential to corrode canisters. Also, the area's vulnerability to earthquakes and proximity to an ever-growing Las Vegas are cause for concern.

Response
DOE agrees that canister corrosion, earthquakes, and the proximity of population centers are important issues in the assessment of the performance of the proposed repository.

The longevity of the waste package is a principal factor in the Repository safety case. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). However, the updated analysis in the Final EIS projects between zero and five waste packages failing due to manufacturing defects.

DOE has evaluated the long-term geologic stability of Yucca Mountain. Earthquakes have occurred in the Yucca Mountain area in the past and are likely to occur in the future. They could affect the postclosure performance of the proposed repository in two ways: (1) through ground motions that could disturb the engineered structures and (2) by direct offset along a block-bounding fault that could act as a pathway for water flow and radionuclide migration to the underlying aquifer. To minimize the potential impacts of earthquakes, DOE would design the engineered structures to withstand the most severe ground motions (see Section I.2.1.7 of the EIS), and would place the waste emplacement drifts away from faults that could serve as fast paths for water.

DOE has conducted an extensive site characterization program, including the regional groundwater flow system around Yucca Mountain. The Department believes that there are no surface-water or groundwater pathways that could affect the population of Las Vegas. All flowpaths terminate in playas where water evaporates and perhaps makes a minor contribution to some local springs. However, all the water flows to the west and cannot reach the Las Vegas area. EIS Sections 3.1.4.2 and 3.1.4.2.2 describe the status of the understanding of the regional groundwater flow, and work continues to enhance our understanding of the regional flow system.

7.3 (4156)
Comment - EIS001512 / 0004
The DEIS includes the statement that the "most important process controlling waste package lifetime is whether water would drip from the seeps onto a waste package." (DEIS, 1999, 5-11.) On the previous page of the DEIS, the statement is made that, "After the water returned to the repository walls, it would drip into the repository but only in relatively few places. The number of seeps that could occur and the amount of water that would be available to drip would be restricted by the low rate at which water flows through Yucca Mountain." (DEIS, 1999, 5-10.) As was previously mentioned, a climate shift could cause a dramatic increase in the water that flows through Yucca Mountain to the repository. In addition, the flow of water through this area is affected by the surrounding geologic conditions, which are uncertain, by the DOE's own admission. On page 5-10 (DEIS, 1999), the DOE admits that the effect of heat (which could arise 15-25 years after closure of the repository as a result of the decay of nuclear materials, or as a result of volcanic activity in the surrounding area) on the water flow and geologic conditions is unknown. The DOE is planning future studies to determine the effect of heat on repository conditions (DEIS, 1999, 5-18), but until that data is known, the DOE's claim that little water would seep into the repository and cause damage to the waste packages is weakened by inconsistency.

Response
DOE based the corrosion models for the waste package design discussed in Section 5.2.2 of the Draft EIS on expert elicitation. The experts felt that Alloy-22 would corrode faster under dripping conditions. Subsequent experimental data, as documented in the "Waste Package Degradation Process Model Report" (DIRS 151624-CRWMS M&O 2000), show the corrosion of the new waste package would be insensitive to the amount of water contacting it (as long as there was any water). The corrosion rate would be the same whether there was only humid air or fast-dripping water. Thus, the effect of seepage on waste package corrosion would not be significant. But to reduce uncertainty in environmental conditions and reduce the potential for rockfall to damage the waste package, the flexible design evaluated in the Final EIS includes a drip shield over the waste package. The drip shield gives

defense-in-depth and added assurance that the repository would perform adequately to protect the public health and safety.

DOE has completed several rock-heating tests, and one large underground test continues. These tests suggest that flow into the heated drifts is highly unlikely. However, the updated analysis performed for the Final EIS conservatively allows for some degree of seepage into a heated repository. The results of the updated analysis, however, indicated that this small amount of seepage would have little effect on the engineered system.

7.3 (4158)
Comment - EIS001512 / 0006
The scientist[s] involved insist that by the time a large portion of the radioactive material in the waste packages could reach groundwater supplies, their concentration would be non-toxic. The non-toxicity of these levels of groundwater contamination is not an assurance that they would not still be detrimental to humans. Furthermore, if the water table were to rise or if the water flow in the area surrounding the repository were to change as a result of heat, the concentrations of radioactive materials contaminating groundwater supplied could also increase. It is likely, if this were to occur, that the concentration of radioactive materials in groundwater would reach toxic levels.

Response
DOE acknowledges that the performance assessment models discussed in Appendix I of the EIS indicate that, eventually, the waste packages would fail and that radioactive materials would be released into the underlying aquifers where they would enter possible exposure pathways to humans. However, the potential exposure routes and acceptable, long-term concentrations of these materials are subject to the environmental protection standards promulgated, at the request of Congress, by the Environmental Protection Agency (40 CFR Part 197). The Department will continue to use the best scientific and engineering techniques available to provide a reasonable expectation that the repository would meet the requirements of 40 CFR Part 197, thus ensuring the long-term protection of the general public and the environment.

Section 3.1.4.2.2 of the EIS discusses several opposing views concerning fluctuations in the elevation of the water table. A small number of investigators believe that the water table at Yucca Mountain has risen in the past to elevations higher than that of the proposed emplacement horizon beneath Yucca Mountain. Based on the results of analyses reported in Section 3.1.4.2.2, DOE does not believe that any credible combination of future climate change, earthquakes, and volcanic eruptions could raise the water table sufficiently high to inundate the emplacement horizon.

7.3 (4159)
Comment - EIS001512 / 0007
Beyond the uncertainty of the above four DEIS claims, there is fundamental error in the modeling done by the DOE to assess the environmental consequences of volcanism, seismicity, and human intrusion. In modeling the possible consequences of these events, the DOE has assumed that only one of these will occur at a time. In other words, the simulations used to assess the environmental impact of these occurrences do not consider the possibility of an earthquake and a volcanic eruption at the same time. The DOE admits the likelihood of a thermal pulse 15-25 years after closure of the repository (DEIS, 1999, 5-10), along with high probability of seismic activity in the area (see 5-16, DEIS, 1999). Modeling the consequences of only one of these possibilities at a time, therefore, incompletely assesses possible environmental impacts.

Response
Since the publication of the Draft EIS, DOE has updated the Total System Performance Assessment to reflect the latest available information. The nominal scenario (undisturbed performance) now includes seismic events because of the likelihood of seismic activity occurring in the 10,000-year compliance period. Igneous activity (or volcanism) is included in the disruptive event modeling. Because DOE modeled the disruptive event as a perturbation of the nominal scenario, seismic and volcanic events can occur (in the probabilistic treatment) at effectively the same time.

The impact of the human intrusion event would be so small that its occurrence in conjunction with other events would be essentially the same.

7.3 (4161)
Comment - EIS001313 / 0002
Yucca Mountain is a poor site for long-term storage, partly because of the rapid movement of water through the ground, which would corrode the underground metal containers and wash the waste into the groundwater, creating a sacrifice zone for a very long time.

Response
As documented in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000), the corrosion of a waste package would be insensitive to the amount of water contacting it (as long as there was any moisture at all). The corrosion rate would be the same whether there was humid air or dripping water. The waste packages would corrode over time and would release waste into the groundwater. However, the updated analysis in the Final EIS projects between zero and five waste packages failing due to manufacturing defects. Chapter 5 of the EIS provides the estimates of potential dose rates, and discusses the uncertainties in those rates.

7.3 (4234)
Comment - EIS001160 / 0049
Examples of possible "worst case" scenarios which should be considered within the FEIS as a means to bound impact assessment and to identify reasonable mitigation measures include:

Disruptive event (i.e. volcanism, nuclear criticality) of unanticipated nature through repository horizon and of sufficient force to produce an emission plume and related deposition across White Pine County. Direct impacts include increased risk to residents and visitors of the County to exposure to radionuclides. Indirect impacts include enhanced public perception of risk and related area stigmatization.

Response
The EIS does not present a worst-case scenario for dose-to-receptor analysis and calculations because no matter what worst-case choice was presented, it would be always possible for someone to develop a worse scenario. This was recognized as a potential issue by the regulators, and in their regulations they settled the issue by prescribing a modeling approach and identifying the potential dose recipients to be evaluated in the analyses. As part of the analytical approach, DOE uses a statistical method to sample distributions of variable parameters relating to the calculation of dose. Realistic distributions of parameters are randomly sampled 300 times and these values are used for 300 simulations of repository performance, in terms of potential doses to receptors. The simulation results are used to show the mean and 95th-percentile doses (risks) to receptors.

The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probability and effect of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicate the potential risk, as reported in the EIS.

One change in the Final EIS is the addition of an aerial pathway for release from the analyzed eruptive scenario. This scenario was added to the three already analyzed in the Draft EIS (Chapter 5, Section 5.7.2, p. 5-43). The dose rates reported in Chapter 5 are well below the Environmental Protection Agency standards (40 CFR Part 197).

The Department recognizes that there is often a difference between calculated and perceived risk. However, the Department has focused its analyses upon impacts that can be estimated. It is then up to the decisionmakers and regulators that represent the public to make informed decisions regarding the future of the project. See Section 2.5.4 and Appendix N of the EIS for treatment of this topic.

7.3 (4316)
Comment - EIS001219 / 0005
The concentration of 70,000 metric tons of high level radioactive waste poses a high threat of overheating, risking atmospheric releases and all of the canisters will eventually leak, poisoning the ground water.

Response
The effects of thermal loading on the long-term performance of the proposed repository have been a subject of intense study and empirical data gathering for several years. Since the publication of the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance and improve operational safety and efficiency. The design evolution process has resulted in the development of the flexible design (see Chapter 2 of the Final EIS). In developing the flexible design, DOE considered the concerns expressed by the Nuclear Waste Technical Review Board about difficulties in reducing large uncertainties regarding waste package and repository performance related to high (above the boiling point of water) repository rock temperatures associated with the preliminary design in the Viability Assessment (DIRS 152574-Cohon 2000). The Board suggested that it might be possible to reduce such uncertainties by developing an adequate technical basis for a lower-temperature repository design.

The flexible design includes the ability to operate the repository in a range of operating modes that address higher and lower temperatures and associated humidity conditions. Higher-temperature means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96ºC (205ºF)]. The lower-temperature operating mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperatures would not exceed 85ºC (185ºF). To ensure the impact analysis covered the full range of potential impacts, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85ºC.

The risks of package failures leading to atmospheric releases would be extremely small based on test results and calculations that consider all plausible features, events, and processes. Eventually, however, the waste packages would fail to contain the waste. At that time there would be small releases of gases to the atmosphere as well as releases to the underlying aquifer. With the understanding that absolute assurance of "zero" release of waste materials is not possible over long periods, the Environmental Protection Agency has promulgated environmental protection standards for the Yucca Mountain Repository based on the concept of "reasonable expectation" (40 CFR Part 197). Prior to the Secretary recommending development of the proposed repository, DOE must provide a reasonable expectation of compliance with these long-term environmental protection standards as well as a reasonable expectation that the Yucca Mountain site would meet Nuclear Regulatory Commission site suitability standards (10 CFR Part 63). These regulations have been promulgated to ensure protection of the public and the environment. Chapter 5 of the Final EIS indicates that the flexible design would meet the environmental protection standards.

7.3 (4323)
Comment - EIS001222 / 0002
I recommend that this proposal be dropped immediately and permanently for the following reasons:

Any containers holding the waste are vulnerable to decay during the extremely long time that waste continues to be hazardous (thousands to millions of years). Because many containers could begin to leak at about the same time, it may be impossible to send people in to repair damaged containers without their receiving a fatal dose of radiation. This could allow contamination to spread into the surrounding area. Furthermore, leaks could occur long after our civilization has died out, leaving no one to take proper action to prevent large-scale releases.

If containers do leak and cannot be repaired, it is possible that a sufficient concentration of radioactive material could exist at some point to begin a chain reaction which could lead to a very serious nuclear explosion and spreading of radioactive particles over a large portion of the US and the world.

Response
DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. This EIS provides the Department's best estimate of the impacts that could occur when the containment system inevitably degraded. The EIS confirms that the Proposed Action would be expected to result in release of radioactive contamination to the environment. However, the EIS also shows that these releases under the Proposed Action would not exceed environmental protection standards (40 CFR Part 197) within 10,000 years of repository closure, standards specifically enacted to ensure the safety of future generations.

Federal regulations (10 CFR Part 63) require that the repository be designed to preserve the option of waste retrieval on a reasonable schedule for as long as 50 years after the start of waste emplacement. Consistent with these requirements, the operational plan for the Yucca Mountain Repository provides for a design and management approach that isolates wastes from the public in the future while allowing flexibility to preserve options for modifying emplacement and retrieving the waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel.

As explained in Section 5.8 of the EIS, DOE believes that an explosive nuclear criticality event would not be credible. Supporting information, including the scientific bases, regarding nuclear criticality can be found in the Science and Engineering Report (DIRS 153849-DOE 2001) and its referenced supporting documents.

7.3 (4328)
Comment - EIS001222 / 0007
The wastes will be hazardous long after our civilization has died out. No method to communicate the dangers and effective handling procedures to future civilizations has been devised. It is highly irresponsible to subject our descendents to hazards of which they know nothing, especially since it can be so easily avoided.

Response
DOE and other scientific advisory groups continue to study effective means of communicating hazards to future civilizations. However, the current belief is that the repository area would be identified by monuments designed, fabricated, and placed to be as permanent as practicable. These monuments would be intended to notify persons in the area that the repository exists. The notification allows the intruders the option to make informed decisions regarding the use of the surface and subsurface areas for habitation or other activities. Although the design and ultimate placement of these monuments is still under study, National Research Council (DIRS 100018-1995) contains additional information on the subject of human intrusion and long-term passive institutional controls.

7.3 (4572)
Comment - EIS001521 / 0086
Page 9-12, 9.2.8 LONG-TERM REPOSITORY PERFORMANCE, third paragraph, first bullet-- (Long-Term Performance Measures Under the Proposed Action) Given that the thickness of the unsaturated zone between the proposed repository horizon and the water table would range from 175 to 365 meters (see page 3-41, fifth paragraph), saying that the thickness is about 300 meters is incorrect. Hopefully the thickness range, and the lesser number in particular, was used in designing the engineered-barrier system.

Response
DOE agrees that it would have been more accurate to specify the range of overburden thickness between the surface and the repository depth. Therefore, the Final EIS was revised to indicate the actual range rather than an approximation value.

The Total System Performance Assessment of the long-term consequences reported in Chapters 5 and Section 8.3.1 did, in fact, use the actual depth range from the surface to the repository and the actual depth range from the repository to the regional water table, in a multidimensional modeling approach.

7.3 (4578)
Comment - EIS001521 / 0092
Pages I-88 through I-96, Figures I-27 through I-35, respectively--Very few faults are shown on the base maps of these figures and as such, they misrepresent the complex faulted-geologic structure that is representative of the Yucca Mountain area. By looking at these figures one would conclude that not one major, or minor, fault is coincident with the location of a proposed repository block and this simply is not true! An accurate depiction should be shown on all figures.

Response
The level of detail for Figures I-27 through I-35 of the Draft EIS was appropriate to the purpose of each of these figures. Major block-bounding faults shown in these figures were for the purpose of assisting the reader to visualize

the location of the repository blocks relative to major geologic structures. Section 3.1.3.2 presents the details of mapped fault structures at the Yucca Mountain site. No figures like these appear in the Final EIS.

7.3 (4607)
Comment - EIS001430 / 0004
I note that Long term (100 to 10,000 years) impacts also seem to be pretty well bounded but with more uncertainty (e.g. Table 5-3, page 5-22). However, impacts beyond 10,000 years seem to need more study, indeed, DOE is planning additional studies as discussed on page 5-13. I would hope that results would be available for the final EIS. If not, the mitigation measure to delay closure up to 300 years (p. 9-16) is recommended.

Response
The additional studies referred to in the Draft EIS are continuing. Some results from those studies have provided refinements for the analysis in the Final EIS, especially in the areas of engineered barrier degradation and radionuclide mobilization. The refinements include the use of more experimental data, accounting for more process coupling in the near field, refined and expanded colloid transport models, and other modeling and basis data changes. DOE agrees that the robustness of the engineered barrier system would dominate early behavior (up to 10,000 years) and that modeling and data related to mobilization and transport become much more important in analyzing impacts for the longer period (1 million years). The ongoing studies have helped provide a more refined forecast of very long-term behavior.

Decisions on mitigation measures such as a delay of closure to 300 years would depend on many considerations, which could include postclosure performance. While the projected 1-million-year performance could play a role in such decisions, other equally important factors might not favor such a move.

7.3 (4641)
Comment - EIS001164 / 0002
Another part of the assumptions built into the analysis are the hydrologic assumptions. I have spent my life in a profession that is just now awakening to the fact that climate has changed pretty dramatically and is going to change very dramatically in the future. That may not be a problem for the present generation, but of course, it's a tremendous problem for future generations, and it's for the future generations that really motivates me to come here because we are proposing to dispose of nuclear waste that will be toxic for longer than all civilizations have existed on earth. That is frankly an immoral act.

Response
DOE is committed to protecting public health and safety and the environment, both current and future, by designing a suitable repository for the Nation's radioactive waste. Climate is one of the important considerations in analyzing the future behavior of the proposed repository. As discussed in Section 5.2.4.1 of the EIS, no one can predict future climate exactly. However, based on past climatic conditions and long-term climate cycles, possible future climates can be postulated. The long-term performance analysis in this EIS considered the effects of these future climates by including a pattern of wetter and cooler climates as indicated by the geologic record.

7.3 (4780)
Comment - EIS001519 / 0006
It is impossible to guarantee the safety and functionality of the storage canisters over the long term in regards to the construction of the canisters. Primarily, the actual canisters have not been built yet. Only blueprints exist from which the DOE has made predictions. In addition, seismic events or corrosion and destruction of the surrounding rock by the intense heat from the decaying fuel could subject the canisters to extreme pressures or weights that could cause them to rupture. Faulty canister construction would also present the possibility of waste fuel contaminating the area.

Response
The experiments and analyses documented in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000) provide the basis for the waste package modeling and life expectancies. This report identifies and discusses each potential waste package degradation mode. The degradation model includes those modes that analyses did not screen out as highly improbable.

The longevity of the waste package is a principal factor in the repository safety case. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). However, the updated analysis in the Final EIS projects between zero and three packages failing due to manufacturing defects.

Obviously, there is uncertainty associated with the extrapolation of experimental results for such long periods and for the other human factors mentioned in the comment. DOE selected the design analyzed in the Final EIS to mitigate the uncertainties by adding features (such as the drip shield) to provide defense-in-depth. This provides greater assurance that the repository would meet its performance standards in the face of uncertainty.

7.3 (4814)
Comment - EIS000938 / 0009
Volume II, Page I-9 through I-12. What is the conclusion or impact of these [nuclides] on public health both in the repository and during transportation to the site? Page I-14, Table I-9, why was the performance assessment calculations only modeled to the year 2055 when some of the materials have a half life of over a million years?

Response
Chapter 4 of the EIS describes the short-term (about 100 years) impacts resulting from construction, operation and monitoring, and eventual closure of the repository. Similarly, Chapter 5 describes the potential long-term impacts related to the expected performance of the repository for up to 1 million years after closure. In addition, Chapter 6 describes the impacts of transporting spent nuclear fuel and high-level radioactive waste from 77 sites in the United States to Yucca Mountain. Consistent with the National Environmental Policy Act process, DOE has presented environmental information in the EIS without conclusions as to whether the level of environmental impacts may be acceptably small or unacceptably large. These are in essence policy decisions that will ultimately be made by the President and Congress, if necessary, based, in part, on recommendation of the Secretary of Energy.

Table I-9 of the Draft EIS summarizes radioactivity data for the nine radionuclides modeled in the long-term performance assessment calculations using inventories projected through to 2055. DOE conservatively assumed 2055 because that year would include all of the spent nuclear fuel and high-level radioactive waste projected to be generated at commercial and DOE sites as well as all Greater-Than-Class-C low-level waste resulting from the decontamination and decommissioning of commercial nuclear reactors. The periods for analyzing public health impacts and estimating peak dose rates are 10,000 years and 1 million years, respectively. Note that further ingrowth of radionuclides and reduction of some others by decay after 2055 is accounted for in the long-term performance analysis.

7.3 (4840)
Comment - EIS001340 / 0001
In EIS Report Chapter 2.4.1. Proposed Action and No-Action Alternative: Under scenario 2, EIS assumes in 100 years there would be no effective institutional controls at present storage facilities, allowing for possible leakage due to deterioration of stored canisters, but in Yucca [Mountain], storage after 110 or 120 years, if it's possible for casks to leak on sites now after 100 years. What happens to casks or canisters underground in the proposed Yucca [Mountain] site when they do the reclamation they propose and cover all tunnels, fill in shafts and remove all signs of entrances and the canisters then overheat or start to leak?

The metal canisters being experimented with by infallible man did not hold up to the expectations. There would be no way to retrieve them after closure of the site. When the cooling shafts are filled in and tunnels closed off unexpected temperatures could create the previous mentioned volcanic eruptions of radioactive materials into the atmosphere under such pressure it could go much further than any previously thought accident occurrences. Its hard for me to conceive a cooldown of this waste in only 100 to 120 years when it's actively dangerous for up to 250,000 years!

Response
Section 2.1.2.4 of the EIS discusses the steps DOE would take to close the Yucca Mountain Repository. Since the publication of the Draft EIS, the Department has modified the repository design to include drip shields over the

waste packages and forced ventilation during the operation and monitoring phase. The drip shields would be placed over the waste packages immediately before closure. The forced ventilation would end when DOE closed the repository. The current design does not involve the placement of backfill over waste packages.

DOE selected the waste package materials and designed the packages to function in the postclosure environment. This includes heating of the packages over several hundred to 1,000 years as a result of radioactive decay of the wastes. Over a span of about a few thousand years, DOE estimates that the temperature in the repository environment would return to preemplacement conditions. Under the higher-temperature operating mode of the updated design discussed in the Final EIS, DOE anticipates that only a small portion of the rock would be above 100ºC (212ºF) for a relatively short period. The waste packages would experience slightly higher temperatures. These temperatures would not result in volcanic activity at Yucca Mountain.

The updated analysis in the Final EIS indicates that only one or two waste packages would be likely to fail in the first 10,000 years. However, the analysis also indicates that over long periods, water would eventually contact the waste packages, that the packages would ultimately corrode, and that waste materials would be released from the repository.

Prior to recommendation of the Yucca Mountain site for development of a geologic repository, DOE would have to provide a reasonable expectation that the repository could meet the environmental protections standards (40 CFR Part 197) developed by the EPA to protect human health and the environment.

7.3 (4881)
Comment - EIS000337 / 0021
Pg. 5-23, 4th par, last sentence: "...DOE believes the performance results of this EIS are conservative estimates...." The question to be asked, "Who knows how conservative the DOE estimates are?"

Response
The probabilistic approach (Monte Carlo method) to the impact simulations that DOE uses in the long-term performance analysis in this EIS is intended to account for uncertainty in data and models. All the principal data used in the simulations for the long-term impacts are distributions or ranges. These parameter distributions use conservative assumptions when there is insufficient information available to provide reasonable expectation that the estimated consequences are not underestimated. In the EIS, the results of the of the multiple simulations are presented in terms of mean and 95th percentile values, which represent the likely consequence and the consequence level where 95 percent of the simulations are less than the reported value, respectively. The spread of these values provides insight into the level of uncertainty and conservatism.

7.3 (4883)
Comment - EIS000337 / 0023
Pg. 5-37, last par, 3rd line: "...zirconium alloy would provide some impediment...if the waste package was breached." Another example of adjectives that have no meaning in an engineering report.

Response
This comment cites a statement in Section 5.4.4 of the Draft EIS that summarizes results of a quantitative analysis. Table 5-16 lists the impact results.

7.3 (5418)
Comment - EIS001887 / 0119
Page 2-57; Section 2.1.4.2 - Design Features and Alternatives to Control the Thermal/Moisture Environment in the Repository

Any continuous postclosure ventilation considerations should eliminate all options that result in postclosure openings from the interior of Yucca Mountain to the surface. (See Appendix E at E.2.2.3). Any openings would constitute a large and unacceptable uncertainty in postclosure performance that could not be mitigated. Site characterization studies have shown that, due to the fractured nature of the rock, Yucca Mountain is a naturally ventilated setting above the water table. This fact must be taken into account in long-term performance assessment.

Response
Table 2-4 of the Draft EIS contained an error that suggested that DOE considered continuous postclosure ventilation to be part of every Enhanced Design Alternative. Section E.2.2.3, correctly indicated that all Enhanced Design Alternatives except one included preclosure – but not postclosure – continuous ventilation.

The Draft EIS evaluated the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for repository surface facilities, and disposal containers (waste packages). It also evaluated the plans for the construction, operation and monitoring, and closure of the repository. To ensure flexibility to future decisionmakers, the Draft EIS reported that DOE was designing a repository with the capability for closure as early as 50 years or as late as 300 years after the start of emplacement.

DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of a final repository design and as a result of any licensing review of the repository by the Nuclear Regulatory Commission. The design evolution resulted in the flexible design evaluated in the Supplement to the Draft EIS and subsequently integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements.

For the reasons stated above, DOE developed analytical scenarios to estimate the range of environmental impacts that could result from the Proposed Action for the analyses performed for the Supplement to the Draft EIS. These analytical scenarios include the low, intermediate, and high thermal load scenarios presented in the Draft EIS, as well as the higher- and lower-temperature repository operating modes being considered for the flexible design. Section 2.2.1 of the Supplement summarizes the operational parameters for the three thermal load scenarios analyzed in the Draft EIS and the two repository operating modes analyzed in the Supplement. Section 2.2.2.2 describes the operational parameters for the higher- and lower-temperature operating modes. The lower-temperature operating mode considered for the flexible design included evaluation of a postemplacement ventilation period as long as 300 years. However, at the present time, continuous postclosure ventilation is not an option under consideration for the flexible design and, therefore, has not been included in the evaluation of long-term performance presented in Chapter 5 of the Final EIS. Chapter 2 of the Final EIS states that only postemplacement ventilation is under consideration for the flexible design. If postclosure continuous ventilation became incorporated in a future design, DOE would conduct the evaluations suggested in the comment.

7.3 (5444)
Comment - EIS001887 / 0136
Page 2-75; Table 2-7 - Impacts Associated with the Proposed Action and No-Action Alternative
Long-term air quality: It is possible that there would be carbon-14 releases to the air from the postclosure repository. It is incorrect to say there would be no air releases.

Response
It is true that there could be postclosure releases of carbon-14 to the air from the repository. In fact, all of the very small carbon-14 releases estimated in Section 5.5 of the Draft EIS were predicted to occur after repository closure. In addition, Chapters 5 and 8 of the Final EIS now include analyses of atmospheric releases of radon-222 in the postclosure environment. Therefore, Table 2-7 has been revised in the Final EIS to reflect the appropriate impacts.

7.3 (5632)
Comment - 010062 / 0003
I noted the stated radionuclides that may be water soluble. What percentage of the waste packages will these be within spent fuel rods for how long before deterioration/decay? I assume a substantial portion of the cask's content is water-soluble radionuclides initially, since all isotopes of uranium are reportedly water soluble.

Response
In the simulations of long-term performance all of the radionuclides are considered to be water-soluble. The solubilities and rates of dissolution are characterized in the models for release of material after a package is breached. The solubilities are input as ranges of possible numbers in a statistical distribution and are very important to the results that are reported in the EIS.

7.3 (5650)
Comment - EIS001887 / 0268
Page 5-6; Section 5.1 - Inventory for Performance Assessment Calculations

Plutonium should be included in both the radionuclide inventory assessment and the chemical toxicity assessment. Recent evidence indicates that plutonium moves more quickly than originally thought.

Response
As described in Section I.3.2.1 of the Draft EIS (Section I.3.2 of the Final EIS), the radiological toxicity of plutonium far exceeds its chemical toxicity. In addition, while there are established radiological limits for exposure to plutonium, there are no such limits for chemical toxicity. Therefore, because DOE thoroughly evaluated the radiological consequences of plutonium, it did not analyze it for chemical toxicity.

Recent evidence indicates that plutonium moves more quickly in groundwater than originally thought. This is believed to be due to its association with colloids. The models discussed in Appendix I of the Final EIS include colloid-facilitated transport of plutonium. This modeling is informed by both experimental and analytical work, and benefited from observations made on the Nevada Test Site where plutonium was found to be associated with colloids in groundwater.

7.3 (5656)
Comment - EIS001887 / 0276
Page 5-17; Section 5.2.4.1 - Uncertainty Associated With Societal Changes, Climate, and Other Long-Term Phenomena

The statement regarding benefits from future human activities such as technology for radiation removal from water and the environment and cures for cancer is not relevant in this Draft EIS. These concepts cannot be offered or committed to as mitigation measures and surely cannot be justified as an excuse for releasing radionuclides to the environment. This statement should be removed.

The time and magnitude of the projected peak dose is sensitive to the idealized climate cycle pulses. The uncertainty associated with the superpluvial pulses should be illustrated.

This section fails to include the potential for global climate change to affect repository performance and environmental consequences. The oversight also exists in Section 5.9, page 5-46, Consequences to Biological Resources and Soils. The section does address the thermal loading effect (Table 5-18, page 5-47) to biological resources and soil. However, the potential temperature increases are overly conservative and their estimated ranges from low to high are ignored. Clearly, there is a potential for vegetation to disappear above the repository and for the soil cover to be eroded away. The consequences of this to the site's geohydrology and repository performance should be addressed in Section 5.4.1, 5.4.2, and 5.4.3. These weaknesses exist because DOE failed to adopt an ecosystem approach for the Draft EIS, as recommended in Attachments [to this comment document] F, G, K, and L and by Bartlett and Malone (1993), Clark and Canter (1977), and Salk and others (1998).

Response
DOE agrees that the potential benefits from future developments, such as radiation removal technology and cancer cures, are not relevant to this Proposed Action and that such benefits do not justify releasing radionuclides to the environment. Section 5.2.4.1 of the EIS specifically notes that DOE did not take such benefits into account.

Global climate cycles and superpluvial pulses would affect repository performance, and the time and magnitude of the projected peak dose. As stated in Section 5.2.4.1, estimates of future climatic conditions are based on what is known about the past, with consideration given to climate impacts caused by human activities. DOE based updates to the model representing global climate change on the latest research of the U.S. Geological Survey and the Desert Research Institute. The long-term performance analysis in this EIS captures the uncertainty associated with the superpluvial pulses, and this EIS presents sensitivity analyses to indicate the effect of such pulses on overall system performance.

Since the publication of the *Viability Assessment for a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) and the Draft EIS, DOE has evaluated different thermal management strategies for lower- and higher-temperature operating modes. As a result, the design basis for the proposed repository has evolved. The thermal load is determined by such factors as inventory, burnup, number and mix of assemblies per waste package, age from discharge, staging receipt and emplacement of assemblies, spacing of waste packages and drifts, ventilation rates and periods, and the overall repository footprint. The thermal load would affect the temperature distributions in the engineered system, the near-field environment, the geologic environment, and the surface temperature of soils in the accessible environment. DOE has evaluated these temperature distributions and the coupled thermal-hydrological-chemical-mechanical effects on repository performance.

Section 5.9 of the EIS describes impacts to surface soils, vegetation, erosion, runoff, and plant and animal habitats. Table 5-15 lists predicted increases in soil temperature as a function of depth for the high thermal load scenario. Although not modeled, the magnitude of the increase in soil temperature would be smaller for the low and intermediate thermal loads. Thus, DOE agrees that the predicted temperature increases listed in Table 5-15 would be a conservative upper limit. Section 5.9 specifically acknowledges that there is a potential for diminished vegetation and soil erosion. These, in turn, could lead to an increase in sediment load in the surface runoff from Yucca Mountain.

Sections 5.4.1, 5.4.2, and 5.4.3 of the Draft EIS consider the radiological consequences of the potential future release and migration of radionuclides from the repository for the high, intermediate, and low thermal load scenarios, respectively. The consequences would occur because of the hydrogeologic conditions of the Yucca Mountain area, which are documented in the Viability Assessment (DIRS 101779-DOE 1998) and its companion 11-volume Technical Basis Document (DIRS 108000-CRWMS M&O 1998). Soil erosion localized over the repository footprint of several hundred acres would have little impact on the regional groundwater flow system comprising an area of hundreds of square miles. Thus, the EIS evaluates the influence of hydrogeologic conditions on repository performance, not the converse.

Section 3.1.5 of the EIS acknowledges the opposing views of the State of Nevada, Malone and others to an integrated ecosystem approach. DOE relied on extensive interdisciplinary collaboration to evaluate system impacts. When applicable, the Department adopted the concepts of ecosystem management of the Council on Environmental Quality (DIRS 155275-CEQ 1993), as required by DOE Policy 430.1, *Land and Facility Use Planning*. DOE has conducted extensive studies of the ecosystem surrounding Yucca Mountain for many years, and used the results of those studies to make decisions necessary to maintain or improve ecosystem integrity and diversity and to predict future impacts of the Proposed Action. Appendix C summarizes DOE interactions with state and Federal agencies to ensure protection of the ecosystem. For example, it has interacted with the National Park Service to protect pupfish and with the U.S. Fish and Wildlife Service to protect desert tortoises, the only species in the repository land withdrawal area that is listed as threatened under the Endangered Species Act. Therefore, DOE believes that the assessment methods it used to develop the EIS were extensive, consistent with the regulatory framework provided by 40 CFR 1502.25 and 10 CFR 1021.341(b), and sufficient for evaluating potential impacts of the Proposed Action.

7.3 (5657)
Comment - EIS001887 / 0275
Page 5-16; Section 5.2.3.6 - Nuclear Criticality

The Draft EIS should provide more information as to what “minor effects” a nuclear criticality incident would have on repository performance and what analysis was performed to support this conclusion.

Response
Section 5.8 of the EIS summarizes the impacts of a nuclear criticality on repository performance. Updated analyses regarding criticality have been completed since the publication of the Draft EIS. This EIS summarizes the results of these analyses. This summarization is based on analyses documented in the Science and Engineering Report (DIRS 153849-DOE 2001) and its referenced supporting documents.

The results of these analyses indicate that for a steady-state in-package criticality, the additional heat output is only about 2 kilowatts per package, which is inconsequential compared with the overall repository heat load. Additionally, a small increase in the radionuclide inventory (25 percent increase in total radioactivity in one waste

package) would occur. Because of the small increases in radioactivity and heat output, there is no chance that the waste package and the engineered barrier system could be mechanically disrupted by a criticality.

In the unlikely event that an external criticality occurred, the resultant increase in the radionuclide inventory would be very small.

7.3 (5659)
Comment - EIS001887 / 0278
Page 5-20; Section 5.2.4.3.2 - Weighting of Alternative Conceptual Models

The reference designs of the repository and waste package in the Draft EIS are not the designs currently under consideration. This alone undermines DOE's ability to use the TSPA [Total System Performance Assessment] results in this Draft EIS for selection of the preferred alternative.

There has been considerable debate over the actual flow paths that would be followed by the radionuclides released from the repository. Modeling results performed by the State of Nevada (Lehman and Brown, 1994, Lehman and Brown, 1995) indicate major differences may exist in flow path direction, velocity, and sorptive capability compared to that used in the latest assessments by DOE, including the Draft EIS, if all data sets are utilized.

By failing to evaluate credible alternative models or opposing views of the saturated zone, DOE is not in compliance with NEPA [National Environmental Policy Act]. Being out of compliance with NEPA means automatic noncompliance with the NWPA. DOE is specifically out of compliance with NEPA 1502 for not summarizing, discussing, or using important data sets. DOE has failed to evaluate credible opposing viewpoints and does not propose testing to reduce uncertainty in the choice between alternative conceptual flowpaths. (See Attachment [to this comment document] U for a more detailed discussion of this issue.)

Response
The EIS now contains analysis of the updated design and incorporates a refined Total System Performance Assessment model (DIRS 153246-CRWMS M&O 2000) that includes many new modeling approaches. The new modeling approaches account for many alternative conceptual models, including the ones mentioned in the comment.

The *Saturated Zone Flow and Transport Process Model Report* (DIRS 151948-CRWMS M&O 2000) describes alternative conceptual models of the saturated zone flow system. Specifically, it discusses the model presented by Lehman and Brown (DIRS 149173-1996; DIRS 101254-1998). The main difference between the models is the length of the flowpath through the alluvium. In the performance assessment calculations for the Final EIS, the length of the flowpath through the alluvium was varied to account for uncertainty. Furthermore, DOE used data obtained by Nye County to support the saturated zone model and help define the uncertainty range for the alluvium flowpath length.

7.3 (5664)
Comment - EIS001887 / 0283
Page 5-27; Section 5.4.1 - Consequences from the Groundwater Exposure Pathway for the High Thermal Load Scenario

The assumption that radionuclides would mix in the unsaturated zone has no basis. DOE's own statement, on page 5-10, implies that DOE cannot adequately model the unsaturated zone.

Diluting the concentration of the yearly infiltration from Yucca Mountain into the 17.3 million cubic meters of water use in Amargosa Valley is not conservative. Data from Nye County drilling indicates that the flow is compartmentalized, and there would not be a large amount of dilution of the radionuclides. This statement applies also to the similar dilution used in the Intermediate and Low Thermal Load scenarios.

Response
The approach to modeling reflected in the Supplement to the Draft EIS and the Final EIS (see Sections 5.4.2 and I.2) is very different from that described in the Draft EIS. The saturated zone model in the new model approach is a

three-dimensional model that provides a more realistic representation of the very small amount of mixing in the saturated zone between the proposed repository and the reasonably maximally exposed individual (RMEI) location at approximately 18 kilometers (11 miles). The radionuclide flux arriving at the RMEI location is diluted in a water usage by a hypothetical farming community at that location, as prescribed in the Environmental Protection Agency standard at 40 CFR Part 197. This usage is sampled in a range of approximately 890 to 3,370 acre-feet per year with an average of about 1,940 acre-feet per year. Increasing mixing is allowed in the flow path from 18 kilometers to 60 kilometers (37 miles) because the aquifer changes from mostly fractured rock to mostly alluvial deposits (sand and gravel) in this region (see Section 5.4.1).

The dose to the RMEI and to the individual with RMEI characteristics but located at other distances is derived from this new approach. The approach in the Draft EIS was used because the modeling was one-dimensional, so that a scaling approach was necessary. The results of the new model indicate that the Draft EIS approach was probably quite reasonable and perhaps somewhat conservative.

7.3 (5668)
Comment - EIS001887 / 0286
Page 5-30; Table 5-7 - Peak Radionuclide Concentrations

The Draft EIS should provide Maximum Contaminant Levels (MCLs) as set by EPA [Environmental Protection Agency] for drinking water systems to compare with the peak radionuclide concentrations given in this table.

Response
Section 3.1.4.2.2 of the EIS discusses saturated groundwater quality. The parameters include average combined radium-226 and –228, average gross alpha, average total uranium, average gross beta, and average radon-222. The results of sampling analyses at Yucca Mountain and in the region are listed in Table 3-19. Applicable Maximum Contaminant Level Goals are also listed in the table. DOE elected to list these values here rather than in Table 5-7 because it considers them to be part of the baseline or affected environment. The accompanying text states that analyses also included tritium, carbon-14, chlorine-36, nickel-59, strontium-89 and –90, technetium-99, iodine-129, and cesium-137. Parameters were listed only if concentrations were above a minimum detectable activity level. In the Final EIS, DOE has added Table 3-12 to show Maximum Contaminant Level Goals for nonradiological chemicals.

7.3 (5669)
Comment - EIS001887 / 0290
Page 5-38; Section 5.5 - Atmospheric Radiological Consequences

What analysis supports the expectation that Iodine-129 will dissolve in the groundwater rather than migrating as a gas?

Response
The amount of iodine-129 going to the atmosphere versus that going to water is governed (in the case of a reasonably slow process) by the vapor-liquid equilibrium between dissolved iodine and iodine-bearing vapor in the gas phase. A dominant species with the highest tendency toward the vapor phase would be hydrogen iodide. At 25ºC (77ºF), the partial pressure of hydrogen iodide over a 56-percent aqueous solution (very high concentration) is 0.10 millimeters of mercury. If it is assumed that the repository is at about standard pressure (760 millimeters of mercury), then the mole fraction of the hydrogen iodide in the air over that aqueous solution is 0.00013 or 0.06 weight percent (DIRS 104946-Perry and Chilton 1973). Thus, the partitioning of iodine in a very concentrated solution greatly favors the liquid phase. In a very dilute concentration of 4-percent iodine the vapor phase would be at 0.00064 millimeter of mercury and, therefore, 8.4×10^{-7} mole fraction or 0.00004 weight percent (DIRS 104946-Perry and Chilton 1973). Thus, at low concentrations there is a 10,000-to-1 bias toward the liquid; at very high concentration this becomes a 1,000-to-1 bias. It is a reasonable assumption that essentially all of the iodine would go to the water. If the temperature was much higher, there would probably be a tendency for the iodine to be more predominant in the vapor phase but, because only a few (zero to three, and possibly as many as five) waste packages would fail before the repository had cooled back to ambient conditions, this would not be a factor.

7.3 (5671)
Comment - EIS001887 / 0291
Page 5-38; Section 5.5.1 - Carbon-14 Source Term

This analysis is highly sensitive to the large uncertainties in waste package and cladding degradation models. The uncertainty in the source term associated with these two factors should be discussed in this section.

Response
The commenter is correct that atmospheric radioactive material impacts are sensitive to the uncertainties in the waste package and cladding degradation models. As discussed in Section I.7.1 of the Draft EIS, the impacts from the atmospheric release of carbon-14 were estimated using expected value models for waste package and cladding performance. DOE believes the simplifying assumption used in these models is appropriate given the inconsequential impact estimates.

7.3 (5672)
Comment - EIS001887 / 0293
Page 5-39; Section 5.6.1 - Human Health Impacts From Chromium, and Table 5-17

At the 5 and 20 km locations, the expected chromium concentrations are relatively close to the Maximum Contaminant Level Goal (MCL) and highly subject to uncertainty in waste package failure expectations (and at 20 km, the saturated zone flow model). A slight (but not unreasonable) change in the assumption regarding juvenile waste package failures would result in the Maximum Contaminant Level Goal being exceeded. The conclusion that, for the high and intermediate thermal load alternatives, "DOE anticipates no detrimental impacts to water quality due to chromium contamination" (Page 5-40) is not justified when reasonable uncertainties are taken into account. The analysis is also somewhat sensitive to the waste package design, which, in the Draft EIS, is not the same as that being currently considered. The current design is likely to permit more rapid mobilization of chromium.

Response
As noted by the commenter, the waste package design in the Final EIS is different from the design in the Draft EIS. There is quite a bit more Alloy-22 used in the updated design, much of which would be exposed on the outside of the waste package and supports. However, because of the presence of titanium drip shields, water is not expected to reach much of the chromium-bearing material for 10,000 years after closure. Thus during this period, the most important mechanisms for mobilization of the chromium is the very slow humid-air corrosion of the exposed surfaces under the drip shields and diffusive transport of dissolved materials to the unsaturated zone water. To evaluate the potential outcome of these processes, a conservative calculation was made assuming that all the exposed chromium material would corrode in the humid air and immediately dissolve in the unsaturated zone water. All of this material is then diluted in the standard average uptake in a well at 18 kilometers (11 miles). The results showed concentrations well below the Maximum Contaminant Level Goal for chromium (see Section I.6 of Appendix I of the EIS). Because of the conservative nature of these calculations, DOE believes it is very unlikely that actual concentrations would be much larger.

7.3 (5674)
Comment - EIS001887 / 0294
Page 5-40; Section 5.6.2 - Human Health Impacts From Molybdenum

The above comments regarding chromium also apply to molybdenum in terms of the amount of metal that could be mobilized if uncertainty due to a single assumption regarding juvenile waste package failure and the current waste package design are taken into account. The lack of a drinking water standard is not a justification for releases of molybdenum into groundwater in amounts similar to chromium, especially when adverse effects of molybdenum in water used by livestock have been documented for years.

Response
Concerning molybdenum, Alloy-22 contains 13.5 percent molybdenum. Maximally corroded waste packages and other components containing Alloy-22 would release molybdenum in a manner similar to that of chromium but with a lower activity. Section 5.6 of the EIS states that the estimated 10,000-year peak concentration of chromium in groundwater, based on releases from the preferred repository design, would fall well below present Environmental

Protection Agency guidelines for chromium in groundwater. Although there are no specific standards for molybdenum concentration in drinking water, low concentrations of dissolved molybdenum occur in most public water supplies. There is no established general heath hazard associated with public water supplies with this range of dissolved molybdenum. The concentrations in approved public water supplies are in the range of dissolved molybdenum that would be likely to be released from the proposed Yucca Mountain Repository. Therefore, DOE does not expect potential molybdenum health hazards associated with the use of Alloy-22.

7.3 (5675)
Comment - EIS001887 / 0295
Page 5-42; Section 5.7 - Consequences From Disruptive Events

Because of the wide range of uncertainty associated with the base case dose calculations and the questionable representativeness of the mean of the model realizations, the base case performance should be represented by the 95th percentile of the calculations rather than the mean.

Response
This EIS contains revised calculations of the consequences from the base case (now called *nominal scenario*) and from disruptive events. The results of these calculations discuss both mean and 95th-percentile estimates. DOE included the mean value because the regulators require it.

7.3 (5683)
Comment - EIS001887 / 0299
Page 5-48; Section 5.9 - Consequences to Biological Resources and Soils

The discussion of estimated doses from irrigation water and discharge at Franklin Lake Playa should indicate that the time period considered is 10,000 years. As seen in the referenced Draft EIS sections, peak doses, even at 20 km, could be as high as 1.4 rem/year. None of the peak doses calculated can be considered small and would certainly exceed any standard established for a repository.

Response
DOE agrees that readability could have been improved by stating that the doses referenced on page 5-48 of the Draft EIS were the 10,000-year peak doses. However, the updated analysis for the flexible design in the Final EIS predicts that releases during the first 10,000 years after repository closure would be very small and, therefore, impacts to biological resources and soils would be expected to be very small. The 10,000-year period following closure of the repository is clearly defined in the Final EIS as the compliance period consistent with the Environmental Protection Agency Yucca Mountain environmental protection standards (40 CFR Part 197).

In addition to estimating doses during the 10,000-year compliance period, DOE performed analyses to determine peak doses during the 1-million-year period following repository closure. However, the Department agrees with the Environmental Protection Agency that there would be considerable uncertainty associated with projections for tens of thousands to hundreds of thousands of years. As the Agency notes in 40 CFR Part 197, "Simply because such models can provide projections for those time periods does not mean that those projections are either meaningful for decisionmakers or accurate." The peak dose rates are included in the EIS as a best estimate of a range of possible impacts given the long periods and uncertainties involved. However, because of the large uncertainties associated with these post-10,000-year peak doses, DOE believes that the estimation of impacts that could arise from these doses would be too speculative to be useful to the decisionmaking process and has therefore limited the results for postcompliance periods to consequences (that is, dose).

7.3 (5757)
Comment - EIS001887 / 0360
Page 10-2; Section 10.1.1.3 - Hydrology

This section of the Draft EIS should point out that the resultant peak doses expected from releases of radionuclides to the groundwater are much larger than considered acceptable under any reasonable standard. To illustrate the extent of expected contamination, reference should be made to Table 8-41 on page 8-63, which provides peak dose calculations at various distances from the waste emplacement area. It must also be recognized that the Proposed

Action results in an irreversible commitment of groundwater in Amargosa Valley, Franklin Lake Playa, and springs in Death Valley to contamination by radionuclides at a level that makes the water unfit for human use and a significant danger to the environment.

Response
Chapters 5 and 8 of the EIS describe peak dose rates for the Proposed Action and the cumulative effects of possible past, present, and reasonably foreseeable actions, respectively. Chapter 10 of the EIS, which includes a discussion of irreversible impacts, was prepared pursuant to the Council on Environmental Quality regulations (40 CFR 1502.16) that require the consideration of any irreversible or irretrievable commitments of resources that would be involved in the proposal should it be implemented. In that context, DOE is most concerned with the repository and associated actions and believes reference to cumulative impacts would mask the incremental contribution the repository could have on resource commitments.

As described in Section 3.1.4 of the EIS, DOE has conducted an extensive program to characterize the direction and nature of groundwater flow from the Yucca Mountain site. The general path of water that percolates through Yucca Mountain is southward toward the Town of Amargosa Valley, then beneath the area around Death Valley Junction in the southern Amargosa Desert. The groundwater beneath Yucca Mountain merges and mixes with groundwater beneath Fortymile Wash. This groundwater then flows toward, and mixes with, the large groundwater reservoir in the Amargosa Desert. The natural discharge point of this groundwater occurs farther south in Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume may flow south toward Tecopa into the southern Death Valley area. A fraction of the groundwater may flow through fractures in the relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. Potentiometric data indicate that a divide could exist in the Funeral Mountains between Amargosa Desert and Death Valley. This divide would limit discharge from the shallow flow system, but would not necessarily affect the flow from the deeper carbonate aquifer that may contribute discharge to springs in the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Potential Furnace Creek area impacts would be less than the low impacts described in Chapter 5 for Franklin Lake Playa because impacts would decline with distance from the repository.

The Nuclear Regulatory Commission and the Environmental Protection Agency have developed standards for the long-term performance of the proposed repository. These standards would apply to the first 10,000 years, and the EIS analyses indicate that the repository would meet them.

As appropriate, DOE will continue to evaluate physical locations that the annual peak dose could affect and perform analysis consistent with the risk identified. DOE will also continue to focus its attention at the point of regulatory compliance, which represents a location where impacts would be most likely given the greater possibility for groundwater withdrawal at this location.

7.3 (5759)
Comment - EIS001887 / 0365
Page 10-9; Section 10.2.1.2 - Hydrology

The last statement in this section is specious, at best. Yucca Mountain will result in contamination of a large aquifer and surface water expressions, and the shipping campaign could cause the contamination of many major and minor water bodies throughout the U.S. The perception given by this statement is that it is acceptable to contaminate water in Nevada, but not anywhere else.

Response
DOE acknowledges that some contamination of the aquifers in the Yucca Mountain region could occur. However, the EIS shows that the timing would be very long and the amount of contamination would be very low and within established regulatory standards, which were developed to ensure acceptable human health and environmental impacts. Only minimal surface contamination would occur at Franklin Lake Playa. This is an area of ephemeral surface water, and the impacts would be very low in relation to the standards. The analysis of transportation alternatives indicates no radiological contamination of water bodies of the United States.

The minimal potential impacts to Nevada water bodies would be less than the potentially larger impacts to water bodies near the large population centers in proximity to the generator sites. Chapter 7 of the EIS contains a discussion of the potential of leaving the waste material at commercial nuclear power plants and DOE sites.

7.3 (5775)
Comment - EIS001887 / 0377
Multi-Barrier Concept

Contrary to how a permanent geologic repository is intended to perform under the Nuclear Waste Policy Act, the geological formation is not proposed as the primary containment barrier at Yucca Mountain. Instead, the packaging, consisting of the fuel matrix itself, the fuel rod cladding, and the double wall package must function as the primary containment barrier. Once radionuclides move from the fuel matrix and the waste package, the Yucca Mountain geologic setting provides little resistance. Under the Proposed Action, the function of the geologic setting at Yucca Mountain to merely to decrease the likelihood of human intrusion.

The waste package design in the Draft EIS (not the design currently used by DOE) consists of an outer wall, 10-cm thick layer of carbon steel (corrosion-allowance material) and an inner 2-cm layer of chromium-molybdenum Alloy-22 (corrosion-resistant material). (p. I-34) The computer software WAPDEG quantifies the range of expected degradation. The major factors are temperature and moisture. WAPDEG evaluates generalized and localized corrosion. Corrosion of carbon steel generally begins when the temperature of water is below the boiling point. (p. I-35)

According to these theoretical models, by 5,000 years, nearly every package has a single corrosion-allowance material breach. (page I-40) By 20,000 to 30,000 years, corrosion-resistant material is also breached. High thermal loads generate the earliest breaches. Spent fuel dissolution depends critically on temperature, carbonate concentration, and pH.

DOE calculates the dose for a reference person in the Amargosa Valley – an adult, who lives year-round on a farm, grows a garden, and raises livestock. (page I-48)

In addition to food, radiation pathways considered by DOE include incidental ingestion of contaminated soil and groundshine. (page I-49) It is not clear that the radiation pathway, dust resuspension, was considered. DOE conducted a survey to determine food consumption habits in Amargosa Valley. To calculate health effects from radioactive input, DOE used ICRP-30 dose conversion factors. It is important to note that the more recent dose conversion factors from ICRP-60 would have allowed DOE to also calculate the dose to children rather than a reference adult, which would likely have resulted in higher dose calculations. Four locations to estimate doses were considered – 5, 20, 30, and 80 kilometers distant. As calculated, the maximum peak dose would occur well after 10,000 years. For 10,000 years, the highest dose would be at 5 km. (page I-51) The first failure for the intermediate thermal load scenario is 9,000 years after repository closure. (page I-52) For the low thermal load case, the first failure occurs at 27,000 years after repository closure.

DOE has high expectations for the containment potential of the cladding. Not taking credit for the cladding increases the mean dose at 20 km from 0.22 mr/y [millirem per year] to 5.4 mr/y at 10,000 years. (page I-54) At 1,000,000 years, the doses can be quite high, 260 mr/y at 20 km with cladding credit, and 3,000 mr/y without cladding credit. These latter doses are extremely high, far above regulatory limits and entirely unacceptable.

Note: Because the performance assessment for long-term repository performance used in this DEIS is not the one that will be used in the FEIS to support site recommendation, no further review of Appendix I was undertaken. For this reason alone, the DEIS is insufficient.

Response
The design and performance of the repository as described in the Draft EIS and in the Final EIS are not contrary to the Nuclear Waste Policy Act of 1982, which calls for the use of a deep geologic repository for the disposal but does not prohibit the use of engineered systems as part of the facility. The Act also calls for the location of repository in a deep geologic medium but does not set down any specific requirement that the primary containment be the geologic system. Section 2(18) of the Act defines the repository as follows:

"The term repository means any system licensed by the Commission that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel, whether or not such system is designed to permit the recovery, for a limited period during initial operation, of any materials placed in such system. Such term includes both surface and subsurface areas at which high-level radioactive waste and spent nuclear fuel handling activities are conducted."

The use of a multiple barrier system for accomplishing the isolation and providing a defense-in-depth approach is also identified, as is the need for possible retrieval of the material if deemed necessary during the operations and monitoring period:

"Such criteria shall provide for the use of a system of multiple barriers in the design of the repository and shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel emplaced in the repository as the Commission deems appropriate." (Section 121(b)(1)B of the NWPA)

Several items indicate that the Yucca Mountain disposal concept, as described in this EIS, is indeed a geologic disposal concept. First, there is the reliance on the geology after eventual waste package failure to (1) contain those radionuclides that have a very low natural solubility in this geologic setting; and (2) control the movement of the more soluble fraction of radionuclides by having relatively little water available to aid movement. Of that more soluble fraction, the cationic (positively charged) radionuclide species are expected to be strongly sorbed to the minerals of the underlying tuff rock layers. Finally, the depth to water in the geology under and adjacent to Yucca Mountain essentially prevents inadvertent use of water for small-scale domestic or agricultural purposes until almost 20 kilometers south of the proposed repository.

Part of the compliance strategy is a defense-in-depth approach where various components of the engineered and natural system supply independent attenuation of dose impacts. To support the defense-in-depth case, a number of analyses have been performed where the contribution of individual components has been minimized by assuming a 95-percent failure of the component. The results, reported in the Science and Engineering Report (DIRS 153849-DOE 2001) indicate that the system is quite robust even with failures of individual components.

Refined models of the cladding have been developed as a result of additional available data and considerable effort since the Draft EIS. The new models are very conservative yet they indicate only minor cladding failures beyond the initial assumed failures for very long times. A sensitivity study of the contribution of cladding to the overall system performance presented in the Science and Engineering Report indicates that peak dose increases about 40 percent when the cladding is assumed to have failed completely (DIRS 153849-DOE 2001). This would increase the peak annual committed effective dose equivalent for the current design from about 150 millirem (about 40 percent of background) to about 210 millirem (about 60 percent of background).

In the Final EIS, the typical receptor is assumed to be an adult living at the distance chosen for the analysis. Only the impacts to this representative adult are presented in the EIS. DOE has determined that this amount of information is sufficient to identify the potential risks relative to making a decision under the applicable Federal regulations.

With regard to estimating dose to special groups within the general population (for example, children, pregnant women, and the fetus), DOE recognizes that metabolic models weighting factors [such as those described in ICRP (DIRS 101836-1991)] are constantly under study and refinement. This research will no doubt continue into the future. For this reason, DOE has decided to use the methodology specified by the regulatory standards for the Yucca Mountain Repository promulgated by the Environmental Protection Agency (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63). This method of dosimetry is fully described in (DIRS 101075-ICRP 1979; DIRS 110351-ICRP 1980; and DIRS 110352-ICRP 1981). The dose conversion factors derived from this methodology and used in the EIS are provided in Federal Guidance Reports 11 and 12 (DIRS 101069-Eckerman, Wolbarst, and Richardson 1988 and DIRS 107684-Eckerman and Ryman 1993, respectively). In addition, the EIS has incorporated the reasonably maximally exposed individual (RMEI) concept, described in the preamble to 40 CFR Part 197, to project potential doses for long periods. In specifying its use, the Environmental Protection Agency stated that it believes:

". . . that the RMEI approach is sufficiently conservative and that it is fully protective of the general population (including women and children, the very young, the elderly, and the infirm). The risk factor upon which the dose level was established is very small, 5 chances in 10,000,000 per rem for fatal cancer. The lifetime risk then is this factor multiplied by the total dose received in each year of the individual's lifetime. We believe that the risk prior to birth is very similar to this risk level; however, relative to the rest of that individual's lifetime, the difference is small."

In addition, the Environmental Protection Agency defines the reasonably maximally exposed individual as an individual that has the food and water intake rates, diet, and physiology similar to those individuals in communities currently living in the downgradient direction of flow of the groundwater passing under Yucca Mountain. Thus, in estimating the risks to humans, DOE chose factors typical of individuals living in the Yucca Mountain region of influence, such as lifestyle, diet, water usage, farming and agricultural practices, and environmental parameters, that would lead to the highest exposures.

DOE recognizes that the Environmental Protection Agency has recently published an age-specific risk factor of 5.75 chances in 10 million per millirem for fatal cancer (DIRS 153733-EPA 2000). However, for the EIS, DOE used the values of 5.0 and 4.0 chances in 10 million per millirem for fatal cancer as recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991). Both the Environmental Protection Agency and DOE recognize that there are large uncertainties associated with these risk factors as expressed by the National Council on Radiation Protection and Measurements comment on the result of their uncertainty analysis in the risk coefficients that " … show a range (90 percent confidence intervals) of uncertainty values for the lifetime risk for both a population of all ages and an adult worker population from about a factor of 2.5 to 3 below and above the 50th percentile value" (DIRS 101884-NCRP 1997). DOE believes that the 15-percent difference in these risk factors is well within other uncertainties and would provide little additional information to the decisionmaking process that this document informs. For these reasons, DOE will continue to use risk factors recommended by the International Commission on Radiological Protection in its National Environmental Policy Act documents.

Chapter 5 of the EIS states the consequences of two repository operating modes in terms of radiological dose and converted to incremental lifetime risk (70 years) of contracting a fatal cancer. The estimates in the EIS assume a risk of 0.0005 latent cancer per millirem for members of the public, based on risk estimates provided by the National Council on Radiation Protection and Measurements (DIRS 101856-NCRP 1993). Thus, there is no appreciable difference between the lifetime risk factors of the Environmental Protection Agency and National Council on Radiation Protection and Measurements, both of which capture the increased sensitivity of the fetus and children.

The Final EIS contains long-term performance results based on the newer design and improved models for Total System Performance Assessment.

7.3 (5942)
Comment - EIS001622 / 0045
Page 5-10, last paragraph. DOE states that water "would drip into the repository but only in a *relative few* (emphasis added) places." What percentage of the repository does DOE estimate will be affected by dripping water?

Response
The percentage of the repository waste packages predicted to be subject to dripping varies with the climate, the thermal-hydrologic state, and the region of the repository. For example, the Draft EIS reported that under the high thermal load scenario for the present-day (dry) climate and expected (nonstochastic) values, the fraction of waste packages affected by dripping water for modeled repository regions 1 through 6 would range from 0.0082 to 0.093.

Similarly, for the long-term average climate the fraction would range from 0.23 to 0.33 for these six regions. For the superpluvial climate used in the Draft EIS, the range was from 0.42 to 0.49 for regions 1 through 6. These values are illustrative in that they are deterministic (expected mean) values for a single thermal load scenario, and will differ for the other thermal load scenarios and vary stochastically in the full simulations used to prepare the long-term consequences.

Chapter 5 of the Final EIS presents results from analyses updated from those in the Draft EIS, in terms of design and climate and natural system modeling. The general pattern discussed above has not changed dramatically except that drip shields now afford further protection, and the superpluvial climate is now incorporated as a short-duration characteristic of any pluvial state. The latter change is reflected in the input parameter distribution for the pluvial condition of future climate.

The waste packages are subject to local and regional changes induced by these changing climatic conditions, sequentially, during the simulation. Using the above ranges from the Draft EIS, less than 1 percent of the waste packages would be dripped on under the present-day climate, but roughly 20 to 33 percent would be dripped on under potential future climates. If there were an equivalent episode corresponding to the Draft EIS superpluvial climate, about 45 percent of waste packages would see drips over a short duration. Waste package failure would occur over very long times, so that many waste packages would only be subject to dripping conditions during the wetter climates, and would be dry between. The releases that lead to the long-term consequences reported in Chapter 5 of the Draft EIS incorporated all of this information, and these models have been updated for the analyses reported in the Final EIS.

Experimental data, as documented in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000), show the corrosion of the waste package would be insensitive to the amount of water contacting it (as long as there was any water). The corrosion rate would be the same whether there was humid air or dripping water. The effect of seepage on waste package corrosion would not be significant.

7.3 (5975)
Comment - EIS001879 / 0007
The impacts of Yucca Mountain on the County's precious water resources are also of paramount concern. The Draft EIS confirms that proposed action will result in the release of radioactive contamination into the only source of water available to the community of Amargosa Valley; only the timing and magnitude of the releases are uncertain. Additionally, the proposed action has the potential to render the water supplies of the Town of Pahrump and all of southeastern Nye County vulnerable to contamination. The DOE's hypothetical maximally exposed individuals will, in reality, be Nye County citizens, real people with real families. The United States must guarantee that the future generations of Nye County residents will have a reliable supply of safe water.

Response
As stated in the comment, the EIS confirms that the Proposed Action would be likely to result in the release of radioactive contamination into the saturated zone that provides water to the community of Amargosa Valley. However, the EIS shows that these releases would well below regulatory standards within 10,000 years of repository closure, standards specifically enacted to ensure the safety of future generations.

The general direction of groundwater flow from the Yucca Mountain site is south, with Franklin Lake Playa the most likely surface discharge point. Because Pahrump is southeast of Yucca Mountain and considerably out of the groundwater flow path, that community would not likely experience any groundwater impact.

7.3 (5982)
Comment - 010140 / 0004
Table 3-14, this table absolutely says there's no engineered barrier failure before 10,000 years. This is very optimistic and is based on a new magic bullet alloy. DOE wants the reader to believe that within one year the corrosion rates have decreased in either temperature scenario so as to have no failures. This is very suspect.

The last line of the table indicates that the actinides have a half-life of less than a million years. This is not true. All the waste packages have failed and I'd like to know what the controlling parameter was that made it only 800,000 years.

Response
DOE based the development of models that predict the performance of corrosion-resistant, nickel-based Alloy-22 in the repository on data from research literature and testing (including long- and short-term tests). The Department performs long-term tests under expected repository conditions, and short-term tests under expected repository conditions and very aggressive conditions. The American Society for Testing and Materials codified this approach

in a standard procedure (DIRS 105725-ASTM 1998). Analyses of the tests used a suite of tools, including standard microstructural evaluation and atomic force microscopy, which permits the examination of surface films in such great detail that even very slow degradation rates can be evaluated. DOE would continue to test samples of Alloy-22 and other alloys that would be exposed in the repository and in the laboratory for decades to confirm the results collected to date. In addition, DOE would explore analogs of Alloy-22 to provide confidence in its long-term performance.

DOE based its selection of materials on input from independent experts and laboratory tests, and from the actual performance of materials in full-size industrial applications. The corrosion tests involve Alloy-22 and other candidate waste package materials subjected to environments that are at least as aggressive as any expected inside Yucca Mountain. DOE would continue these tests during waste emplacement operations to confirm the expected waste package performance.

In the Final EIS, analyses have been refined and include early failures caused by defects in the waste package. The results show a very small dose from these failures. See Section 5.4 for more details.

7.3 (5988)
Comment - EIS001879 / 0012
The evaluation of chemically toxic constituents does not account for background concentrations that are already in the groundwater, decay products, nor the contribution from underground testing areas and other contaminant sources on the Nevada Test Site (NTS). The first constituent in Table I-13, barium, is used for illustrative purposes, but these comments apply to other toxic constituents as well. Table I-10 gives the inventory of barium placed in the repository as 19,000 kilograms and Table I-13 summarizes the release concentration for barium from the release of high-level radioactive waste due to the corrosion of a waste container using a "series of simple calculations." Based on this methodology, barium was eliminated from further detailed analysis. However, the "series of simple calculations" fails to account for a number or factors.

If a leak from Yucca Mountain occurs, the concentration of barium in the groundwater will depend upon a number of factors including the form of the barium (as a salt such as barium sulfate or as a metal hydroxide resulting from the decay of dissolved cesium), the chemistry of the water (particularly the sulfate concentration), the chemistry of the formations through which the water flows (particularly with respect to whether or not reducing or oxidizing environments are present), and the ion activity of the Group IIA alkaline earth metals and the anionic species (typically Cl, SO_4, F,CO_3, HCO_3, etc.).

The ultimate concentration of barium (or any other constituent for that matter) must be based upon an understanding of the natural baseline concentration and the three potential additional sources: 1) the quantity released from the wastes and/or waste package; 2) the quantity resulting from the decay of radioactive isotopes released from the wastes or CRUD; and 3) the quantity that could be contributed from the underground testing areas located on the NTS. In assessing the total inventory of barium that will be released, the Draft EIS does not take into account the decay of cesium to barium. Cesium will be released from the dissolution of the waste materials and any cesium released will be fully decayed to barium in about 1,000 years. Any release of cesium from the repository, or its decay products, could lead to a significant increase in the barium concentration in the groundwater above the levels shown in Table I-13. After only one half-life for cesium (30 years), more than 23,000 kilograms of barium will have been created through the decay of cesium, an increase in the total barium inventory of more than 100 percent. The EIS should be revised to account for the decay of cesium, other toxic constituents, and the decay products of radionuclides in the evaluation of release concentrations and subsequent wellhead concentrations.

The release of barium from the wastes and/or waste package will depend largely on the specific barium salt (or salts) that form in the repository and the sulfate concentrations in the near field. Other anions available from the wastes and/or waste package may locally increase the solubility of barium to levels that effectively overwhelm the available sulfate through precipitation with a corresponding reduction in the sulfate concentration and a corresponding increase in solubility. A "front" of barium-enriched water may thus migrate away from the leaks in the repository in the form of a plume of contaminated groundwater.

The basis for the barium concentration limit listed in Table I-13 is not given in the Draft EIS. Table I-11 lists source concentrations for some toxic materials based upon solubility in repository water but does not include barium.

Given that natural concentrations of barium in public water supply systems in the United States average 0.043 mg/L [milligram per liter] and that the groundwater down gradient of Yucca Mountain has barium concentrations as high as 0.04 mg/L, the concentration limit of 0.00412 mg/L listed in Table I-13 is obviously too low. Similarly, the concentration limit listed in Table I-13 for manganese is 4.4 x 10-11 mg/L but the concentrations as high as 0.1 mg/L are known to occur in the groundwater down gradient of Yucca Mountain, almost ten orders of magnitude greater than the concentration limit listed in Table I-13. The rationale for selecting the constituents listed in Table I-13 should be presented in the EIS along with a clear explanation of how the concentration limits were derived and an explanation of why some of the contaminants occur at background concentrations one to ten orders of magnitude above the "concentration limit" listed in Table I-13.

The EIS must be revised to accurately present the concentrations of chemically toxic and radioactive constituents in the groundwater. The use of a "series of simple calculations" must not be used in lieu of more accurate tools, specifically chemical models that can account for the complexities of multiple contaminant sources, different receiving waters, variations in the formations through which the flow occurs, and the contribution of nonradiologic contaminants from the decay of radionuclides.

The dilution factors given for the chemically toxic materials are questionable (page I-19, Table I-13, and accompanying text). The Draft EIS gives no rationale for an order of magnitude dilution for the saturated zone. Presumably this factor is from the Total System Performance Assessment (TSPA). However, the TSPA clearly indicates that dilution factors may be as low as 1.0 or as high as 72. Thus the saturated zone dilution factor (based upon 100 realizations of the conditional, axiomatic performance assessment models) would range from one full order of magnitude less to 70 times greater than the value used in the Draft EIS calculations. A conservative approach based on simple calculations should use conservative values based upon the range of outcomes from the models, rather than a single expected value. The EIS should be revised accordingly.

With respect to the unsaturated zone, the Draft EIS used the ratio of the total cross-sectional of all waste packages to the total surface area of the repository. This simple approach takes the maximum credit for dilution. When coupled with the equally simplistic annual fractional release rates given on page I-18, the resulting approach is not conservative.

The well concentrations listed in Table I-13 and the accompanying text does not give any indication of the time since the release or the distance to the "well." The EIS should be revised to include this information. If the "well" is located at the point of the leak, then it should be so stated in the EIS.

With respect to the contribution of contamination from the NTS, the Draft EIS states (page 8-76) that the estimate of the maximum potential dose from the underground testing area has a high degree of uncertainty but that "the use of bounding assumptions ensures that any reduction in uncertainty would only lower the already low estimated impact." The statement is inconsistent with the assumptions used in the analysis regarding the removal of technetium through precipitation caused by reducing conditions along the carbonate aquifer flow paths, dilution in uncontaminated water from recharge over the NTS, and aquifer mixing with transport. These assumptions all tend to dilute the dose and are thus not conservative.

For example, technetium would not be removed unless flow is through carbonate aquifers, which has not been established over most areas and is known to be a hydraulic impossibility in some areas where the head in the carbonate aquifer is above the volcanic confining units. Recharge is not equally distributed over the testing areas so any uniform dilution with bulk recharge over the NTS would not result in a conservative dose estimate; rather, the approach takes the maximum credit for dilution from recharge. Assuming that all of the underground testing inventory would migrate through the same locations as releases from the repository is, as correctly stated in the Draft EIS, a conservative approach. However, without much more detail concerning the other assumptions and what specific dilution factors were used in the analysis, it is misleading for the Draft EIS to characterize the overall results as being conservative. The results are presented to the nearest 0.01 millirem, which implies a much greater degree of certainty than actually exists. The EIS should be revised to clearly state the assumptions, the values of the dilution factors that were used, and the uncertainty in the results.

Given all of these considerations, the wellhead concentrations listed in Table I-13 may not represent reasonably expected conditions, and must be recalculated and revised to include the baseline natural concentrations, the toxic

materials generated by the decay of radioactive constituents, a range of dilution factors, and realistic concentration limits.

The Draft EIS does not clearly present how the concentrations used in the screening process and presented in Table I-13 relate to the concentrations presented in Table 5-17. The value presented in Table I-13 for the well concentration of chromium is 1.1 mg/L while the highest value in Table 5-17 is only 0.037 mg/L. These values suggest that chromium released from the repository at a maximum concentration of 300 mg/L is diluted by a factor of 8, 100 in only five km of transport. Such a large dilution factor is not considered likely and there is insufficient information given in the Draft EIS Chapter 5, Appendix I, and the TSPA to determine the validity of the numbers presented. The specific methods used in calculating the concentrations for chromium listed in Table 5-17 should be given. The EIS and its supporting documents should be revised so that the methods used in modeling the concentrations are clear and can be tracked by readers and decision makers.

With regard to Table 5-5, the text of the Draft EIS states, "(T)he values in Table 5-5 include a scaling factor for water use." The EIS should be revised to state the scaling factor value, and the rationale for the use of the scaling factor.

Later in the same paragraph the Draft EIS states, "The performance assessment transport model calculated the dose rates for the maximally exposed individual assuming dissolved radionuclides would mix only in water that flowed through the unsaturated zone of Yucca Mountain with no further mixing in the saturated zone aquifer. Infiltration through the Yucca Mountain repository accounts for only about 27,000 cubic meters of water per year. This compares to an annual water use in the Amargosa Valley of about 17.3 million cubic meters. **The analysis diluted the concentration of the nuclides in the 27,000 cubic meters of water throughout the 17.3 million cubic meters of water prior to calculating the population dose**," (emphasis added).

The rationale for the three order-of-magnitude dilution factor and resulting doses and latent cancer fatality (LCF) probabilities should be clearly stated in the EIS as being an artifact of the use of a 1990 population distribution and the use of an assumed dilution factor that is based on the entire water production of the hydrographic basin without regard for where that production occurs. The population of Amargosa Valley has gown since the 1990 census and Nye County projections suggest that growth in this community will continue into the foreseeable future. The use of the 1990 census data results in an overall analysis that is not conservative.

The dilution factor is not correct as it includes water that is not along the flow path between Yucca Mountain and a receptor population. For example, in 1998, more than 2,000 acre-feet of groundwater was used by the Barrick Bullfrog mine and the American Borate operations. The groundwater was produced from areas that are not between Yucca Mountain and the receptor population. The inclusion of the agricultural water production in the dilution factor is also questionable. In 1998, more than 12,000 acre-feet of groundwater were pumped for irrigation in Amargosa Desert. Only a portion of this production was derived from areas between Yucca Mountain and the receptor population, that is, from the area where the simulated plume would occur.

Finally there is some question as to whether or not any dilution factor of this type should be included at all. The approach used assumes that dilution will occur in direct proportion to the water extracted, and this might not be true. If the contamination were the result of a one-time release, then the contaminants would probably be diluted to some extent depending upon the location of the drinking water supply wells with respect to the contaminant plume. The contamination will be continuous, however, at the annual release rates provided in Section I.3.2.3.2 (page I-18) of the Draft EIS and will thus be far less likely to be diluted.

Receptors who rely on water pumped from a well having a capture zone that intercepts a portion of a plume will drink water that has contaminant concentrations represented by the relative proportions of the capture zone intercepting and not intercepting the plume. As the capture zone of a well is directly proportional to the volume pumped and the duration of pumping (and is also affected by the aquifer mechanics and the hydraulic gradient), a domestic well will typically exhibit a very small capture zone while an agricultural production well will have a much larger capture zone. Thus, the well of concern, that is the one used to supply drinking water, is likely to have far less dilution than an agricultural production well. The use of a simplistic approach toward dilution based on total water withdrawals is certainly not conservative and the evaluations should be revised using a range of realistic dilution factors.

Response
The basis for eliminating most chemical elements has changed in the Final EIS. Because of the new design, there would be a limited number of waste package failures in the first 10,000 years (one to three and possibly as many as five) and only a small fraction would fail even at 50,000 years. Therefore, an insignificant quantity of chemical constituents inside the package containment would be released in the first 10,000 years, the maximum period for evaluation of hazardous constituents. Constituents outside the waste package such as chromium from Alloy-22 have been further evaluated in the updated Appendix I and reported in Chapter 5. The inventory of barium has been corrected in the Final EIS to account for ingrowth from cesium decay. It should be noted however, that the "simple calculations" in the Draft EIS were conservative in nature because maximum source terms were calculated. All complex processes thereafter serve only to attenuate the value of these "simple calculations."

7.3 (5995)
Comment - EIS001879 / 0022
Comment: p. 5-39, Section 5.6 Consequences of Chemically Toxic Materials

An evaluation of the human health impacts from lead should be included in this section.

Response
DOE used a preanalysis (called a "screening analysis") in the EIS to determine if any potentially toxic materials would have a likelihood of producing a significant impact if they leaked from the repository. Section I.3.2.3.2 of the Draft EIS describes the first stage of the screening analysis. Using a very conservative estimate, the largest concentration of lead projected to reach a well 20 kilometers (12 miles) away would be a small percentage of the Maximum Concentration Level for lead (0.015 milligram per liter as established in 40 CFR 141.2; see Table I-13 of the Draft EIS.) This was the basis for eliminating lead from further evaluation, and the work to incorporate the new design strengthens this conclusion.

7.3 (5997)
Comment - EIS001879 / 0025
With regard to the groundwater measures under the proposed action, it must be clearly stated in the Draft EIS that in spite of all of the wonderful characteristics of the site, the Performance Assessment results indicate that the repository will leak and that the groundwater will be contaminated.

The statement that, "The sparsely populated hydrogeologic basin into which groundwater from Yucca Mountain flows is closed, providing a barrier to a general spread of radionuclides in the event waste packages were breached and radionuclides reached groundwater" is incorrect, misleading, and should be deleted from the EIS. The Jackass Flats hydrographic basin is not closed nor is the Amargosa Desert hydrographic basin. There is no barrier between the general spread of radionuclides from the repository to receptor populations in Nye County.

Response
DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. This EIS provides the Department's best estimate of the impacts that could occur when the containment system inevitably degraded. The updated analysis in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197), which would be between zero and five packages projected to fail due to manufacturing defects.

DOE has conducted an extensive program to determine the suitability of the Yucca Mountain site for a geologic repository. DOE recognizes that additional data would further define the flow system and reduce uncertainties about the interactions among the alluvial, volcanic, and carbonate aquifers in the saturated zone. Studies are planned to gather this information. Section 2.1.2.3 of the EIS describes the types of tests, experiments, and analyses that DOE would conduct as performance confirmation activities. This program would continue for perhaps for more than 300 years after the end of waste emplacement (through closure of the repository as described in Section 2.1.2.4). The purpose of the performance confirmation program is to determine if the repository is performing as predicted and discussed in Chapter 5 of the EIS.

DOE has initiated a program to evaluate the hydrologic processes in the saturated zone, particularly the hydrogeologic relationships between the volcanic, alluvial, and carbonate aquifers. This is currently being addressed through a cooperative agreement between Nye County and DOE, referred to as the Early Warning Drilling Program. Recent results from this program have been incorporated into the Final EIS; this program is described briefly in the next paragraphs.

The purpose of the Early Warning Drilling Program is to characterize and monitor the saturated zone along possible transport pathways from Yucca Mountain. DOE would continue to characterize the saturated zone south of Yucca Mountain through simultaneously collecting data from this program, in addition to using data obtained by Nye County scientists. These data would be used to refine the understanding of flow and transport mechanics in the saturated alluvium and valley-fill material south of the repository, and to update conceptual and numerical models.

In addition to the Early Warning Drilling Program, a series of test wells is planned along the groundwater flow path between the Yucca Mountain site and the town of Amargosa Valley as part of an Alluvial Testing Complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash to strengthen the basis of the site-scale saturated flow and transport model. Single-well and multiwell tracer tests will be conducted using both reactive and conservative tracers. DOE supports continuing research in all aspects of the geology or hydrology that enhances the understanding of the site. If any critical information should be found, DOE would re-evaluate its impact on the suitability of the site.

7.3 (6027)
Comment - EIS001898 / 0001
In preparing the FEIS, NRC [Nuclear Regulatory Commission] also requests that DOE consider relevant technical comments previously submitted by the NRC. The NRC has provided such technical comments in reports on specific technical issues and in comments on DOE's Viability Assessment in June 1999.

The comments on the Viability Assessment also address the issue of quality assurance (QA). DOE's application of a rigorous and effective QA program is crucial to its ability to demonstrate the validity of its findings and analyses in any license application. The NRC staff will continue to evaluate DOE's efforts to implement an effective QA program.

Response
DOE has an ongoing program to address Nuclear Regulatory Commission comments on the Viability Assessment and other technical issues, largely as they have been translated into its comprehensive listing of scientific modeling issues in the Commission's Issue Resolution Status Reports (see, for example, DIRS 135160-Bell 1996; DIRS 154605-NRC 2000). Not all technical issues raised by the Commission are closed, but DOE has made and will continue to make a good faith effort to address each issue to the extent practicable. As reported in the Final EIS, the Department has made a number of modifications to the design of the repository and to the Total System Performance Assessment model that address Commission concerns. As of September 2001, the Key Technical Issues have all been declared "Closed-Pending" by the Commission.

DOE has made a similar best effort to address the status of model validation and data quality assurance. The Department recognizes that it needs to apply a rigorous and effective quality assurance program, and that doing so will be crucial to demonstrating the validity of findings and analyses in any License Application. In response to previous Nuclear Regulatory Commission comments in this area, DOE has established a schedule for achieving quality assurance goals by the time of the License Application, if Yucca Mountain is found suitable and approved for development of a repository. DOE has met interim quality assurance goals for the Site Recommendation phase.

In the September 6, 2001, Quarterly Meeting with the Nuclear Regulatory Commission, DOE outlined the transition plans for the respective quality assurance programs which would support becoming a licensee. The Commission indicated further evaluation of implementation of these plans would take place in approximately 6 months.

7.3 (6106)
Comment - EIS001654 / 0052
Another example of such potential confusion to the layperson is Table 5-7 displaying "peak radionuclide concentrations" in picocuries per liter for ten different radionuclides at four distances from the repository with both

mean and 95th percentile consequences. Such data may be helpful to the scientists involved in the repository design or later in license application review, but it lacks meaning to the non-expert.

What is the meaning of population dose? It is presented in terms of "person-rem." There is a definition in the box on page 5-25, but we are unaware that there is a proposed standard for such a parameter. It is calculated for the three thermal load cases but the explanation of the value of the data is not clearly presented.

Put another way, which data is the most appropriate figure of merit for radiological consequences:

- Peak dose rate (millirem/year)
- Population dose (person-rem), or
- Peak radionuclide concentrations (picocuries/liter)?

This section (5.4) should be revised and tied in more explicitly to the EPA [Environmental Protection Agency] proposed standards.

Finally, it would be helpful to make notation on all charts, such as Figure 5-4, when non-linear scales are use used.

Response
DOE carefully designed the formats of the tables in Chapter 5, such as Table 5-7 of the Draft EIS, to present the complex results of a stochastic analysis as simply as possible. The EIS must meet often-conflicting demands to be technically accurate and to acknowledge uncertainty, and at the same time to communicate impacts to the public. DOE used mean and 95th-percentile consequences to provide a sense of the expected behavior of the system and an acknowledgement of the prospect of poorer performance that would be possible given the uncertainties. DOE believes that this strikes a balance between the detailed presentation of full stochastic results (which might indeed interest only scientists involved in repository design) and the presentation of a single value that would fail to acknowledge the system uncertainty.

The population dose is the sum of individual doses in a defined population. It is a commonly used measurement for expressing impacts to a population rather than a defined individual. The commenter is correct in that there is no standard for this measurement. However, because there is interest in impacts to populations as well as to a reasonably maximally exposed individual, DOE has included it in the analysis.

Each measurement mentioned (peak annual individual dose, population dose, groundwater protection consequences) is appropriate for different purposes. For proposed regulatory standards expressed in terms of peak individual dose limits (or public interest in the highest dose to an individual), the peak annual individual dose (millirem) is appropriate. For interest in impacts for the local population as a whole, the population dose (person-rem) is appropriate. For groundwater protection standards (in addition to health-based dose standards), the peak radionuclide concentration (picocuries per liter) or drinking water dose (millirem per year) is appropriate.

The Environmental Protection Agency had not released its proposed Environmental Radiation Protection Standards for Yucca Mountain, Nevada (64 *FR* 46976, August 27, 1999) when DOE published the Draft EIS. The results described in the Final EIS address the final standards and include other information that may be of interest to the public and decisionmakers.

The suggestion to use additional notation to point out the use of nonlinear scales in figures is a helpful one, and DOE has inserted the additional notation in the relevant figures.

7.3 (6275)
Comment - EIS001639 / 0003
The EIS is flawed in that discussions concerning waterborne radiological consequences are vague. The tables and conclusions can not be independently verified because the various tables are presented with inconsistent units and without enough information to verify the conversion calculations. It is also impossible to trace information from one table to another. As a result the conclusions of the waterborne radiological consequences as presented are unverifiable.

Response
Without specific knowledge of which tables or calculations concern the commenter, DOE cannot make corrections or revisions to the EIS. In general, however, DOE acknowledges the complexity of the issues considered in the EIS and has extensively revised the document to improve readability. With regard to the presentation of quantitative information in the EIS (the presentation of numerical estimates, standard use of units, conversion factors, etc.), interested readers will need to read the cited reference material for a complete understanding of the derivation of, and interrelationships between, specific entries. Because of the volume and complexity of supporting documents, it is not feasible to publish the reference material as part of the EIS. Information on these documents is available from DOE on the Internet (*www.ymp.gov*) and at DOE Reading Rooms (listed in Appendix D).

7.3 (6278)
Comment - EIS001639 / 0005
When exploring the effects of a 27,000 cubic meter spill of contaminated ground water into the water supply of Amargosa Valley the EIS assumes dilution of the contaminates into the valley's entire yearly water usage of 17.3 million cubic meters. Clearly, the contamination would occur over a very short period and should have been diluted over the period of the spill. This calculation probably would have far exceeded the safe level of allowable radionuclides.

Response
The purpose of the repository is to protect the public health and safety as required by the regulations, such as the Nuclear Regulatory Commission regulations specifying licensing criteria at 10 CFR Part 63. The regulation specifies the critical group to protect, its location, and how to calculate the dose rate to the critical group based on the annual radionuclide release rate 20 kilometers (12 miles) from the repository and the annual water usage of the critical group.

The 27,000 cubic meters (7.1 million gallons) of water flowing through Yucca Mountain every year is an ongoing, continuous process, not a spill. Because the release would be continuous after a waste package began to fail, an estimate of dilution in the water used by the critical group is based on the ratio of water infiltrating through the repository footprint (that is, 27,000 cubic meters) and the annual water use of Amargosa Valley (that is, 17.3 million cubic meters). DOE believes that application of this dilution factor is conservative (that is, tending to overestimate impacts) because credit has not been taken for additional dilution that is likely to occur in the saturated zone.

7.3 (6349)
Comment - EIS001793 / 0004
It is known that the steel containment canisters last used to vitrify in an attempt to stabilize nuclear waste fuel rods would not remain intact for more than a few centuries in any known storage method.

Response
DOE agrees that the long-term protectiveness of the stainless-steel canister that surrounds the vitrified high-level radioactive waste form is limited. It is for that reason that the performance assessments discussed in the Draft and Final EIS took no credit for this material as a barrier.

The long-term performance analysis in the Final EIS conservatively neglected the potential benefit of stainless steel, which would be the inner barrier of the waste package, and thus neglects the potential delay to water entering a waste package provided by this barrier. Its function would be to provide structural strength for handling and emplacement of the waste packages. In addition, the high-level radioactive waste (in a glass matrix) would be in a stainless-steel canister. This canister would be inserted into the waste package and would be in contact with its inner barrier of stainless steel. Having the same metals inside each other would minimize the likelihood of crevice corrosion as water enters the cracks between the two metals. But in any event, for conservatism, the stainless-steel canister is not modeled as a barrier.

7.3 (6403)
Comment - EIS001632 / 0002
EPA [Environmental Protection Agency] could not always find data or explanations to support the conclusions drawn. A prime example of this is that EPA found insufficient data to support the prediction of the movement of radionuclides in the saturated zone beneath the repository. These data are needed to determine if the facility's

performance will satisfy applicable radiation standards designed to protect ground water resources and public water supplies. As you know, EPA has proposed standards applicable to Yucca Mountain.

Response
DOE assumes that the fundamental data referred to in the comment mean such things as aquifer properties, retardation coefficients, hydraulic heads, etc. Such data are detailed in the documents referenced in Appendix I of the EIS.

Appendix I contains detailed information in support of Chapter 5 of the EIS. As stated in the introduction to Appendix I, the long-term performance analysis was conducted using a TSPA model and supporting data derived from the TSPA models and data that support other Yucca Mountain Project documents. As also stated, the purpose of Appendix I is not to republish the large body of available information but to reference the sources of the information and describe any special additional modeling and data used for the EIS. Some common background material was duplicated as an overview to enhance understanding of the incremental material. Thus, much of the detailed data on saturated zone modeling in this EIS is from the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000) and the *FY 01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001), as referenced in the Final EIS.

The Final EIS discusses the new Environmental Protection Agency standard (40 CFR Part 197).

7.3 (6443)
Comment - EIS001632 / 0016
Page 2-74, Section 2.4-3, first paragraph: The last sentence indicates that long-term (100 to 10,000 years) impacts were assessed only where DOE "could establish estimates of impacts." Were there any important impacts which were not assessed for this reason? If so, how does DOE plan to address them? (See 40 CFR § 1502.22)

Response
The full quote of the last sentence is:

"Because these projections are based essentially on best available scientific techniques, DOE focused the assessment of long-term impacts on human health, biological resources, surface-water and groundwater resources, and other resource areas for which the analysis determined the information was particularly important and could establish estimates of impacts." (Draft EIS, p. 2-74)

The intent of this statement is that DOE assessed all important impacts in the long-term period. No analyses were omitted because of inability to establish an estimate. Some resource areas (such as noise, utilities, and services) were deemed to have no foreseeable impact and no detailed analysis was necessary. DOE realizes that even the full quote is confusing and has, therefore, revised the language in the Final EIS.

7.3 (6501)
Comment - EIS001632 / 0036
Container breaches. The final EIS should discuss the expected scenarios for container breaches and the associated impacts on groundwater, taking into account groundwater contamination levels at various distances and under various repository loadings. These analyses should cross-reference discussions on impacts to groundwater.

Response
In the analysis of long-term performance, breaches of the containers were not treated as separate scenarios but rather the result of modeling a number of features, processes, and events that then lead to various types of container breaches. As such then, there are no expected scenarios for container breaches. The impacts to groundwater result directly from the overall scenarios considered: nominal or "undisturbed" scenario, volcanic events, and human intrusion. These are clearly differentiated in the Draft EIS and the Final EIS with regard to groundwater impacts. Container breach is merely a process that is component to these broader scenarios. The Final EIS points out that general corrosion is a primary process for failure driving the dose results for the whole post-10,000-year period. Section I.5.1 of the Final EIS discusses waste package failures versus time and discusses the modes of failure and the relationship to the annual dose history.

7.3 (6544)
Comment - EIS001632 / 0041
Long-Term Repository Performance: General Comment

EPA [Environmental Protection Agency] disagrees with certain aspects of the performance assessment described in Section 5 an in Appendix I. The Total System Performance Assessment, presented in the Viability Assessment for Yucca Mountain and captured in the draft EIS analysis, relies in some instances on extreme performance cases which either omit or overestimate certain effects.

EPA recommends using an approach--reasonable expectation--which focuses on a more realistic depiction of repository performance and which recognizes the inherent uncertainties in projecting repository performance over the long term. This more realistic approach projects the expected behavior of the waste containment and isolation system, but avoids extreme assumptions and use of unrealistic performance scenarios.

We believe the final EIS would be strengthened by identifying the more conservative assumptions used in the assessment. Identifying these would give the reader a better sense of the variability inherent in the estimates of repository performance and provide the public with a more balanced performance projection.

Response
In general, the uncertainty approach used in the EIS uses realistic ranges of values for inputs and, where possible, acknowledges the uncertainty. In some instances, conservative assumptions are necessary to avoid the possibility of understating the potential impacts of the proposed Yucca Mountain Repository.

An interesting outcome of a full uncertainty analysis of a system such as the proposed repository is that the use of "expected values" (for example, averages) for all parameters does not actually predict the expected outcome very well. Because of the skewed aspect of many input parameters to the models (a reflection of the real nature of the underlying data), the results predicted using only mean values actually produce a low-probability occurrence, usually in the 90th percentile or above of the outcomes predicted in a full stochastic assessment. Thus, it is more reasonable to perform a full stochastic assessment and report the expected outcome in terms of the statistics computed from the results. DOE did this in the EIS by reporting the mean outcome and the tail probability (95th percentile). However, the EIS has been revised to more clearly and more fully discuss both the modeling uncertainties and the degree of conservatism in the modeling.

7.3 (6546)
Comment - EIS001632 / 0042
Table S-1 on page 5-5 and the related discussion in sections 5.1 and 8.3.1.2.3 (Atmospheric Radioactive Material Impacts) fail to consider post-closure releases of radon from the spent nuclear fuel in the time period beyond 10,000 years. EPA's [Environmental Protection Agency's] proposed standards for Yucca Mountain at 40 CFR Part 197 require an analysis of the dose to a reasonably maximally exposed individual for the period beyond 10,000 years through the time of peak dose (64 *FR* 46976, August 27, 1999). The National Academy of Sciences' Yucca Mountain panel in 1995 estimated that the Yucca Mountain site would be stable on the order of one million years. The final EIS must therefore discuss releases of radon-222 (222 Rn), which will result from the decay of the considerable inventory of uranium in the spent nuclear fuel.

Response
Chapter 5 and Section 8.3.1 of the EIS now include analyses of atmospheric releases of radon-222 to the time of peak dose.

7.3 (6547)
Comment - EIS001632 / 0043
Section 5.5 (Atmospheric Radiologic Consequences) concludes that carbon-14 (14C) is the only radionuclide that has the potential for transport through the atmosphere. Likewise, section 8.3.1.2 addresses only 14C releases with respect to cumulative impacts. The draft EIS does examine the exposures to workers and offsite individuals from radon as a result of various operations. However, as noted by Sullivan and Pescatore ("Release of Radon

Contaminants from Yucca Mountain: The Role of Buoyancy Driven Flow," T.M. Sullivan and C. Pescatore, Brookhaven National Laboratory, PNL-52468, February 1994):

"Barometric and wind pumping at Yucca Mountain may cause long-term 222Rn removal from the oxidized spent fuel waste. The problem of enhanced 222Rn release to the accessible environment would pose itself later in time (after 20,000 years and peaking in roughly 200,000 years) and would last for as long as unsaturated conditions would prevail at Yucca Mountain."

Response
Chapter 5 and Section 8.3.1 of the EIS now include analyses of atmospheric releases of radon-222 to the time of peak dose.

7.3 (6548)
Comment - EIS001632 / 0044
EPA's [Environmental Protection Agency's] analysis of spent fuel radionuclide inventories in support of the promulgation of 40 CFR Part 191 (see EPA 520/4-79-007A, 1977) indicates a 222Rn [radon-222] content of about 1 curie per metric ton of heavy metal, at 100,000 years following discharge from a light water reactor. This would imply a repository inventory for 222Rn of about 63,000 curies at about 100,000 years for the currently authorized Yucca Mountain repository. Because of its energetic radiations and numerous daughter radionuclides, 222Rn presents a significantly larger risk per unit of radioactivity than 14C.

Response
Chapter 5 and Section 8.3.1 of the EIS now include analyses of atmospheric releases of radon-222 to the time of peak dose.

7.3 (6550)
Comment - EIS001632 / 0045
Section 5.5 also indicates (introductory paragraph) that impacts for the global population were estimated. What value was used for the projected collective dose received by the global population?

Response
The referenced statement in Section 5.5 of the Draft EIS is an error. There was no global population calculation performed for the Draft EIS. The statement has been removed.

7.3 (6552)
Comment - EIS001632 / 0046
Page 5-5: The final EIS should explain the statement on page 5-5 that chemically toxic materials were eliminated from consideration because "their total quantity would be very low and dilution in the repository environment would reduce their concentration to below toxic levels before they entered the saturated ground water system."

Response
The overview of the screening process in the Draft EIS referred to a process detailed in Appendix I. DOE believes that Appendix I provided sufficient detail for a full understanding of what was done. In the updated analysis presented in the Final EIS, a different screening process was used due to design changes. This new screening process is detailed in Appendix I and cross-referenced in Chapter 5 of the Final EIS. The discussion in Final EIS Appendix I was designed to provide as clear and comprehensive explanation as possible.

7.3 (6563)
Comment - EIS001632 / 0050
Page 5-43, Section 5.7.2, second paragraph: It would be helpful to have a graphic representation of the results of the volcanic activity analyses.

Response
Section 5.7.2 of the Final EIS presents dose history curves for the volcanic scenarios showing the mean and 95th-percentile curves along with lines for the nominal case for comparison to results for various volcanic disturbance scenarios and the undisturbed waterborne release results.

7.3 (6591)
Comment - EIS001380 / 0014
APPENDIX I (Environmental consequences of long-term repository performance), page I-25, section 1.3.3.

I am aware of the data in NRC [Nuclear Regulatory Commission] NUREG-2907 regarding routine radionuclide airborne and liquid releases from commercial nuclear power plants that generate 90% of the wastes targeted for Yucca Mountain. That compilation documents dozens of reportable radionuclides and noble gases that nuclear reactors and their fuel generate. It is known by everyone in the industry that tritium passes through nuclear fuel cladding. Why wasn't tritium included in the analysis in this section? Thus, I find the statement that "the only radionuclide that would have a relatively large inventory and a potential for gas transport would be C-14" to be ridiculous and very inaccurate. What does a statement like "relatively large inventory" signify, relative to what? To most of the public, the inventory is monstrous compared to any other nuclear repository in the world. This too brief paragraph needs to be rewritten to reflect the true facts.

Response
The majority of radionuclides routinely released from operating commercial nuclear reactors consist of noble gases and tritium. Although tritium is produced in the fuel rods as a fission product, the majority of tritium released by these plants is produced as a fission or activation product in the coolant water circulating outside the fuel rods. In addition, at high temperatures tritium will migrate through most metals, including those typically used as fuel cladding. However, once the fuel rods are removed from the reactor environment and allowed to cool, this process slows appreciably. On the other hand, most of the noble gases are produced as fission products inside the fuel rods. However, most of these gases have half-lives on the order of minutes or hours and are therefore of little consequence within days after the reactor is shut down.

Tritium, with a half-life of 12.3 years, will remain within the fuel rods for some time after shutdown, but migration through the fuel rods is not appreciable at temperatures experienced during storage or disposal. In addition, the analysis in the Draft and Final EISs indicates that all but about three waste packages are unlikely to fail within several thousand years. Therefore, the tritium contained within the waste packages would decay to inconsequential quantities before any releases to the environment would be likely. For this reason, tritium was screened out as a potentially important isotope for consideration of long-term repository performance.

The statement "relatively large inventory" implies what was said above. The use of the word "relative" in this context means in relation to other gaseous radionuclides in the repository inventory.

The radioactive inventory emplaced in the Yucca Mountain Repository would be large. However, prior to recommendation of the Yucca Mountain site for development of a geologic repository, DOE would have to provide a reasonable expectation that the repository could meet the environmental protections standards developed by the Environmental Protection Agency to protect human health and the environment (40 CFR Part 197).

7.3 (6637)
Comment - EIS001632 / 0072
Section I.3.2 states that waterborne chemically toxic materials that could threaten human health are present in materials disposed of in the repository, the most abundant being uranium, as well as nickel, chromium and molybdenum (used in the waste package). EPA [Environmental Protection Agency] agrees with the analysis on page 5-6 of the conditions under which waste materials disposed at Yucca Mountain could threaten human health: (1) the waste packages and their contents are exposed to water, (2) radionuclides and/or chemically toxic materials in the package materials or wastes become dissolved or mobilized in the water, and (3) radionuclides or chemically toxic materials are transported in water to an aquifer; further, such water must be withdrawn via a well or surface discharge point and used by humans as drinking water or in the human food chain.

Response
Thank you for your comment.

7.3 (6650)
Comment - EIS001522 / 0002
The DEIS is scientifically and empirically questionable because it repeatedly alleges that "in general the EIS analyses showed that the environmental impacts associated with the Proposed Action would be small" (DEIS, 1999, 2-74). This claim is questionable, in part, because it relies on a logical fallacy of composition. This fallacy consists of assuming that because something is true of the whole therefore it is true of the part, or assuming that a necessary condition for something to be true of a part is that it be true of the whole. Committing this fallacy, the DOE asserts that "no substantial impacts were identified; therefore, cumulative impacts…would not cause…concerns" (DEIS, 1999, 8-59). However, there could be no large impacts from radiological exposures over a given year, but the cumulative impact of these exposures could be great. For example, an annual chest x-ray might not be an important source of exposure, but having one every year for 30 years might have a substantial cumulative impact.

Another reason that the DOE errs in claiming that there will be no substantial impacts of the Yucca Mountain repository, over its life, is that the DOE's own peer reviewers unanimously concluded that it was impossible to show, scientifically and statistically, that the impacts would be small, because they could not be calculated; as the DOE peer reviewers noted, in a unanimous "Consensus Statement:

Many aspects of site suitability…predictions involving future geologic activity, future value of mineral deposits and mineral occurrence models…rates of tectonic activity and volcanism, as well as mineral resource occurrence and value, will be fraught with substantial uncertainties that cannot be qualified using standard statistical methods (Younker, Albrecht, et al, B-2).

Moreover, the National Academy of Sciences committee on Yucca Mountain admitted that it was impossible to calculate the effects of repository intrusion, something that must be known in order to conclude that the environmental impacts will be small (NRC 1995). The same Academy Committee also noted that it was impossible to predict human/social factors, such as institutional control of radioactive waste, beyond one hundred years (NRC 1995). If the National Academy believes that one cannot predict human intrusion and meaningful human behavior after 100 years, then the DOE DEIS (1999, 7-6) needs to explain how it can claim to predict what will happen 10,000 years into the future, and especially, that there will be no adverse environmental impacts as a result of the proposed Yucca Mountain facility. That is, it is scientifically impossible to conclude that the impacts of a repository, for thousands of years into the future, will be small, because it is impossible to know the future to the degree of precision necessary to draw this conclusion. There is no prior experience with permanent radioactive waste disposal on which to draw, and no nation has yet successfully employed permanent disposal.

Response
As part of its analysis of cumulative impacts, DOE attempted to quantify, where possible, the total radiation dose that may have been received by local residents from past activities in the Yucca Mountain area. The Department calculated the total risk to the population based on the assumption that radiation risks from actions evaluated in the EIS would be additive. However, the Department cannot, in this analysis, account for each individual resident's past or future radiation exposure. To do so would require accounting for lifestyle habits such as the frequency of airline flights, past residences in locations that receive substantially higher or lower cosmic radiation, the type and frequency of medical diagnostic tests and treatments, and a myriad of other factors. Therefore, the EIS provides a baseline estimate of the exposure of affected individuals in Chapter 3 and Appendix F and provides estimates of the incremental impacts from the Proposed Action in Chapters 4 and 6. In addition, in Chapter 8, the EIS identifies those actions that are imminent or reasonably foreseeable to add to these impacts to determine the overall cumulative impact estimates.

In the case of the quote in the comment from page 8-59 of the Draft EIS, the statement is referring to the evaluation of short-term environmental justice impacts. As discussed in Sections 8.2.13 and 8.4.2.1.2 of the EIS, environmental justice impacts would exist (1) if an activity would have significant environmental impacts and (2) if such impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. Under these criteria, DOE believes that there would be no significant impacts with regard to environmental justice.

The Total System Performance Assessment Peer Review panel stated "…the panel finds that, at the present time, an assessment of the future probable behavior of the proposed repository may be beyond the analytical capabilities of

any scientific and engineering team. This is due to the complexity of the system and the nature of the data that now exist or that could be obtained within a reasonable time and cost." However, the panel also noted that the goal of the performance assessment is "whether it can be shown with reasonable expectation that the repository will comply with the applicable regulatory limits" (DIRS 102726-Budnitz et al. 1999). Reasonable assurance is the standard applied in the licensing of commercial nuclear facilities and has served the Nation well in terms of assuring safety in and around nuclear facilities. DOE maintains that it can perform projections of long-term behavior consistent with the regulatory goals of providing a reasonable expectation or reasonable assurance of compliance with dose-based standards.

The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can statistically incorporate them into the risk analysis. Chapter 5 of the Final EIS contains an assessment of the probability and effect of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

As discussed in Section 3.1.3.4 of the EIS, site characterization activities have found no economic deposits of base or precious metals, industrial rocks or minerals, or energy resources based on present use, extraction technology, and economic value. The operating gold and silver mines visible from the mountain are in a different type of rock than Yucca Mountain. Those rocks formed deep in the earth and uplift has exposed them. Yucca Mountain was formed by volcanic ash flow and ash fall.

Questions concerning human intrusion have been considered by DOE and are acknowledged to be an important issue because the future behaviors of humans cannot be predicted. The Nuclear Regulatory Commission and Environmental Protection Agency have specified in their respective regulations for Yucca Mountain the way to analyze human intrusion. The regulations describe a stylized calculation that attempts to address why humans would intrude into the repository. DOE incorporated the advice provided by National Research Council (DIRS 100018-National Research Council 1995).

DOE recognizes that there is uncertainty in both the scientific predictive capability and in the likelihood and nature of human error. Therefore, a defense-in-depth approach is being used that, for example, places a drip shield over waste packages to reduce uncertainties in repository performance that result from the inability to predict, with certainty, the locations and rates of water seeps into the repository. Multiple levels of validation are practiced to discover and fix errors. Multiple levels of sophisticated checking are being planned to ensure that the manufacturing of the engineered components would be as error-free as modern technology will allow. DOE is highly aware of the problems errors can cause and is doing its utmost to protect the public from both the short-term and long-term potential effects that could result from such errors.

DOE has adopted this defense-in-depth philosophy and a performance assessment methodology that accounts for the variability inherent in natural processes, limits to our knowledge and information, differing views of experts, unpredictability of some phenomena, and uncertainty in system behavior. The methodology is widely accepted both nationally and internationally. It is based on recommendations of the National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission. It conforms to international practices in other countries, including Member States of the Nuclear Energy Agency and the United Nations' International Atomic Energy Agency. Peer review groups with expertise in the analysis of environmental risks have endorsed the general approach.

DOE agrees that it is not possible to predict with certainty what will happen hundreds or thousands of years in the future. However, the same physical, chemical, and geologic processes active today would likely be active in the future. Thus models built to explain such processes as waste package degradation and radionuclide and water movement in the present are expected to be representative of those same processes in the future. Scientists from outside the Yucca Mountain Project evaluated the degree to which one may have confidence in the predictive ability of the scientific models. Though they supplied some critical observations, they also suggested work that could bolster the scientific basis of the modeling. This EIS shows the results of more than two years of work addressing those external review committee suggestions, and that work continues.

DOE believes that the EIS adequately analyzes and represents the possible range of environmental impacts at the repository and that the EIS is one of the documents that provides information to the decisionmaking process. Any decision to approve the site also requires the Site Recommendation document, which specifically addresses the case for compliance with the requirements of the Site Suitability Guidelines (10 CFR Part 963), which in turn incorporates requirements from regulations by the Environmental Protection Agency and the Nuclear Regulatory Commission. If this societal decision was made, the licensing process, with its focus on science and supporting detail, would help increase the basis for confidence in the long-term projections of potential risk. This EIS supports an important step in the decisionmaking process, but it is not the last step, and work will continue to increase the basis for confidence.

7.3 (6750)
Comment - EIS001522 / 0005
The DEIS allegation that environmental impacts of Yucca Mountain "in general…would be small" (DEIS, 1999, 2-74) is not only inconsistent with existing empirical data and with the DOE's own claims about groundwater, perched water, and upwelling, but this DOE claim is also logically invalid because it begs the question. It begs the question because the DOE has not yet determined many scientific facts whose validity is essential to drawing this conclusion. For one thing, to allege that future impacts would be small, despite the million-year lifetime of the repository, seems incredible, because it is impossible to predict the specifics of what will happen over so long a time frame. Also such DOE predictions are disguised as scientific when, in reality, they are no more than guesses.

Response
Council on Environmental Quality regulations require consideration of both "context" and "intensity" when assessing the significance of a Proposed Action (40 CFR 1508.27). The regulations also require that National Environmental Policy Act documents are written in plain language so the widest audience can readily understand them. As a consequence, DOE has used descriptive terms, such as "small," to help convey the relative impacts of various actions on the environment.

In keeping with these requirements and consistent with standards established by the Nuclear Regulatory Commission (DIRS 101899-NRC 1996), DOE has determined, in general, that "small" means potential environmental effects (with or without mitigation) that would not be detectable or that would be so minor that they would neither destabilize nor noticeably alter any important attribute of the resource. For example, human health impacts that do not exceed permissible levels as defined in Federal or state regulations are generally considered to be small because adverse health effects would be unlikely for exposure to these levels.

Although uncertainties will always exist in long-term predictions of complex system performance, DOE maintains that it can perform projections of long-term behavior that are consistent with the regulatory goals of providing a reasonable expectation of compliance with dose-based standards. The Department believes that the EIS adequately analyzes and represents the possible range of environmental impacts at the repository and that the EIS is one of the documents that can provide information to the decisionmaking process.

7.3 (6876)
Comment - EIS001522 / 0014
Throughout the Yucca Mountain DEIS, the DOE ignores factual events that are difficult, if not impossible to know, and then, despite these omissions, invalidly concludes that the impact from the proposed waste facility will be low. Consider some of these omissions: "The impact of such human intrusion was not included directly in the final presentation of results...the probability of human intrusion occurring was not modeled" (DEIS, 1999, 5-16). After ignoring crucial variables, such as human intrusion, that could cause massive environmental impacts, the DOE notes that it will use "insight based on the best information and scientific judgments available" in its analyses (DEIS, 1999, 5-17). Likewise the DOE says that, regarding radiological impacts on populations over long periods of time, "the DOE does not have the means to predict such changes quantitatively with great accuracy; therefore, the analysis does not attempt to quantify the resultant effects on overall impacts" (DEIS, 1999, 5-17).

DOE's ignoring key considerations, about which it is ignorant, is especially problematic because the very things about which it is most ignorant are those things to which conclusions about repository safety are most sensitive, and even the DOE admits this. For example, the DOE considers approximately 20 parameters and then assesses its confidence in its models' accuracy, as well as the sensitivity of the repository safety/performance, relative to each of

these parameters. Interestingly, the DOE admitted that its confidence in its models for water seepage into drifts, in its models for transport of radionuclides through the unsaturated zone, and in its models for transport of radionuclides through the saturated zone, all were "low," even through the significance of these parameters, for repository safety/performance, respectively, was "high," "high," and "medium" (DEIS, 1999, 5-22). If the crucial factors that affect repository safety are those about which DOE confidence is low then how is it that the DOE can allege that the proposed repository will have no significant environmental impacts? Obviously, if the DOE claims about low confidence are to believed, then they are not consistent with its claims about low impacts from the proposed repository.

Moreover, the DOE admitted that the peer review panel gave 145 pages of suggestions for improvement of its analyses, and then noted that "all of the suggestions are being addressed" (DEIS, 1999, 5-23). If even the peer review panel was critical of DOE efforts, then one wonders why the public should be railroaded into approval of the Yucca Mountain facility before all the concerns of the peer review committee have been dealt with. Indeed, these corrections should all have been completed before the DEIS was even submitted. To submit it prior to such correction is to show that DOE's decision -- about moving forward on Yucca Mountain -- is completely independent of what expert scientists say. Since when are projects submitted for approval on the basis of a promissory note, a promise to remedy poor science that should not even have occurred in the first place? The peer review committee noted that "the report of the DOE failed to provide a statement of the 'probable behavior of the repository' as requested by Congress" (DEIS, 1999, 5-23). If the peer review committee is correct that DOE has not accomplished the Congressional mandate, then there is no reason, other than bias, that the DEIS should be presented for approval.

Response

The probability of human intrusion occurring was not modeled, but the possible consequences were qualitatively evaluated for a few intrusion scenarios. What this means is that DOE assessed the consequences of an intrusion event and stated them as if the probability was 1. Figure 5-7 of the Draft EIS shows dose history curves resulting from intrusion scenarios. In the case of the large intrusion scenario (the higher of the two scenarios analyzed) and the assumed high dissolution rate, the figure shows an estimated incremental dose increase of about 1 millirem per year over the undisturbed case. Thus, DOE did not ignore the human intrusion possibility but carefully analyzed it in a manner suggested by National Research Council (DIRS 100018-National Research Council 1995) and required by the Environmental Protection Agency's recent *Environmental Radiation Protection Standards for Yucca Mountain, Nevada* (40 CFR Part 197). The result reported in the Draft EIS was one-fifteenth of the standard set by the Environmental Protection Agency. The Final EIS includes an updated version of this analysis.

The quote "…the DOE does not have the means to predict such changes quantitatively with great accuracy..." from Section 5.2.4.1 of the Draft EIS refers to the movement of populations and changes in the magnitude of populations, societal habits, etc. This position agrees with recommendations of National Research Council (DIRS 10018-National Research Council 1995). In addition, the Environmental Protection Agency standard for the performance of the repository embraces this concept. Furthermore, the size of the population would have no effect on the fundamental long-term impact (dose to the reasonably maximally exposed individual) because that impact would concern a single hypothetical individual. Population dose would be estimated as a simple linear multiple of the number of people in the potentially affected area. Thus, DOE considered future population changes based on recommendations of the National Research Council and the Environmental Protection Agency, both of which Congress directed to participate in setting appropriate standards for the performance of the proposed repository [via Section 801(b) of the Energy Policy Act of 1992.

DOE acknowledges that the *Final Report/Total System Performance Assessment Peer Review Panel* (DIRS 102726-Budnitz et al. 1999) was negative in its comments on several important aspects. The Peer Review Panel did report that DOE had failed to provide a statement of the probable behavior of the repository. However, DOE feels that the panel interpreted the Congressional language narrowly. DOE believes that the intent of Congress was for the Viability Assessment (DIRS 101779-DOE 1998) to make a preliminary determination "…of whether it can be shown with reasonable assurance or reasonable expectation that the repository will comply with the applicable regulatory limits" [Energy Policy Act, Section 801(b)]. However, in the absence of final standards for Yucca Mountain at that time, DOE could not make comparisons to them.

The Peer Review report went on to say that:

"As noted above, the assigned objective of the TSPA-VA [Total System Performance Assessment-Viability Assessment] was to assess the probable behavior of the repository. In contrast, the objective for TSPA-LA [Total System Performance Assessment-License Application] will be to determine whether it can be shown with reasonable expectation that the repository will comply with the applicable regulatory limits. These are significantly different objectives, and recognition of this distinction should be an important element of the path forward to the TSPA-LA" (DIRS 102726-Budnitz et al. 1999).

The Panel did not intend for its recommendations to enable the calculation of "probable behavior," as it saw the meaning of that term. Rather, it thought that satisfying these recommendations would enable a determination "… of whether it can be shown with reasonable assurance that the repository would comply with applicable regulatory limits."

DOE has addressed many of the Panel's recommendations in the revised TSPA models used to support long-term performance analysis reported in the Supplement to the Draft EIS and in the Final EIS. This EIS and supporting reports describe the manner in which DOE has addressed these recommendations.

7.3 (6906)
Comment - EIS001784 / 0002
I worry about some of the basic scientific assumptions implicit in the Yucca Mountain EIS, specifically many assumptions are based on the DOE and NRC [Nuclear Regulatory Commission] being able to predict and plan for what will occur 10,000 years down the road. No, I didn't make a mistake -- I wish I had. The figure used repeatedly is 10,000 years, not days or months. To me, this is absurd rationalization. Suppose, for example, Yucca Mountain incurred a direct nuclear bomb attack and the stockpile was damaged or became unstable. How would that affect the carefully constructed 10,000 year timetable? We are assured the Yucca Mountain waste containers are invulnerable. However, there is abundant evidence of leakage from the current repository casks at nuclear power and weapons plants. Why hasn't this same degree of proposed engineering safety been built into existing facilities? After all, haven't the NRC and DOE been safeguarding us all along?

Response
Examination of the elements of the Total System Performance Assessment model can lead to the conclusion that many things have been left out of consideration. It is important to recognize that the model is a product of a much broader analysis of all possible features of the system, events, and processes that could be important to the behavior of the system. The development of the model proceeded as follows:

- Development of a list of possible features, events, and processes based on lists previously compiled on an international scale and on input from many experts
- Estimates of the effect on performance of each item on the list
- Estimates of the probability of occurrence of each item on the list
- Development of screening arguments for items to be deleted from further consideration in the model. These arguments are based on three major considerations:
  - Consequences
  - Probability
  - Regulatory considerations (some items are specifically eliminated in the regulations)
- Incorporation of appropriate items into the model

This screening process is documented in a Features, Events, and Processes Database that lists the items and screening arguments (DIRS 154365-Freeze, Brodsky, and Swift 2001).

The features, events, and processes considered in the process described above include such things as nuclear bomb attack events and others, in addition to expected processes such as the eventual degradation of waste packages over a long period of time. Therefore, the analysis provided by use of the Total System Performance Assessment model actually reflects a greater analysis that considered all conceivable things that could affect performance and is not, as characterized by the comment, a "carefully constructed 10,000-year timetable." Rather, it is a carefully constructed set of scenarios developed from a complete list of all that could be wrong or go wrong, and are known to definitely affect performance.

The experiments and analyses documented in the "Waste Package Degradation Process Model Report" (DIRS 151624-CRWMS M&O 2000) provide the basis for the waste package modeling and life expectancies. This report identifies and discusses each potential waste package degradation mode. The degradation model includes those modes that analyses did not screen out as highly improbable.

The longevity of the waste package is a principal factor in the Repository safety case. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). However, the updated analysis in the Final EIS projects between zero and five waste packages failing due to manufacturing defects.

There is obvious uncertainty associated with the extrapolation of experimental results for such long periods and the other human factors mentioned in the comment. DOE selected the design analyzed in the Final EIS to mitigate the uncertainties by adding features (such as the drip shield) to provide defense-in-depth. This provides greater assurance that the repository would meet its performance standards in the face of uncertainty.

DOE acknowledges that it cannot build a containment system that can provide perfect containment forever. The EIS provides DOE's best estimate of the impacts that could occur when the containment system inevitably degraded. The EIS confirms that the Proposed Action would likely result in release of radioactive contamination to the environment. However, the EIS shows that these releases under the Proposed Action would be well within environmental protection standards (40 CFR Part 197) within 10,000 years of repository closure, standards specifically enacted to ensure the safety of future generations. See Section 5.3 of the EIS for additional information.

7.3 (6947)
Comment - EIS000812 / 0004
I have read that groundwater studies have shown that tritium is present in the water in the unsaturated zone. This was not mentioned in the Summary. If in fact this is the case, tritium was unleashed by nuclear weapons testing in the area in the 40's, 50's and 60's. In other words, it has taken about 50 years for the tritium to percolate through the volcanic rock. The summary has stated that minor releases of gases and carbon 14 would happen from time to time. How long will it take for that material to filter through to the ground water. What will happen when the containers are breached (as there seems to be a good deal of agreement by all that this may happen in the future) and radioactivity is released into the ground water, maybe not in the next century, but in 2 or 300 years? What would be a plan of action to counteract this problem?

Response
It is true that the waste packages would fail in the distant future, and the gaseous release estimates given in Section 5.5 are based on the expected failure rates of the waste packages. Section 5.5.2 details the impacts to the local population. Because the resulting doses would be exceedingly small, no action would be taken to counteract them.

Note that the tritium (as well as chlorine-36) present deep in the unsaturated zone at Yucca Mountain arises mostly from ocean testing in the Pacific during the 1940s, 1950s, and 1960s, not from surface testing at the Nevada Test Site during the same period. This tritium and chlorine "signature" occurs throughout the world, and is still widely found in low-infiltration areas (deserts). Data gathered on the presence and distribution of these isotopes led to improved models of vadose zone hydrology for Yucca Mountain that recognize the possibility of more rapid movement of some of the infiltrating water. These improved vadose zone hydrology models were used in the Draft EIS. The Final EIS includes results based on improvements to these models since DOE issued the Draft EIS.

7.3 (7109)
Comment - 010229 / 0002
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 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.

Response
In considering the points in this comment, it is important to focus on a fundamental idea: The period of significant heat release is very short compared to the lifetime of waste packages. Thus, even if the heat were to be detrimental to waste packages and performance in general, the heat is gone before any significant amount of waste package failures occur and thus has no important influence on long-term performance. This was seen in the Draft EIS case and also in the Final EIS case (see Section 5.4).

Sensitivity studies, which included a temperature sensitive model of corrosion, showed improved performance (less than half the mean peak dose that is reported in the Final EIS) (DIRS 155950-BSC 2001). The fact that there is improved performance is not surprising because the non-temperature-dependent model is conservative and actually uses what is essentially corrosion under all adverse conditions including high temperature. When the temperature-dependent model is employed, the conservatism of assuming a constant, higher rate is removed so that corrosion after the short heat pulse is much slower than that of the conservative model. Improved performance then results. Even in these sensitivity studies the higher-temperature operating mode results differ by about 30 percent from the lower-temperature operating mode (DIRS 154659-BSC 2001) because of the fundamental fact that the period of heat generation is short compared to package and drip shield lifetimes.

After consideration of the Draft EIS and a large body of subsequent study and analysis, DOE concluded that general lowering of repository temperature would not improve the overall long-term performance of the repository.

7.3 (7131)
Comment - EIS001879 / 0013
The Draft EIS presents an assessment of human health and safety that purports to meaningfully portray the risks associated with the repository. Unfortunately, this assessment is based on an approach that is fraught with uncertainty and plagued by a lack of data. Further, the results have been severely criticized by expert panels assembled specifically to evaluate the validity and results of the specific models used to predict risk associated with the proposed repository.

The Draft EIS analysis in Chapter 5 follows the approach recommended by the National Research Council, 1995 Technical Bases for Yucca Mountain Standards; hereafter referenced as NRC, 1995). In Section 5.2.4.1, the Draft EIS goes on to state "The analysis in this chapter follows the recommended approach, using as defaults societal conditions as they exist today; as such, **it is based on the assumptions that populations would remain at their present locations and population densities would remain at their current levels**," (emphasis added). The approach introduces uncertainty into the analysis and the basis for the assumption is not valid. The reference to NRC (1995) is taken out of context; the discussion to which it is germane is the NRC's consideration of a population-risk standard, not impact analysis in a NEPA [National Environmental Policy Act] document. The Draft EIS attempts to use the NRC discussion as a rationale for ignoring the present (1999-2000) population of Amargosa Valley and short-term (50 year) future growth in the area, which is very predictable.

With respect to the future number of cancer fatalities in the vicinity of Yucca Mountain, NRC (1995, page 61) states, "...the total number of fatal cancers cannot be known without knowledge of the number of future persons residing in the Yucca Mountain vicinity. This number is obviously unknowable." Further, the NRC (1995, page 63) states, "For identifying the distribution and the varied lifestyles of a larger population, more assumptions of greater uncertainty would be required. The resulting data for a risk assessment would become so arbitrary that no adequate decision basis would result. **We therefore conclude that there is no technical basis for establishing a**

population-risk standard that would limit the risk to the nearby population for a Yucca Mountain repository," (emphasis added). Later in the same report (NRC, 1995; p. 96) additional findings are made with respect to future populations and future scenarios, "**(A)s far as we are able to determine, there is no sound basis for quantifying the likelihood of future scenarios in which exposures do or do not occur; about all that can be said is that both are possible .... Any particular scenario about the future of human society near Yucca Mountain that might be adopted for the purposes of calculation is likely to be arbitrary, and should not be interpreted as reflecting conditions that eventually will occur,**" (emphasis added).

DOE clearly disregarded these portions of the cited document in the preparation of the Draft EIS insofar as Tables 5-5, 5-9, 5-13, 5-13, 8-40, 8-44, and 8-48 all contain population-based impacts that are based upon the arbitrary assumption that the population levels in 10,000 years will be the same, and will be distributed in the same manner as in 1990. As a consequence, the information in these tables is misleading, is based upon a number of other arbitrary assumptions, and does not provide an adequate decision basis. The decision maker, when reading these tables, might misinterpret the values to be based upon proven science, an adequate database, and logical assumptions, when in fact the values are based upon an unrealistic scenario, inadequate data, arbitrary assumptions, and questionable judgment. These tables must be deleted from the EIS.

Section 5.2.4.2 has the heading "Uncertainty Associated with Currently Available Data," yet contains nothing about this uncertainty. Rather, the entire discussion is a synopsis of the DOE's plan to collect additional data to reduce the amount of uncertainty. The entire discussion in this section should be deleted and replaced with a discussion of the adequacy of the existing database (not the results of models, but rather actual data) for each key parameter in performance assessment. The section should clearly state that the data used to support the TSPA [Total System Performance Assessment] did not include any permeability, porosity, transmissivity, storativity, groundwater age, or water chemistry data for the area between Yucca Mountain and the closest receptor population, in the Lathrop Wells area of Amargosa Valley. This section should also make it clear that the corrosion rates, fractional release rates, and other key parameters used in the TSPA are based upon inadequate testing and measurements.

Section 5.2.4.3.5 ("Confidence in the Long-Term Performance Estimates") does not accurately summarize the uncertainty associated with long-term performance estimates. For example, Table 5-3 lists the confidence in models to reasonably represent specific impacts and processes, and the significance of uncertainty to the estimate of performance, and cites the Viability Assessment as the source document for the information presented in the table. A review of the corresponding portion of the Viability Assessment (Volume 4, Section 2.2.4.1) reveals that the significance of uncertainty estimates were made "by considering quantitatively the effects of uncertainties associated with each principal factor on the peak dose rate calculated by TSPA. Judgments were then made taking into account limitations of the quantitative approach." The EIS should be revised to state that the significance of uncertainty measures listed in Table 5-3 is based upon judgment.

Additional uncertainty is contributed from the time periods used for analysis. The Draft EIS breaks the analysis into two periods: 1) construction, operation, and monitoring and closure through the year 2025; and 2) long-term repository performance during the first 10,000 years after closure. However, the Draft EIS does not have comparable evaluations for both periods of time nor does the Draft EIS present the consequences of radionuclide and hazardous chemical contamination for the period between closure and 10,000 years after closure and simply states that "all peaks [for radionuclides] occur at or near 10,000 years." This statement appears to be based on the results of the TSPA-VA [Total System Performance Assessment – Viability Assessment}, which used bulk permeability values that were based either on expert elicitation or the results of the USGS [U.S. Geological Survey] site-scale model. The use of bulk permeability values does not yield a conservative result, but rather an average result. In actuality, the permeability values vary considerably and result in a similar variability in groundwater travel times and hence breakthrough curves for contaminants at a given distance from Yucca Mountain. Of importance with respect to groundwater flow and contaminant transport is that flow will predominate through preferential pathways that exhibit the fastest, not the bulk permeabilities.

Further, the statement is inconsistent with the findings of the TSPA-VA, which indicate that several specific contaminants have breakthrough curves that peak well before 10,000 years, such as technetium, plutonium on colloids, carbon-14, and others.

Response
DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency, and Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex systems over long periods. In 10 CFR Part 63, the Nuclear Regulatory Commission acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." In 40 CFR Part 197, the Environmental Protection Agency establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. The Agency also recognizes the need for expert judgment in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Sciences observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events.

DOE confidence in the disposal techniques is based on defense-in-depth that, for example, would place drip shields over waste packages to account for uncertainties. DOE has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components. DOE believes this process results in a representative estimation of impacts that is sufficient for comparing the relative merits of the various repository scenarios, including the preferred alternative. DOE continues to evaluate the sufficiency of its approach to dealing with uncertainty at the process level (scientific) and the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before License Application, should the repository be recommended as a suitable site.

With regard to criticism from expert panels, DOE welcomes the reviews and suggestions provided by the Total System Performance Assessment Peer Review Panel and other groups and individuals. DOE has responded to these organizations by improving models and incorporating design enhancements to reduce uncertainties in long-term performance predictions. DOE has incorporated responses to the comments of the expert panels in the analyses conducted for Supplement to the Draft EIS and the Final EIS.

For the Final EIS, DOE projected Nye County population through 2035 (see Section 3.1.7). Figure 3-25 shows estimated residences within an 80-kilometer (50- mile) radius of the repository. The Department also projected population through 2035 for each sector within the grid. The Nye County population projections and allocation of population to grids within the 80-kilometer area includes Amargosa Valley. DOE has revised the discussion of conservatisms, limitations, and uncertainties associated with potential radiation health effects in Section F.1.1.5.

Although DOE recognizes that the National Research Council rejected a population risk standard in favor of an individual risk standard, it has traditionally included potential impacts to affected populations in its National Environmental Policy Act documents as a measure for use in the decisionmaking process. When providing these estimates, the Department is careful to state all important assumptions and limitations applied in the calculation and interpretation of the values. For example, the text discussing the summary population impacts (see Table 5-17) states that adverse health impacts would be unlikely to result from groundwater contamination. The updated population dose analysis in the Final EIS uses the updated 2035 population values.

In general, it is DOE policy to not republish details in an EIS that are available in other public documents because of the enormous volume of this supporting material. A detailed discussion of the database in the EIS would be voluminous. The intent of the discussion in Section 5.2.4.2 of the Draft EIS was to provide the reader an understanding of how DOE handled uncertainties in the projections. DOE has improved cross-referencing to help the reader find such details in the Final EIS. In addition, DOE the Department incorporated data from many of the studies discussed in the EIS characterizing the area near the Lathrop Wells area -- much of this from well testing by Nye County. A significant amount of additional data from seepage and heater testing has been used in both model formulation and in data used in the Total System Performance Assessment. Comprehensive data from new Alloy-22 corrosion tests have been incorporated, as has a new suite of colloid transport models. Details of most of the data and associated uncertainties are in various Analysis/Model Reports and Process Model Reports referenced in Section 5.2.4 of the Final EIS.

Section 5.2.4.3.5 of the Draft EIS was partially based on judgment but also on a number of sensitivity studies in the Viability Assessment (DIRS 101779-DOE 1998). DOE agrees that the judgment aspect should have been stated more clearly. This section required a complete rewrite because of large revisions to the design and the performance assessment models. DOE has deleted the section, including Table 5-3, and instead has provided a discussion of unquantified uncertainties from an ongoing study. In addition, many referenced sections of other supporting documents provide further insight into the modeling confidence.

DOE is not sure what thus comment means by "comparable evaluations" for preclosure and postclosure-to-10,000-year periods. Each of these evaluations has many unique aspects including how the public could be exposed and many processes unique to the time scale involved. As such, they would be two different types of analyses. Because it is much harder to account for processes and properties over many thousands of years, the uncertainties are much more extensive in the second period. The only comparable feature then would be the result, forecast of dose to the public, and this is included in the analysis. Chapter 5 of the Draft EIS reports a third period (10,000 to 1 million years), and the consequences (as dose or concentration) of radionuclides and hazardous chemicals for the period from closure to 10,000 years. The statement that peaks would occur at 10,000 years is for the closure-to-10,000-year period. This is because the dose curve would still be rising at that time. Because the discussion of peaks was for the total dose from all radionuclides, the statement is true even though some individual contributors (especially short-lived radionuclides) could have peaked before 10,000 years. Furthermore, Chapter 5 reports the all-time peaks as the 1-million-year results. These peaks would be higher that those for the 10,000-year period and would occur much later. With regard to bulk permeabilities, the model in the Draft EIS was much simpler than that used in the Final EIS, but all key parameters were sampled over a wide range, including very pessimistic values that could contribute to doses from preferential pathways. Thus, the long-term dose forecast contains much higher values for the 95th-percentile case than for the mean. Pessimistic situations such as preferential pathways, lower sorption values, and less dispersion are accounted for in the very wide distributions sampled in the probabilistic formulation. These are manifested in the 95th-percentile values given in the EIS.

7.3 (7137)
Comment - EIS001898 / 0017
The methodology for estimating the environmental impacts from the release and transport of toxic materials should be well documented in the FEIS. The estimates should incorporate the current waste package materials and design.

Basis:

The release and transport of toxic materials (chromium (Cr) and molybdenum (Mo)) from waste package corrosion to a receptor group was modeled using the EQ6 geochemical speciation code (Figure 1-1). It is unclear how this code was used to estimate the corrosion products or the corrosion rate for toxic materials.

The assumed dissolution rates and mineral formation kinetics are critical to substantiating the claim that release and eventual exposure of a receptor group to the potentially toxic waste package corrosion products (e.g., chromate, molybdate) is minimal as stated in Section 5.6 (Environmental Consequences from Long-Term Repository Performance-Consequences from Chemically Toxic Materials).

We understand that DOE is expected to select Enhanced Design Alternative II (EDA-II) for the potential license application in the near term (TRW, 1999). EDA-II includes an outer overpack of 5cm thick Alloy-22. The DEIS design includes a 2cm thick inner overpack of Alloy-22, so the quantities of Alloy-22 will more than double, even assuming constant numbers of waste packages, if the EDA-II design is used. Because Alloy-22 is approximately 56 percent Ni by weight, the volume of Ni present in the repository is considerably more than the amount of Cr and Mo present. In addition, nickel (Ni) will also likely dissolve at roughly the same rate as Cr and Mo during corrosion. The FEIS should document that Ni does not pose a health risk.

Recommendation:

The discussion of toxic materials should be consistent with the current waste package design at the time of the FEIS. DOE should provide the technical basis for waste package corrosion rates, and should provide technical support for claims that exposure to potentially toxic materials released by waste package corrosion is minimal.

Reference:

TRW Environmental Safety Systems, Inc., *License Application Design Selection Report*. B00000000-01717-4600-00123. Revision 01. Las Vegas, NV: TRW Environmental Safety Systems Inc. May 28, 1999.

Response
The Draft EIS methodology for estimating source concentrations was detailed in Appendix I on pages I-15 to I-18 (Section I.3.2.3.1). This section describes in detail how the values in Tables I-11 and I-12 were developed using the EQ3/6 software. The values in Tables I-11 and I-12 were then used to develop the screening information in Table I-13 as explained in section I.3.2.3.2 (pages I-18 to I-19). This screening process determined which elements required more rigorous analysis (taking into account many other mitigating processes). Chemicals eliminated in the screening process demonstrated such low potential concentrations, in these calculations, that more rigorous analysis (which would account for additional mitigating processes) was unnecessary to establish there would be no significant impacts. In the screening analysis, EQ6 simulations of the reaction of the solution resulting from corrosion with the host rock demonstrated that nearly all the dissolved nickel would precipitate (resulting in a concentration of only about 0.0001 milligram per liter) upon contact with the crushed tuff invert (see Draft EIS Table I-12 and accompanying discussion). For this reason, nickel was not considered further in the impact analyses. Detailed analysis for those chemicals not screened out are described in Section I.6 of the Draft EIS. This material was referred to in Chapter 5 of the Draft EIS on page 5-39.

The Final EIS analyzes the new waste package design (Alloy-22 outer shell with stainless-steel sleeve). The new analysis conservatively assumes the nickel reaction with tuff would not take place. As detailed in Section I.6 of the Final EIS, bounding calculations (not taking into account many mitigating processes) still indicate a nickel concentration producing only a small fraction of the oral reference dose for nickel.

7.3 (7232)
Comment - EIS001337 / 0108
Page 5-6 Section 5.2. The postulated sequence of events does not include the potential for atmospheric releases due to volcanism, gaseous releases, and human intrusion. Other possible sequences of events relating to atmospheric pathways should be described and analyzed in the DEIS.

Page 5-16 3rd paragraph. Why did the DEIS not consider the potential for portions of the content of a waste package to be brought to the surface as a result of drilling induced human intrusion? Such an occurrence seems more plausible than release to the water table and would likely occur prior to drilling reaching the water table. In practice, a drill penetrating a cask would likely result in fatal exposure to the drill crew at the surface and drilling would likely not proceed to the water table.

Page 5-49 Section 5.10. Table 5-19 should also show LCF's [latent cancer fatalities] during the year of projected peak dose, which is expected to be some time after 10,000 years.

Response
The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probabilities and effects of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

One change in the EIS is that now there is an aerial pathway release from the analyzed eruptive scenario. The dose rates in Chapter 5 are well below the 40 CFR Part 197 environmental protection standards. In addition, Section 5.5 discusses the potential impacts associated with atmospheric releases.

The drilling intrusion scenario is a prescribed scenario defined in the regulations (40 CFR Part 197 and 10 CFR Part 63). As prescribed the scenario does not provide for effects on the drilling crew or any other transport to the surface.

In the preamble to 40 CFR Part 197, the Environmental Protection Agency recognized that, while there is no scientific basis for limiting the time period of the individual risk standard to 10,000 years or any other period, there is considerable uncertainty that current modeling can provide meaningful projections for tens of thousands to hundreds of thousands of years. The preamble states that "Simply because such models can provide projections for those time periods does not mean that those projections are either meaningful for decisionmakers or accurate." It further states that " … as the compliance period is extended to such lengths, uncertainty increases and the resulting projected doses are increasingly meaningless from a policy perspective."

The Environmental Protection Agency requires a calculation of peak dose (40 CFR 197.30) within the period of geologic stability, which is 1 million years for the repository. The Agency requires DOE to include these results and their bases in the EIS for Yucca Mountain as an indicator of long-term performance. This analysis also serves as another source of information for the decisionmakers in making both design and licensing decisions. However, the Agency has recognized the inherent uncertainties associated with these long-term projections and has, therefore, not applied a regulatory standard to the results. Therefore, DOE considers estimates of resultant health impacts to be too speculative and has not included them in the EIS.

7.3 (7404)
Comment - EIS001957 / 0023
Section 5.4 Waterborne Radiological Consequences -- This section of the draft EIS does not address potential waterborne radiological consequences to Death Valley NP [National Park], its resources, staff, or visitors from water from the regional groundwater flow systems overlain by the proposed repository. Analysis of those potential impacts must be completed in the final EIS.

Also, there is little explanation of the basis for the estimation of a 1,150 person-exposure to possible groundwater contamination events within 50 miles of the proposed site. We are concerned this underestimates the current combined population and daily visitation in the area, and is even more inconsistent with projected trends into the foreseeable future.

Response
As described in Section 3.1.4 of the EIS, DOE has conducted an extensive program to characterize the direction and nature of groundwater flow from the Yucca Mountain site. The general path of water that percolates through Yucca Mountain is southward toward the Town of Amargosa Valley, then beneath the area around Death Valley Junction in the southern Amargosa Desert. The groundwater beneath Yucca Mountain merges and mixes with groundwater beneath Fortymile Wash. This groundwater then flows toward, and mixes with, the large groundwater reservoir in the Amargosa Desert. The natural discharge point of this groundwater occurs farther south in Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume may flow south toward Tecopa into the southern Death Valley area. A fraction of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. Potentiometric data indicate that a divide could exist in the Funeral Mountains between Amargosa Desert and Death Valley. This divide would limit discharge from the shallow flow system, but would not necessarily affect the flow from the deeper carbonate aquifer that may contribute discharge to springs in the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Potential Furnace Creek area impacts would be less than the low impacts described in Chapter 5 for Franklin Lake Playa because impacts would decline with distance from the repository.

The 1,150-person figure referred to in the comment can be found in Section 5.4.1 of the Draft EIS and represents the estimated population of residents that would continue to live in the present location. The Final EIS uses a figure of 74,000 people based on the projected population for 2035 (see Figure 3-20a of the Final EIS). This figure is much higher than the Draft EIS because a much wider population was included (the whole southern half of the population plot) for conservatism and the total population also increased somewhat from the year 2000 figures used in the draft. Because it is impossible to make accurate predictions of future lifestyles and residence locations, the approach used to estimate the potentially affected population is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995). The population estimates in the Final EIS have been revised to reflect the most recent population data. Section 3.1.7 of the EIS describes the derivation of population estimates and Section 3.1.8 discusses an 80-kilometer (50-mile) population grid.

7.3 (7580)
Comment - EIS001912 / 0070
Pg. 5-1 para. 2 states, "Therefore, analysis of impacts to land use, noise, socioeconomics, cultural resources, surface water resources, aesthetics, utilities, or services after closure is not required." Given that the actual consequences of long-term repository performance is unknown, dismissing impacts to these resources is inappropriate at this time. These resource impacts may be relevant under a worst case scenario.

Response
The cited statement needs to be placed in context. No analysis of the listed subject areas would be required for the long-term postclosure period because no activities would take place that could affect these resource areas. All impacts to these areas would take place before final closure.

The EIS presents the long-term performance results in probabilistic terms – a mean and 95th-percentile result. This statistical spread reflects the range of possible behavior DOE believes is credible for the repository system based on wide ranges of parameters. As such, the "worst case" is contained within the range of results. The worst case could be realized as the results approached at the 100th percentile.

7.3 (7603)
Comment - EIS001912 / 0074
Again a worst case scenario needs to be included in the analysis of long-term repository performance. Potential impacts to resources such as land use, consumptive water use, impediments to growth and loss of property values need to be considered if the worst case scenario show a potential for radioactive waste contamination to exceed regulatory levels.

Response
The EIS presents the long-term performance results in probabilistic terms—a mean and 95th-percentile result. This statistical spread reflects the range of possible behavior DOE believes is credible for the repository system based on wide ranges of parameters. As such, the worst case is contained within the range of results. The worst case could be realized as the results approached at the 100th percentile.

The potential long-term (10,000-year) consequences of the proposed repository are presented in Section 5.4 of the Draft EIS and include estimated groundwater concentrations of radionuclides (Table 5-7) for each of the three thermal load scenarios evaluated. In addition, potential consequences (radiation dose) and human health impacts (latent cancer fatalities) resulting from consumption and irrigation of food and feed crops are presented (Tables 5-4 and 5-5), for both reasonably maximally exposed individuals and populations for the three thermal load scenarios evaluated. These estimated consequences are a small fraction of the environmental protection standards (40 CFR Part 197) promulgated by the Environmental Protection Agency for the proposed Yucca Mountain Repository to ensure protection of the environment and human health. Therefore, DOE expects no adverse radiation-related health impacts of any kind to the population around Yucca Mountain within 10,000 years of repository closure. In addition, whereas the repository design evaluated in the Draft EIS projected small releases within the 10,000-year compliance period, the enhanced design evaluated in the Final EIS projects that the Proposed Action probably would result in even smaller releases of radioactive contamination to the environment in the first 10,000 years after repository closure.

With regard to potential impacts to regional use resulting from groundwater contamination, the new analysis presented in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure. These releases are estimated to result in an annual dose to the reasonably maximally exposed individual of less than .0001 millirem, including milk pathways, which is more than 100,000 times less than the individual protection standard set by 40 CFR Part 197.

The long-term impacts on land use and property values are too speculative to be meaningful. After closure, DOE would not modify or develop additional land. Therefore, all direct land-use impacts would have occurred before closure. Secondary impacts to such resource areas as socioeconomics or land use would come from groundwater contamination outside acceptable limits, but the EIS analysis shows there would be no case resulting in contamination levels exceeding acceptable limits.

7.3 (7616)
Comment - EIS002027 / 0003
What will we do when or if it gets in our water?

Response
The EIS analyzes the process of waste package failure and radionuclide migration; Chapter 5 presents the results of the analysis as estimated dose to groundwater users after repository closure, at various distances from the Yucca Mountain site. Because these estimated doses would meet regulatory and licensing requirements, the potential impact to the population would be in the range where no additional water treatment would be needed for domestic or agricultural use of groundwater at the populated locations. If the analyses determined that the repository would not meet the requirements, DOE could not recommend the site, because it cannot plan to mitigate impacts thousands of years in the future.

7.3 (7618)
Comment - EIS001912 / 0109
None of the discussion in the long-term performance section has much to do with mitigation. It has more to do with site selection, design, and defense in depth. Without these measures it is doubtful that DOE would even have a proposed action which could meet regulatory standards.

Response
Section 9.2.10 of the EIS discusses mitigation measures related to the long-term performance of the repository. DOE regulations (10 CFR 1021.331) require preparation of a Mitigation Action Plan when mitigation measures are identified in a Record of Decision. Because DOE does not anticipate issuing a Record of Decision, a Mitigation Action Plan might not be prepared. However, the Yucca Mountain site, if approved consistent with provisions of the NWPA would be subject to licensing by the Nuclear Regulatory Commission. DOE, in submitting its application to construct and operate the repository, would identify relevant commitments and contingencies, including those identified in the Final EIS, for consideration. DOE would reasonably expect a comprehensive set of mitigation measures or conditions of approval to be part of the licensing process.

The estimated long-term consequences associated with the repository (see Chapter 5 of the EIS) would be a small fraction of the environmental protection standards (40 CFR Part 197) promulgated by the Environmental Protection Agency to ensure protection of the environment and human health. In addition, whereas the repository design evaluated in the Draft EIS projected small releases within the 10,000-year compliance period, the enhanced design evaluated in the Final EIS projects that the Proposed Action would likely result in even smaller releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197). As a consequence, DOE does not believe mitigation actions would be required to meet applicable standards, though some mitigation actions could be required to meet License Application conditions or temper potential impacts not subject to regulatory standards.

7.3 (7729)
Comment - EIS002018 / 0004
How long will the nuclear waste be with us?

Response
Some of the radioactive half-lives of the waste materials proposed for disposal at Yucca Mountain are in the millions of years. These time frames are far longer than any natural or manmade isolation system envisioned today could be expected to totally contain the waste.

Eventually, the waste packages would fail to contain the waste. As discussed in Chapter 5 of the EIS, there would at that time be small releases of gases to the atmosphere as well as releases to the underlying aquifer. With the understanding that absolute assurance of "zero" release of waste materials is not possible over long periods, the Environmental Protection Agency has promulgated environmental protection standards for the Yucca Mountain Repository based on the concept of "reasonable expectation" (40 CFR Part 197). Prior to the Secretary recommending development of the proposed repository, DOE comply with those standards as well as the Nuclear Regulatory Commission's Yucca Mountain site suitability standards (10 CFR Part 63). These regulations have been

promulgated to ensure adequate protection of the public and the environment. The results in Chapter 5 of the Final EIS indicate that the flexible design would meet the environmental protection standards.

7.3 (7785)
Comment - EIS001999 / 0001
In class we have been learning about what radiation can do and how long it can last and what effects it can have on plants and animals. I don't think we should put it in that mountain because if it does leak it's going to seep into the water supply. That is my main concern because eventually the desert uses that water and if it contaminates the soil it will kill many plants and animals.

Response
Section 5.4 of the EIS indicates that predicted long-term levels of radionuclide concentration in groundwater and the resultant dose levels at the predicted discharge area in Amargosa Valley, Nevada, would be low. DOE does not expect that the dose rates to plants and animals at that location would cause measurable detrimental effects in populations of any species because the rates would be less than 100 millirad per day. The International Atomic Energy Agency concluded that chronic dose rates of less than 100 millirad per day are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992). DOE acknowledged in Section 3.1.4.2.1 of the EIS that a small amount of groundwater might move beyond the primary groundwater discharge point in Amargosa Valley to discharge in the Furnace Creek area of Death Valley. However, even if this occurred, potential impacts in the Furnace Creek area would be even less than those at the discharge location, because concentrations would decline with distance from the proposed repository.

7.3 (7794)
Comment - EIS001213 / 0002
Once it has been stored there, the DOE can only offer unreal and unproven long-term projections as [to] what the consequences of such disposal would be. The TRANSPORT and STORE plan is pabulum when it comes to addressing the long-term problem. It is a problem that is larger than many of the present election campaign issues. Congress should not be resting on Laws that were passed in 1982. What might have been an acceptable two decades ago is UNACCEPTABLE.

Response
DOE agrees that it can make only projections given the long timeframes involved. However, the objective is to provide "reasonable expectation" of compliance with regulations and standards set forth by the Environmental Protection Agency (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63). Congress commissioned these regulations through the statutory process.

The purpose of the proposed Yucca Mountain Repository is for "permanent" disposal rather than storage. The concept of permanently disposing of nuclear waste in a deep geologic repository stems from studies initiated in the 1950s by the National Academy of Sciences. Continued studies here and abroad have concluded that deep geologic disposal can keep nuclear waste isolated from the environment in geologic formations known to have been stable for millions of years, thus providing a safe location for the waste to decay into a stable form. Sixteen nuclear nations have sanctioned the repository approach to the disposal of spent nuclear fuel and high-level radioactive waste after more than 30 years of consideration.

In 1980 the Department published the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DIRS 104832-DOE 1980). That EIS examined both geologic disposal and alternatives to geologic disposal, including deep seabed disposal, ice sheet disposal, disposal in deep boreholes, transmutation, and space disposal. It concluded, in agreement with the National Academy of Sciences, that deep geologic disposal was the preferred alternative, and that the alternatives to geologic disposal other than continued storage were not technologically viable at the time. Continued storage is viable and safe, but simply postpones the decision to the future in the hope that technology to solve the problem will become available.

DOE's Yucca Mountain-related activities are steered by the requirements of the NWPA, which directs the Department to only consider the Yucca Mountain site for development of a geologic repository. As required by the Act, DOE is proceeding with site characterization activities at Yucca Mountain to determine its suitability as a potential repository for disposal of the Nation's high-level radioactive waste and spent nuclear fuel. At the same

time, DOE is continuing with development of a repository design for Yucca Mountain, which includes extensive review by independent technical peers including the National Academy of Sciences and the Nuclear Waste Technical Review Board. Ultimately, the repository would be licensed by the Nuclear Regulatory Commission, using standards established by the Environmental Protection Agency. These scientific peer reviews and regulatory requirements ensure that the repository design would be based on sound science.

7.3 (7826)
Comment - EIS001653 / 0023
Pg. 2-56 Sec 2.1.4 states, "This analysis used conceptual designs, which is typical of an EIS". Conceptual designs are not typical of an EIS when they have not been proven to work. It is appropriate to conceptualize designs, which are known to work such as roads, bridges, buildings, etc. However, DOE cannot currently demonstrate with any level of assurance which design may or may not meet regulatory standards. As of the date of publication of this DEIS can DOE demonstrate with a reasonable degree of assurance which design alternative will perform to regulatory standards? Subsequent to the release of the DEIS, has DOE dropped consideration of a hot repository? If yes, it does not appear that the hot repository design alternative was viable-its certainly brings into question the other as well. The FEIS should discuss changes to designs that have been made and how such changes improve performance.

Response
The Draft EIS evaluates the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). It also evaluates the plans for the construction, operation and monitoring, and closure of the repository. DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review of the repository by the Nuclear Regulatory Commission. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

For the reasons stated above, the analyses performed for the Supplement to the Draft EIS, DOE developed analytical scenarios to estimate the range of environmental impacts that could result from the Proposed Action. These analytical scenarios included the low, intermediate, and high thermal load scenarios presented in the Draft EIS, as well as the higher-temperature and lower-temperature repository operating modes being considered for the reference design. The low, intermediate, and high thermal load scenarios presented in the Draft EIS were not carried forward to the Final EIS. Section 2.2.1 of the Supplement summarizes the operational parameters for the three thermal load scenarios analyzed in the Draft EIS and the two repository operating modes analyzed in the Supplement. Section 2.2.2.2 describes the operational parameters for the higher-temperature and lower-temperature repository operating modes. DOE developed these scenarios and operating modes to accommodate and maintain flexibility for the potential future evolution of the design and plans for the repository. To not underestimate the impacts that could result from future design evolution, these scenarios and operating modes incorporate conservative assumptions. Sections 2.2.1 and 2.2.2 of the Supplement discuss the design and operational evolution, respectively.

The Supplement evaluates the environmental impacts of the flexible design higher-temperature repository operating mode, which is the design focus of the Science and Engineering Report (DIRS 153849-DOE 2001). In addition, the Supplement evaluates the impacts for the flexible design lower-temperature repository operating mode [which embraces a range of operational parameters, as described primarily in Section 2 of the Science and Engineering Report (DIRS 153849-DOE 2001)]. The differences between these modes deal with the highest postclosure temperatures of the waste package surface, the temperature of the emplacement drift rock walls, and the overall temperature of the repository rock. Section 2.3 of the Supplement describes the design modifications including the addition of drip shields and refined waste packages. DOE is not currently considering any backfill in the emplacement drifts as part of the design.

The Final EIS carries forward the information presented in the Supplement and addresses all aspects of the Proposed Action, including the flexible design. DOE acknowledges in the EIS that the flexible design could be further modified or refined during the license application process, if the site is approved for development. DOE believes

that the information on the environmental impacts that could result from the Proposed Action or the No-Action Alternative complies with the Nuclear Waste Policy Act requirements for a Final EIS to accompany any recommendation by the Secretary of Energy to the President to approve Yucca Mountain for development as a repository. This belief is based on the level of information and analysis, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts that could occur, and the use of bounding assumptions where information is incomplete or unavailable or where uncertainties exist.

Chapters 4, 5, and 6 of the EIS describe the environmental impacts of the Proposed Action. The results in these chapters indicate that there would be small risks associated with the proposed repository. However, prior to the Secretary recommending development of the proposed repository, DOE must provide a reasonable expectation of compliance with Environmental Protection Agency long-term environmental protection standards (40 CFR Part 197) as well as a reasonable expectation that the Yucca Mountain site would meet the Nuclear Regulatory Commission licensing requirements (10 CFR Part 63). These regulations have been promulgated to ensure protection of the public and the environment.

7.3 (7962)
Comment - EIS002041 / 0005
My class and I are also worried about our water supply. If there is a leak from a cask and it goes into our water supply almost or all the people would get contaminated.

Response
DOE is very concerned about the environmental impacts of the proposed Yucca Mountain Repository and the design and evaluation of the repository reflects those concerns. The Environmental Protection Agency provides standards for protecting public health and safety, including specific provisions for protecting the quality of water supplies (40 CFR Part 197). DOE recognizes that groundwater and surface water provide potential exposure pathways and is proposing a system of multiple natural and engineered barriers designed to protect human health and the environment for thousands of years.

DOE includes groundwater pathways in its analyses of the health risks of the proposed repository. The largest potential risk to groundwater users lies with the people of Amargosa Valley because groundwater in the saturated zone beneath the proposed Yucca Mountain Repository flows in a generally southerly direction toward this community.

The EIS examines the potential consequences to individuals in the Amargosa Valley from both radioactive and nonradioactive contaminants transported through air, water, soil and food pathways. Chapter 5 of the EIS presents an evaluation of the long-term environmental impacts of the proposed repository on the people of Amargosa Valley. These evaluations demonstrate compliance with the Environmental Protection Agency environmental protection standards. Therefore, DOE believes adverse health impacts to people in Amargosa Valley and Amargosa Desert would be highly unlikely.

7.3 (8005)
Comment - EIS000817 / 0060
Has this fill placement system for closure really been thought out in detail? What about weight and pressure of the fill on the containers? What happens when you cut the ventilation off? What goes first? -- The seals? The welds? The supports for the casks? How will things fall apart inside and outside the cask over time? -- How will the casks affect each other?

Response
Since the publication of the Draft EIS and the *FY 01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001), DOE has modified the repository design (flexible design) to include drip shields over the waste packages and forced-air ventilation during the operation and monitoring phase. In addition to the elimination of backfill material, the flexible design incorporates modified ground support and corrosion-resistant packages and package supports. Detailed descriptions of the important features and degradation mechanisms of the flexible design (including natural barriers, drip shields, and package failure modes) are described in the *Total System Performance Assessment – Site Recommendation* (DIRS 153246-CRWMS M&O 2000). As discussed in that document, the primary failure mode of the waste packages is expected to be at the welds where the outer and middle

closure lids are joined. However, the analysis has determined that these failures are not likely to occur within 10,000 years of repository closure. However, failure of up to 5 waste packages because of manufacturing defects is included in the model. Section 5.4 describes the potential long-term impacts of the flexible design.

The primary way in which casks affect each other is through the generation of heat or thermal load. In the Draft EIS DOE evaluated three thermal load scenarios including: high thermal load [85 MTHM (metric tons of heavy metal) per acre], intermediate thermal load (60 MTHM per acre), and low thermal load (25 MTHM per acre). In contrast to the focus of the Draft EIS on areal mass loading, the flexible design focuses on controlling the temperature of the rock between the drifts, as well as the surfaces of the waste packages and the drift walls, to meet thermal management goals established for possible repository operating modes. As a consequence, the designs differ with respect to some operating parameters. For example, the flexible design differs from the design evaluated in the Draft EIS in the range of areal mass loading considered (25 to 56 MTHM per acre versus 25 to 85 MTHM per acre, respectively). However, the flexible design would achieve its thermal management goals by varying other parameters, such as the linear thermal load (heat output per unit length of emplacement drift, expressed in terms of kilowatts per meter). The flexible design also would emplace waste packages relatively closer together than the Draft EIS design, which did not consider linear thermal load. Under the flexible design, DOE could vary other operating parameters such as ventilation rates and the blending of hotter and cooler spent nuclear fuel.

7.3 (8111)
Comment - EIS001653 / 0070
Throughout the DEIS, DOE has relied upon boundary analysis to determine a range of possible impacts. If the performance assessment process is currently unable to accurately predict possible long-term repository performance, and the high thermal load alternative is no longer viable, does the analysis is Chapter 5 still depict a reasonable range of impacts? Please explain.

Response
DOE used stochastic analyses to characterize impacts with respect to uncertainty in inputs, models, and conceptualizations where possible, and has used a range of calculations as necessary to ensure that the predicted impacts would be conservative (that is, would not underestimate impacts).

A high-accuracy prediction of impacts for the long periods involved for the disposal of spent nuclear fuel and high-level radioactive waste is not possible and, therefore, the Nuclear Regulatory Commission and Environmental Protection Agency regulations and the National Environmental Policy Act do not require such a level of accuracy. Rather, they require the best estimate of the impacts, calculated using the best available information. Chapter 5 of the Draft EIS did provide this estimate.

DOE has updated the repository design since publication of the Draft EIS to reduce uncertainties and to improve long-term performance. The Final EIS evaluates this newer design, including the range of impacts that could occur under different operating modes. The Department believes that the impacts presented in Chapter 5 represent a reasonable range of impacts that could occur.

7.3 (8147)
Comment - EIS000817 / 0081
P. 3-14 -- As I look at the climate, it looks like there can be heavy downpours -- “an inch in a matter of hours” -- what do you do if you find out later that water is coming into the tunnels before expected? Can you pump it out or dry it out in any way? Is there any brainstorming on such a problem? What do they do in mines when this happens?

Response
Heavy downpours of precipitation can occur anywhere in the continental United States. In desert environments such as the Great Basin where the proposed repository would be, torrential rains are often accompanied by rapid surface runoff, flooding, gullying, and other erosive processes because of the lack of vegetation and the thin soil cover. These surface conditions mean that during large precipitation events the land is not able to absorb as much precipitation as during comparable events in nondesert environments. DOE’s design for the surface facilities includes water diversion structures to accommodate these possible events. These design features channel, divert, or otherwise control this runoff to prevent incursion of this fluid into the subsurface facilities.

7.3 (8175)
Comment - EIS000817 / 0089
I am very concerned about the evaluation of the peer review panel and their view on uncertainties in [the] corrosion rate of the waste package. That is my biggest concern too. The NRC report says that the water seepage calculations vary by several orders of magnitude -- why?

Response
As a result of the evaluation of the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) and concerns such as those of the Total System Performance Assessment Peer Review Panel, DOE changed the waste package design and added a drip shield over the waste package. The waste package would have Alloy-22 as the outside layer with stainless steel on the inside. The titanium drip shield would add further defense-in-depth to the design.

The peer review panel pointing out that DOE based the waste package corrosion model for Alloy-22 in the Viability Assessment (DIRS 101779-DOE 1998) (and the Draft EIS) on very little data. In fact, it was based on expert elicitation. For the Final EIS, DOE based the waste package corrosion model on corrosion experiments on Alloy-22 at Lawrence Livermore National Laboratory. Those experiments showed that Alloy-22 is very corrosion resistant and, even accounting for uncertainty, would be unlikely to fail for many thousands of years.

Seepage remains uncertain because of heterogeneity of the rock. The seepage models acknowledge and account for the uncertainty. In addition, DOE has added a drip shield to the design to help mitigate some of the uncertainty and sensitivity to seepage. The recent corrosion data also indicates a reduced sensitivity of corrosion rates to seepage (DIRS 155950-BSC 2001 and DIRS 153246-BSC 2001).

7.3 (8184)
Comment - EIS000817 / 0090
Scientists are conducting tests of the first full scale mock radioactive waste casks heated in the rock to see effect on water -- did water actually "pour out of the borehole in July"? If so, then you have a lot of work to do in this area. If chlorine 36 percolated halfway through the mountain in just 50 years, you have a big problem here. The fact that concern over water collecting above the repository and heating up made you scrap the hot design just last year shows you have a long way to go. 81 meters of spacing might not keep boiling water in drainage routes you expect. You continue to be "surprised by the water." It will go wherever it can. And you don't know for sure how fast radionuclides will travel through the rock either. It can hitch a ride on a lot of particles you may not expect at all. What are tests here?

Response
The Drift Scale Test, which is a full-scale mockup of radioactive waste emplacement, is providing much useful information about the movement of water in response to heat. DOE anticipated the fact that water collected in (the comment says "poured out of") a borehole. During the test, the heating evaporates water out of the matrix, and the water condenses in cooler regions and flows in the fractures. This test heats the rock to a similar degree as the current repository design would and helps validate models of water drainage between the drifts. The design analyzed for the Draft EIS would have boiled the water between the emplacement drifts and prohibited free drainage during the boiling period. The uncertainties in analyzing the rewetting of the entire repository horizon were part of the reason for the new design, which would have a portion of the rock between drifts below boiling, allowing drainage.

The chlorine-36 analysis indicated that water moved quickly through known through-going faults and well-developed fracture systems close to those faults. Overall, most of the water that infiltrates Yucca Mountain moves slowly through the matrix of the rock during some of its journey to the level of the proposed repository. Similarly, water (and radioactive contamination) would move through the mountain much more slowly than the limited chlorine-36 data would indicate.

Other tests, such as radionuclide transport tests, helped develop conceptual models for radionuclide transport through Yucca Mountain. The results of these tests constrain the useful data for the transport models. These tests also looked at the mobility of particles of very small size. In addition, work done in cooperation with Nevada Test Site geochemical investigations into the potential for colloids, very fine mineral particles, has shown there is some

potential for colloid-enhanced radionuclide movement. These facts have been incorporated into the modeling of radionuclide transport that is part of the total system evaluation in the Final EIS.

7.3 (8195)
Comment - EIS001873 / 0014
Yucca Mountain is essentially a radionuclide delivery system. Eventually the repository will leak, canisters will deteriorate, the environment will be contaminated and people will be exposed. Geologic and climatic events, which cannot be predicted, will likely speed up the process, as will completely unforeseeable events involving human intrusion.

Response
DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency, and Nuclear Regulatory Commission also recognize the difficulty of understanding the behavior of complex systems over long periods. In 10 CFR Part 63, the Nuclear Regulatory Commission acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." In 40 CFR Part 197, the Environmental Protection Agency establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. The Agency also recognizes the need for expert judgment in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Sciences observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events. These models, using the best available information and methods, also account for the uncertainties related to the inability to accurately predict geologic and climatic disruptive events as well as our inability to predict future human behavior.

DOE acknowledges that it cannot build a system that can provide perfect containment forever. This EIS provides the Department's best estimate of the impacts that could occur when the containment system inevitably degraded. The updated analysis in the Final EIS projects between zero and five waste packages would fail due to manufacturing defects within 10,000 years. This small number of package failures probably would result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197).

7.3 (8197)
Comment - EIS000817 / 0091
To predict that the containers will last 10,000 years is absolute folly in my opinion. To expect one container to fail in 1000 years is more folly. The fabrication of storage casks so far has been a disaster, and with so many new designs coming up, and new fabricators and inexperienced subcontractors -- expect a lot less than perfection in QA, fabrication, materials, inspections. As more and more casks are needed by commercial reactors, and the need is to get them "fabricated yesterday" as pools are filling rapidly -- expect more of the likes of March Metalfab -- where some weld repairs were not even documented! (People have been forbidden from this work as punishment for NRC [Nuclear Regulatory Commission] violations.) And even the NRC, in licensing the certificates for more and more casks, is making a huge mistake in "generic" rulemaking and handing out exemptions, as far as I can see it.

Response
The experiments and analyses documented in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000) provide the basis for the waste package modeling and life expectancies. This report identifies and discusses each potential waste package degradation mode. The degradation model includes those modes that analyses did not screen out as highly improbable.

The longevity of the waste package is a principal factor in the isolation of waste in the repository. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). However, the updated analysis in the Final EIS projects the probability that a number

of waste packages would fail due to manufacturing defects. The probability of failure of waste packages is provided in Table I-3.

Obviously, there is uncertainty associated with the extrapolation of experimental results for such long periods and the other "human factors" mentioned in the comment. DOE selected the design analyzed in the Final EIS to mitigate the uncertainties by adding features (such as the drip shield) to provide defense-in-depth. This provides greater assurance that the repository would meet its performance standards in the face of uncertainty.

7.3 (8200)
Comment - EIS000817 / 0093
You know for Mr. Van Luik to say "In some sense, it's science fiction to project out 300,000 years," is right -- it is science fiction. For him to say then, "Absolutely nobody is going to get hurt by this repository for hundreds of thousands of years," implies that then somebody will -- this is all fiction too -- it may happen long before then.

Response
The quotations cited in the comment were part of a discussion of how uncertainties spread and grow with time because there is no sure way to forecast the future. However, the second quotation is a judgement made by a DOE employee in the face of that uncertainty. In other words, as time projections move farther away it is less likely that they are reliable, but we have greater confidence in the first few hundred thousand years, and greater confidence yet in the first 10,000 years.

Uncertainty is a reality when projecting the actions of natural processes in the future. Uncertainties are introduced by the long timeframes involved and by the evolution of natural and human systems over time. In addition, uncertainties remain about the heterogeneous nature of the site and the innate complexity of an engineered system placed within a natural system. However, this does not mean there is an inability to capture the long-term behavior of the system within a distribution of probable outcomes generated through accepted probabilistic analysis techniques that cover a range of potential futures.

In recognition of the complexity of such techniques and what the results mean, and in recognition of the genuine uncertainty in the results, DOE is using several other approaches to build confidence in the overall safety of the system. First and foremost is demonstrating that the mean values of properly conducted probabilistic calculations are realistic or conservative (not optimistic) indicators of likely performance. Next is the demonstration of a margin between these results and the applicable safety standards. Finally, there is a defense-in-depth approach that can include the use of an additional barrier to provide assurance.

DOE is charged with providing a safe facility for disposing of the Nation's spent nuclear fuel and high-level radioactive waste. In the 1980s regulators made special provisions for the irreducible uncertainties that come with evaluating systems over unprecedented periods. Nevertheless, where those uncertainties could bring system safety into question, action must be taken to ensure confidence. DOE must be confident in its ability to ensure safety at Yucca Mountain. Without confidence within DOE, the Secretary will not recommend the Yucca Mountain site to the President. But confidence does not mean the lack of all uncertainty; rather, it means that uncertainties are recognized, evaluated, and in some cases dealt with through taking action to remove or lessen the importance of an uncertain process to potential performance.

7.3 (8206)
Comment - EIS000817 / 0096
P. 3-51 -- Single borehole tests prove nothing -- I wonder how the groundwater path may change over time or the saturation zone level -- you can't take for granted that water flowing out of the repository in the future will do what you expect. What if the tunnels are "washed out" long before you expect?

Response
Single-borehole tests constitute one of many sources of data and information that DOE used to prepare the analyses summarized in this EIS. The reference to single-borehole testing in Section 3.1.4.2.2 includes qualifications of the limitations of such tests, and DOE has used the derived information accordingly.

The future states of the saturated zone system are included in the saturated zone process modeling which supports the total system performance assessment model. Modeling incorporates uncertainty in many aspects of the flow system (including climate change) and makes a number of conservative assumptions (dilution rates, for example) to avoid any chance of underestimating future impacts.

The tunnels in which DOE would emplace the waste are in the unsaturated zone. The long-term geologic record provides nothing to suggest that the tunnels would wash out during the life of the repository.

7.3 (8209)
Comment - EIS001021 / 0003
We are assured the Yucca Mountain waste containers are invulnerable. However, there is abundant evidence of leakage from the current repository casks at nuclear power and weapons plants. Why hasn't this same degree of proposed engineering safety been built into existing facilities?

Response
DOE acknowledges the difficulties in design and implementation of effective quality assurance programs. However, much has been learned over the past decades about the fabrication, installation, and maintenance of components important to nuclear safety.

The longevity of the waste package is a principal factor in the isolation of waste in the repository. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). The updated analysis in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197), which would be due to the probability that a small number of waste packages (between zero and three, and possibly as many as five) would fail due to manufacturing defects. The probability of failure of waste packages due to manufacturing defects is provided in Table I-3.

7.3 (8236)
Comment - 010229 / 0003
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 1earlier 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.

Response
The Final EIS includes analysis of possible early failures brought on by defects in the waste package. The results show a very small but not-zero dose from these failures (see Section 5.4).

The Final EIS contains an analysis of non-nuclear toxic materials based on the new design of the repository and waste packages. The analyses show that even under very conservative and bounding assumptions, toxic materials have no significant impacts during the compliance period. Further details can be found in Sections 5.6 and I.6.

7.3 (8320)
Comment - EIS001160 / 0101
Page 5-38: The entire paragraph for Section 5.5.1 is vague. It doesn't reference what estimates were used to arrive at the calculation. Admittedly, carbon-14 release would in most probability be small, especially after traversing from storage facility to outside air. However, because the data points were not included, even in the appendices, the reviewer cannot ascertain how the conclusions were reached. Any time "average values for stochastic (random) values" are used, it leads the reader to the suspicion that the values were "made up." The 14C existing in the atmosphere is being formed continually as a result of nuclear reactions between atmospheric nitrogen and neutrons from cosmic rays (DOE Radiological Handbook). At the very least, the baseline data used for this computation and the assumptions made should be listed in the appendices for confirmatory purposes.

Response
Section I.7 details the assumptions used to estimate impacts of atmospheric releases provided in Section 5.5.1. The most important factor for estimating impacts is the expected waste package failure rate. To simplify the analysis, DOE used the average values of stochastic distributions to represent the failure rate. Because the impacts would be exceedingly small, DOE believes that using average values was appropriate. In addition, whereas the repository design evaluated in the Draft EIS projected small releases within the 10,000-year compliance period, the enhanced design evaluated in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197), which would be due to a small number of waste package failures (between zero and five packages) due to manufacturing defects. DOE has updated Section 5.5.1 of the EIS to reflect impacts of atmospheric releases resulting from these package failures.

7.3 (8334)
Comment - EIS000817 / 0115
P. 5-3. Why [are]"idealized" packages with "identical contents" evaluated? This is certainly not dealing with reality. And the steady level of radon will produce problems if it escapes into any monitoring enclosure or if some mechanical robotic things don't function right and people have to go in there and fix things to retrieve the waste later on.

Response
The commenter is correct in that different waste packages would have different radionuclide inventories. The assumption of idealized waste packages with identical inventories was necessary because it is not practical to model 12,000 individual waste packages. However, the use of conservative assumptions related to waste package failure and affected inventories provides reasonable expectation that the potential impacts are not underestimated.

If it became necessary to reenter the repository area, radon and heat protection would be provided by forced ventilation. In addition, protection from direct radiation exposure would be provided, where necessary, by shielding and remote operations similar to emplacement operations. As with emplacement activities, equipment breakdown would be an expected occurrence and has been planned for in such a manner as to ensure the safety of repository workers.

7.3 (8335)
Comment - EIS000817 / 0116
P. 5-4. 250 types of DOE fuel? 16 categories? Wow! What a mess of different materials all together when they degrade. I don't see how you can evaluate possible interactions of materials for all this in the big "radioactive soup" of Yucca Mountain at the point all the casks degrade and get wet. Seems impossible. Too big a risk to take.

Response
To allow for a practical long-term performance assessment of a complex system such as the proposed repository, certain simplifying assumptions must be made. DOE recognizes that these simplifying assumptions introduce uncertainties into the final result. These uncertainties are minimized to the extent possible by use of conservative assumptions, where appropriate, to provide reasonable expectation that potential impacts are not underestimated.

DOE confidence in the disposal techniques is based on defense-in-depth that, for example, places drip shields over waste packages to account for uncertainties. DOE has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components.

DOE believes this process results in a representative estimation of impacts that is sufficient for comparing the relative merits of the various repository scenarios. DOE continues to evaluate the sufficiency of its approach to dealing with uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

7.3 (8336)
Comment - EIS000817 / 0118
P. 5-5. You say the material "screening process" considered total inventory, solubility of the material in water, and chemical toxicity -- but all these materials -- under heat, pressure, and radiation -- could form new materials, couldn't they? And don't count on water to dilute things. Could water make some reactions worse? How do concrete binders and conditioners react with material in degraded BPRAs [burnable poison rod assemblies], for example? You say DOE "selected" chromium, molybdenum, and uranium for detailed assessments. Why wasn't every material possibly created in there given a detailed assessment? The biggest mistake NRC [Nuclear Regulatory Commission] made in certifying the VSC-24 [Ventilated Storage Cask, Model 24] cask was that neither NRC, the vendor, or the utility looked at possible material interactions during all handling procedures -- and the casks' effect on pool water as well as the pool water's effect on the cask! Presto -- an explosion at Pt. Black in Wisconsin that nobody -- nobody expected. So don't expect me to be satisfied with your "selecting" certain materials to look at for detailed interactions. Looks like alloy-22 may not be the answer for a waste container material if it's going to cause many problems when casks finally fall apart and get into the water.

Response
DOE cataloged all materials in the repository (see Draft EIS Table I-10). DOE did not arbitrarily "select" a few materials but rather used the screening process that consisted of a very conservative process to determine which materials could present higher than insignificant impacts (Draft EIS, Section I.3.2.3). These materials were then subjected to a full transport analysis using the same mitigating processes as for the radionuclide analysis (Draft EIS, Section I.6). The starting list was developed in terms of chemical elements (1) because all materials of concern are inorganic and (2) because they are then free to form any species (again a conservative approach). The elements would retain their identity (there would be no significant transmutation effects other than decay in these waste materials). The only new materials formed would be various inorganic oxides, chlorides, carbonates, etc. The main concern would be the dissolved ionic forms (such as Cr+6).

This comment asserts that DOE cannot rely on water for dilution. The Department maintains that, in this system where concentrations are generally small and water is abundant in the saturated zone, such reliance is reasonable. The anecdote concerning a cask does not seem to bear any analogy to the chemical transport concern that this comment addresses.

In the Final EIS the original screening analysis has been replaced by a somewhat different one, but the specific materials emerging are the same. An analysis of the remaining materials continues to indicate that no impacts of concern would be likely. This is due largely to the drip shields and other new design features that greatly curtail corrosion of chromium-, molybdenum-, and vanadium-bearing materials.

7.3 (8337)
Comment - EIS000817 / 0119
P. 5-6. Are you sure about trapped gases? Zircaloy can create hydrogen, can't it? Under what conditions? Remember the bubble at Three Mile Island? What caused it? Do we even know really? Or do we know the makeup of the mess left at Chernobyl? Really, do we know the content and interactions there?

Response
Zircaloy can evolve hydrogen gas through chemical reactions with water at very high temperatures. These are the types of temperatures that can occur under severe accident conditions at nuclear reactors (for example, Three Mile Island and Chernobyl). At repository temperatures, however, Zircaloy could not evolve hydrogen gas.

7.3 (8339)
Comment - EIS000817 / 0120
P. 5-7. Water and the waste package = what? You worry most about drips from above. -- But -- be creative. -- What else could water do in there? Could it actually condense on the surface of the cask under certain conditions? Especially as the thermal load becomes less over time? Could it collect on the stands holding the casks and form rust there? Think of your water heater in your basement on bricks -- the plumbers always put it on something to let air circulate beneath the bottom surface in moist basements and where does the hot water heater rust and leak? On the bottom where its surface is on the bricks most likely, right? Or could water collect on the floor of the tunnels -- run in there from fracture paths? Could the drift liner actually be a hindrance by causing moisture to collect on its outer surface or on its inner surface? Could the drift liner crack and let water come in there? Could the drip shield crack if rocks fall on it, and actually exacerbate corrosion by causing water to drip on one area of the cask a great deal by being sort of funneled to the lowest point of the drip shield? -- What could end up focusing a water drip, or a water collection, on one specific area of the cask, causing a hole to form or exacerbate degradation? All sorts of things could happen -- a chip or dent or uneven surface causes water to collect. -- Look at your concrete driveway. -- The pits are the low points and that's where cracks start too. With nobody to check the concrete or the metal as they do at ISFSIs [independent spent fuel storage installations] at reactors, things will just get worse over time if a cask or drift wall has a fabrication defect or is damaged in handling.

Response
In the analyses for the Final EIS, DOE formally documented a screening process for features, events, and processes (DIRS 154365-Freeze, Brodsky, and Swift 2001) that itemizes all known factors that could affect the performance of the repository, from which a determination is made whether to include it or exclude it from the Total System Performance Assessment model used for long-term performance analysis in this EIS. The database discusses each feature, event, and process, along with references to the analysis documenting the screening argument for excluded items or the disposition in the Total System Performance Assessment model for included items. The analysis screens out a factor if it has low probability or low consequence. The issues listed in the comment (condensation, rusting at contact points, rockfall, focused dripping, etc.) are examples of features, events, and processes that DOE has considered in the screening process and, as appropriate, included in the Total System Performance Assessment model.

7.3 (8356)
Comment - EIS000817 / 0123
P. 5-10. Why would the water and gas flow back to the repository? What else could happen here? Temperature and pressure effects on water movement [are] of the utmost importance here. As is rock mineral alteration. We need to know the answers here.

Response
As described in Section 3.2 of the *Total System Performance Assessment-Viability Assessment Plan* (DIRS 100319-CRWMS M&O 1996) and referred to in the EIS, moisture in the rocks around the repository could be vaporized by the postemplacement thermal pulse and driven away from the repository. As this vapor moved away from the heating of the repository, it would eventually condense into liquid. Once condensed, some of this water could intercept the repository and some could flow past the repository. During this period, there would be no additional temperature and pressure effects on the water movement, although the temperature of the flowing water would respond to the ambient conditions of the material through which it would flow. In addition, free water moving through the rock and soil above the repository could affect the local geochemistry, to include even localized alteration of minerals. However, mineral alteration in this context would be confined primarily to the minerals exposed on fracture surfaces, with minimal matrix alteration. DOE expects that the products of this mineral alteration would have no significant effect on the performance of the repository.

The EIS incorporates the possible effects of this water on waste package corrosion and other elements of the engineered barrier system. Chapter 5 of the *Total System Performance Assessment - Viability Assessment Plan* (DIRS 100359-CRWMS M&O 1998) describes the possible corrosion reactions due to water entering the repository. No other effects are likely from the movement or presence of this condensed water.

7.3 (8358)
Comment - EIS000817 / 0124
P. 5-13. Vapor processes need a lot of study as does solubility of materials from casks. Why are we dealing with only "pits and patches"? What about cracks? Especially cracks in welds? Could high thermal loads and radiation exacerbate any small crack that was initially acceptable in UT tests [ultrasonic tests]? Could the crack lengthen or deepen or widen? Current UT testing does not do well with (1) cracks in a line but not connected, (2) parallel cracks, (3) radial cracks, (4) the width of cracks, or (5) transverse cracks. Just how will DOE criteria for closure welds on casks deal with this issue? It took something like 9 months for Palisades to find cracks in welds "to be acceptable" after UT tests on the pad on loaded casks. Then NRC [Nuclear Regulatory Commission] allowed licenses to restrict movement temperature to 35º in order to allow larger cracks in the welds to be acceptable. The cask was certified to be able to be moved at 0º. How will DOE deal with such a situation? How will welds be tested? What cracks will DOE find acceptable? How will these cracks act over time under repository conditions?

Response
The *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000) and its supporting Analysis Model Reports document all of the waste package degradation issues. The *General Corrosion and Localized Corrosion of Waste Package Outer Barrier* (DIRS 152097-CRWMS M&O 2000) discusses the patch and pit corrosion of Alloy-22 and determines that Alloy-22 is not susceptible to localized or pitting corrosion. The *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Steel Structural Material* (DIRS 148375-CRWMS M&O 2000) discusses stress corrosion cracking in the Alloy-22 welds and develops a model for calculating waste package failure by stress corrosion cracking. *Analysis of Mechanisms for Early Waste Package Failure* (DIRS 147359-CRWMS M&O 2000) discusses testing for defects and analyzes the mechanisms and probabilities for early waste package failures.

The issues mentioned in the comment, including cracks, are only some of the degradation mechanisms analyzed in these reports. All credible mechanisms are considered. These analyses document the basis for the waste package degradation model that supports the EIS.

This comment is correct in that weld failure could be an important mechanism. DOE recognizes that residual stress in the weld at the time of manufacture, a well-characterized quantity can lead to the first very thin cracks that constitute a waste package failure in the analyses. The remainder of the waste package is still there, of course, for a long time after the first crack penetration in a weld. Two outer lids in the design means two consecutive weld cracks would have to develop before water could contact the inner stainless-steel barrier. In addition, the analysis conservatively assumes no containment credit for the stainless-steel inner liner.

7.3 (8402)
Comment - EIS001606 / 0002
When people speak about the science, you have got two conflicting methods of science currently. One would be called deterministic where people go into the lab and take some water from Yucca Mountain and soil and rocks and do experiments. And the others are the computer model people, and they don't get along too well. And so we have an ongoing problem.

Response
In DOE's view, deterministic and probabilistic methods are complementary, rather than conflicting. Both methods play a role in characterizing the Yucca Mountain site, developing the design, and evaluating the safety of the proposed repository. The OECD Nuclear Energy Agency describes the roles, differences and commonalties of these methods in "Lessons Learnt From Ten Performance Assessment Studies" (DIRS 103445-OECD 1997).

Laboratory and field experiments are obviously limited to specific sample sizes, volumes, and locations. DOE has adopted a probabilistic performance assessment method that accounts not only for the spatial and temporal variability and uncertainty in the properties of system components, but also limits to our knowledge and information, unpredictability of some phenomena, and low-probability events. The method is widely accepted nationally and internationally. It is based on recommendations of the National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission. It provides an overall estimate of repository performance for comparison to performance measures specified in 40 CFR Part 197 and 10 CFR Part 63. It conforms to international practices in other countries, including Member States of the OECD Nuclear Energy

Agency and the United Nations International Atomic Energy Agency. Peer review groups with expertise in the analysis of environmental risks have endorsed it.

7.3 (8407)
Comment - EIS000817 / 0125
P. 5-13. I find the reference to colloids interesting, for I was reading about colloid transport in a book recently concerning PCB [polychlorinated biphenyl] transport. It also referred to radionuclides moving faster than expected when they attached to colloids.

Response
DOE recognizes that some radionuclides (for example, plutonium and americium) are subject to colloidal transport. Sections I.2.6, I.2.7, and I.2.8 of the Final EIS and their referenced sources describe the colloidal transport in the Total System Performance Assessment model used to generate the estimates of long-term environmental impacts. Through cooperation with other DOE scientific programs, substantial knowledge and experience have been gained recently in modeling colloidal radionuclide transport in the repository environment. The Final EIS includes updated results based the improvements in colloidal transport modeling techniques gained through these efforts.

7.3 (8413)
Comment - EIS000817 / 0127
P. 5-14. You say the dilution factor was "recommended in an expert elicitation exercise" -- What? This is curious. Please explain. Is this all based on a recommendation by one person on his so-called "expert opinion"? Why?

Response
The expert elicitation process assesses uncertainties in processes where data are not readily available or are obtainable only through an unreasonably large commitment of resources. Such an assessment enables analysts to determine the range of possible values for parameters that pertain to the processes, and to sample this range of values for modeling purposes. For example, measuring corrosion of waste package materials under real-time repository conditions would take tens of thousands of years or longer. Therefore, DOE began testing of materials under artificially accelerated conditions. For the purposes of the Viability Assessment and the Draft EIS, DOE also convened a panel of corrosion experts to estimate the range of expected values for parameters used to calculate the resulting range of corrosion rates. Similarly, expert elicitation resulted in a range of dilution factors for the saturated zone modeling. The *Viability Assessment of a Repository at Yucca Mountain* contains details of this expert elicitation (DIRS 101779-DOE 1998).

The process does not rely on a single expert. In the instance mentioned in this comment related to dilution factors, five panelists participated in a 3-day meeting, as documented in CRWMS M&O (DIRS 100353-1998). DOE prefers, however, to obtain data through experiment and field-testing wherever possible. Therefore, the modeling reported in the Final EIS has been updated. The corrosion model is now based on the results of the second year of accelerated corrosion testing. The saturated zone dilution factor, although it has changed little from the expert elicitation value, is now based on data obtained through the Nye County saturated zone drilling program coupled with updated regional and local modeling of the saturated zone.

7.3 (8462)
Comment - EIS000817 / 0138
P. 5-39 -- Alloy-22 needs questioning if it provides 70% of chromium. What else could be used? You don't even know the hexavalent chromium oral route exposure carcinogenicity now.

Response
DOE agrees that oral-route carcinogenicity for chromium is not well known. Because the carcinogenicity of chromium in water has not been established, the Environmental Protection Agency drinking water recommendations are based on the measured occurrence of elements such as chromium in public water supplies. It is these standards for public water supplies to which EIS chromium concentrations are compared.

In the updated design in the Final EIS there is quite a bit more Alloy-22 and much of it is exposed on the outside of the waste package and supports. However, because of the presence of the drip shields (made from titanium) water would not conduct much of the chromium-bearing material during the first 10,000 years after closure. Thus, during

this period, the most important mechanisms for mobilization of the chromium would be the very slow humid-air corrosion of the exposed surfaces (under the drip shields) and diffusive transport of dissolved materials to the unsaturated zone. To evaluate the potential outcome of these processes, a conservative calculation was made assuming that all the exposed chromium material would corrode at the humid-air rate and immediately dissolve in the unsaturated zone water. All of this material would then be diluted in the standard average uptake in the well at approximately 18 kilometers (11 miles). The result shows concentrations would be well below the Maximum Contaminant Level Goal for chromium (40 CFR 141.51). Because of the conservative nature of these calculations, DOE believes that actual concentrations could be much smaller.

7.3 (8463)
Comment - EIS000817 / 0139
P. 5-45. You cannot predict rock size in falls -- nor where they will hit the cask -- or if that part of the cask is already corroded by drips, etc.

Response
The Drift Degradation Analysis (DIRS 119414-CRWMS M&O 2000) and the Engineered Barrier System Degradation, Flow, and Transport Process Model Report (DIRS 151804-CRWMS M&O 2000) documents the rockfall analysis. Based on the rock stresses in the mountain, the drift orientation, the rock fractures, and rock heating and cooling, a model was developed to predict in a statistical sense the probability of a rock of a particular size falling on a waste package. The maximum credible rock would be 13 metric tons (14 tons). For 10,000 years or more, the waste package would withstand that size rockfall without damage. A drip shield over the waste package would also withstand the rockfall. The drip shield and waste package combination would make a very robust design that could withstand the rockfall. Even though the waste package is designed to withstand rockfall for times exceeding 10,000 years, the model for cladding failure allows cladding to fail due to ground motion before the waste container fails. Thus, the effects of seismic events are incorporated in the impacts reported in Chapter 5.

No one can predict exactly what rock could fall or how big it would be. However, the analysis does show that the rocks would be small enough so that the waste package would not be breached from a rock fall. By the time the waste package would have thinned to the point where it could be breached, it would have already corroded through and been considered failed in the analysis. For this reason, the effects of rockfall on the waste package are not a part of the long-term performance analysis in the Final EIS. The previously mentioned analysis showed the effects on system performance would not be significant.

7.3 (8557)
Comment - EIS000817 / 0169
P. 9-13 Barriers: I'm very interested in the ceramic coating idea, but [it] seems to me any rock fall could crack it and exacerbate corrosion in the crack then. Drip shields could get dented by rock fall, form a "funnel type" area where water collects, and also exacerbate corrosion by ending up directing more water on one area of the cask. Could backfill provide a pathway for moisture to the casks, and prevent ventilation from evaporating moisture collecting on the casks and stands?

Response
Ceramic coatings on the waste package or drip shield are not a part of the current design. If it became part of the design, DOE would carefully consider the effect of rockfall and other requirements.

Analyses documented in the Waste Package Degradation Process Model Report (DIRS 138396-CRWMS M&O 2000) show that rockfall has an insignificant effect on either the drip shield or the waste package. For 10,000 years or more, both the drip shield and the waste package would be strong enough to withstand the forces of 13 metric tons (14 tons) of rock falling on them, which is the largest credible rockfall. Therefore, the effects of rockfall on the waste package or drip shield would be insignificant and are excluded from the Total System Performance Assessment model. Even though the waste package is designed to withstand rockfall for times exceeding 10,000 years, the model for cladding failure allows cladding to fail due to ground motion before the waste container fails. Thus, the effects of seismic events are incorporated in the impacts reported in Chapter 5.

Backfill is not a part of the current repository design. It was removed from the design because its water-diverting function was not important to the longevity of the newer waste package design, and also because its thermal

insulation properties, as if it were a blanket, would lead to higher than desirable waste package internal temperatures.

7.3 (8558)
Comment - EIS000817 / 0170
"Richards Barrier"? I'm thinking of how we tried to preserve our garden carrots in sand in a container this year -- didn't work. The sand may delay moisture reaching the package, but it could also be saturated and actually collect moisture and hold it close to the cask surface, not allowing it to dry out at all. "Diffusion barrier," if saturated before expected, would also possibly bring water closer to the bottom of the cask and hold it there rather than letting the cask dry out and remain above the emplacement drift and above seepage flow on the bottom floor. You seem to be torn between ventilation keeping the cask dry and "smothering" the cask with some material to keep water away from it. You can't have both. Either air dry it or encase it, but make sure you have good reasons why.

Response
A Richard's Barrier is a system of two layers of material, a finer one over a coarser one. Testing under many conditions has shown that this barrier can be effective in diverting water because water, unless it is saturating all pores, tends to stay in the finer grade material. It is an important design component in earthfill dams.

As the comment suggests, there are other considerations in the selection of a design and its features. In DOE's evaluations of design options, a Richard's Barrier was included and tested among a number of designs and features. The current design does not include either a backfill or a Richard's Barrier, however. Section 2.1.2.4 summarizes the reasons for the selection of the design and its features.

The invert material would be crushed tuff, the volcanic rock of the repository site. Although there could be substantial water content in the invert as the repository cools, the waste package would begin to corrode as soon as the relative humidity exceeded the threshold relative humidity (50 to 80 percent, depending on the temperature). This would occur before the invert became nearly saturated as the comment suggests it might. Testing and analyses suggest that Alloy-22, the material for the outer barrier of the waste package, would not be susceptible to localized corrosion at contacts with the invert even if it has a high water content.

Ventilation would keep the waste packages dry and the relative humidity low to prevent corrosion before closure. The corrosion models account for the effect of moisture, vapor and liquid, after closure.

7.3 (8560)
Comment - EIS000817 / 0171
The idea of putting spent fuel in canisters first before [putting it] in the casks is an idea, but sounds costly and certainly not "space saving." Adds another containment to corrode through and sounds like a good idea to me. The more full containment barriers, the better, as far as I'm concerned -- for if the welds "go" on one, at least there is another beneath it. All these fillers and barriers have spaces between the particles for water to collect, so I distrust any of them really. They may backfire in your expectations.

Response
The comment contains important insights that have been considered in the formulation of the design reported in the Final EIS. For example, there would be two sequential outer lids and seals rather than one. The potential for crevice corrosion in the gap between the inner and outer layers, as mentioned in this comment, is one reason for using corrosion-resistant Alloy-22 as the outer layer of the waste package and stainless steel for the inner layer. This combination of metals would not be susceptible to enhanced corrosion even if water entered the inevitable thin cracks between the two metals.

The long-term performance analysis for this EIS conservatively neglected the potential benefit of stainless steel, which is the inner barrier of the waste package, and thus neglects the potential delay to water entering a waste package provided by this barrier. Its function is to provide structural strength for handling and emplacement of the waste packages.

Approximately 99 percent of the commercial spent nuclear fuel would have Zircaloy cladding to help protect it. The remainder of the commercial spent nuclear fuel either has stainless-steel cladding or developed perforations while in

the reactor. The high-level radioactive waste (in a glass matrix) would be in a stainless-steel canister. This canister would then be inserted into the waste package and would be in contact with its inner barrier of stainless steel. Having the same metals inside each other minimizes the likelihood of crevice corrosion as water enters the cracks between the two metals. But in any event, the canister is not modeled as a barrier either, for the sake of conservatism. In addition, a drip shield over the waste packages would give further assurance that water would not contact the waste for a long time.

7.3 (8563)
Comment - EIS000817 / 0172
"Getters" could hold water too, couldn't they? I don't know about iron oxides or aluminum in the waste packages. If you ever had to retrieve the fuel -- this could create a real mess in getting assemblies out of a package. And if a canister breached long before expected -- (say a cave-in in the ceiling for some reason) -- could the filler exacerbate corrosion if air and water get in the cask?

Response
Certain design conceptualizations for waste disposal call for the use of various materials with a propensity to sorb radionuclides in waste packages, in backfill materials mixed with the invert material in drifts to support the waste packages, or as part of the properties of the tuffaceous rock around and beneath the repository. However, the repository design used in the EIS does not use or take credit for "getters," as sorbing materials are sometimes called, in the waste package. Although some arguments support the concept that some waste and waste package degradation products might have sorptive properties, there is no credit for these phenomena in the performance assessment model. Although some sorbing materials could retain water and complicate the analysis of corrosion in the waste packages, the overall effect of the use of sorbing materials in the performance assessment would be to make the performance assessment model less conservative. Thus, the present model and design are conservative with respect to sorption processes in and around the waste packages, although some credit can be and is taken for sorbing properties of the invert material in certain design conceptualizations of the engineered barrier system.

7.3 (8874)
Comment - EIS002086 / 0003
Although the EIS document reflects the examination of the analytical structure, accumulative impact evaluations, and substantiates various scientific testing, various impact scenarios, etc., etc., for up to ten thousand years, the secondary impacts have not been considered and the effects it will have on the environment, especially water. And David Chavez spoke of some of the effects and some of the concerns that he has for his tribe. The Colorado River Indian Tribes' livelihood is based upon its economic base, agriculture, and water is very sacred.

Response
DOE has conducted an extensive site characterization program, including a study of groundwater flow in the region around Yucca Mountain (See Section 3.1.4 of the EIS). The proposed repository would be in a closed hydrologic basin from which surface water and groundwater leaves only by evaporation from the soil and transpiration from plants. Based on the evaluations described in Sections 4.1.3 and 5.4, DOE does not believe that the watershed of the Colorado River is at risk from contamination from the repository. As a consequence, there would be no impacts on agricultural or economic resources in the Colorado River basin.

7.3 (8904)
Comment - EIS000869 / 0032
Groundwater contamination at the site could have devastating ramifications for the livestock and agricultural communities surrounding the area, specifically the Amargosa Valley.

Response
This comment raises a concern for the well being of the people and livestock of agricultural communities, specifically Amargosa Valley, the closest population center to the proposed Yucca Mountain repository. Amargosa Valley is most at risk because the water in the saturated zone beneath Yucca Mountain flows in a generally southerly direction.

The EIS examines the potential consequences to individuals in the Amargosa Valley from both radioactive and nonradioactive contaminants transported through air, water, soil, and food chains. Figure 3-75 of Volume 3 of the

Viability Assessment of a Repository at Yucca Mountain (DIRS 101779-DOE 1998) illustrates the pathways incorporated into the biosphere analyses; farming and agriculture practices are included.

The Viability Assessment (DIRS 101779-DOE 1998) describes a 1997 survey that permits an accurate representation of agricultural practices within the 80-kilometer (50-mile) radiological monitoring grid surrounding Yucca Mountain:

"Amargosa Valley is primarily rural agrarian. Agriculture is mainly directed toward growing livestock feed, for example, alfalfa; however, gardening and animal husbandry are common. Water for household uses, agriculture, horticulture, and animal husbandry is primarily acquired from local wells. Although sparsely populated, the Amargosa Valley region does support a population of 1,270 in approximately 450 households. Commercial agriculture in the Amargosa Valley farming triangle area includes a relatively large dairy that operates with approximately 4,500 milk cows and employs approximately 50 people, a garlic farm that produces about 2,000 pounds of garlic per year, and a catfish farm that sustains approximately 15,000 catfish. The area contains approximately 1,800 acres planted in alfalfa, 30 acres in oats, 80 acres in pistachios, and 10 acres in grapes." (DIRS 101779-DOE 1998).

Table 3-25 of that document specifies the consumption rates of drinking water and agricultural products, estimated from the results of the survey and used in the biosphere model. Hence, there is a defensible and traceable basis for addressing potential impacts to Amargosa Valley. Section 5.10 of the EIS describes the long-term environmental consequences of the proposed repository on the people of Amargosa Valley.

7.3 (9028)
Comment - EIS001204 / 0005
The casks would corrode and even before that, would emit great heat and radiation, rendering the place toxic. It would remain so until the year 207,000.

Response
The longevity of the waste package is a principal factor in the isolation of waste in the repository. The evaluation of alternative waste package designs presents a sound technical basis for likely projected lifetimes beyond 10,000 years for the reference dual-shell design under a range of thermal, geochemical, hydrological, and radiological conditions. This container would consist of a thick inner shell of stainless steel and a thick corrosion-resistant outer shell of a high-nickel alloy (Alloy-22). However, the updated analysis in the Final EIS projects between zero and five packages failing due to manufacturing defects.

Before recommendation of the Yucca Mountain site for development as a geologic repository, DOE will have to provide a reasonable expectation that the repository would meet Environmental Protection Agency standards (40 CFR Part 197) to protect human health and the environment. Compliance with these standards will ensure that concentrations of toxic materials would be such that the occurrence of adverse health effect would be highly unlikely for all potentially exposed populations in the region of influence.

7.3 (9038)
Comment - EIS000817 / 0117
P. 5-5. I think your theory that all these gases formed will decay, before canisters fail, is totally wrong.

Response
The wastes that would be disposed in the proposed Yucca Mountain Repository contain some radionuclides in gaseous form. However, the half-lives of most of these radionuclides are short (on the order of a few hundred years) compared to the waste package lifetimes (thousands of years). Thus, most gaseous radionuclides, except carbon-14, would have decayed away prior to breach of the waste packages. Section 5.5 of the EIS describes the impacts of carbon-14 releases.

The final EIS also considers (see section I.7.3) the gas radon-222 that is formed as part of the radionuclide decay chain resulting from emplacing uranium-234 in the repository. This gas is expected to decay before reaching the ground surface because it has a half-life of about 3.8 days.

7.3 (9150)
Comment - 010447 / 0001
I am most doubtful that the Yucca Mountain Project is based on sound science and undisputed facts establishing long-term safety and stability of nuclear waste deposited there.

First, the region is suspected to be seismically active.
In addition, water flows beneath the mountain, so it could infiltrate the waste containers, corrode them and carry radioactive waste into the groundwater.

Response
As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring seismic activity and studying the geologic structure at and near Yucca Mountain since 1978. Using the results of these and other studies conducted in the region, along with input from panels of recognized experts on seismic risks and hazards, surface facilities at the repository would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of once in 10,000 years. This is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

The 1992 earthquake at Little Skull Mountain 20 kilometers (12 miles) southeast of Yucca Mountain was the largest recorded earthquake within 50 kilometers (31 miles) of the proposed site of the repository. This earthquake, with a Richter magnitude of 5.6, did not damage facilities or structures at Yucca Mountain. It did, however, cause about $100,000 damage to buildings at the Field Operations Center in Jackass Flats about 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility). These buildings were not constructed to the seismic design specifications that would be used for surface facilities at Yucca Mountain.

The State of Nevada ranks third, behind Alaska and California, in seismic activity. Nevada's reputation as a seismically active state comes from major historic earthquakes in western and central Nevada with magnitudes of 7 or more on the Richter scale. This seismic belt may be an extension into Nevada of the Death Valley-Furnace Creek fault system in southeastern California. The average frequency of earthquakes of magnitude 6.0 to 6.9 in western Nevada has been about one every 10 years; earthquakes of magnitude 7 and greater average about one every 27 years. Yucca Mountain does not lie within this highly active seismic belt. Nevertheless, DOE estimated the impacts from extremely large and unlikely seismic events ("beyond design-basis") that could cause the waste-handling building to collapse and damage the pressurized-water reactor fuel assemblies. DOE concluded that the impacts from such an extreme event would be small because of the physical form of the fuel assemblies, protection by the building rubble, and the long distance to the nearest population.

As described in Chapter 5 of the EIS, during the first 10,000 years after closure of the repository, earthquake-induced shaking could dislodge rocks from the roof of the emplacement drifts. The likelihood of falling rocks splitting open a waste package is essentially zero because waste packages would be protected by titanium drip shields. Even if a drip shield were ruptured by falling rocks, the force and impact would be absorbed by the drip shield and not transferred completely to the waste package. Furthermore, the metal walls of the waste package itself would be designed to withstand the impact from falling rocks.

Based on the results of analyses reported in Chapter 5 of the EIS, DOE believes that a repository at Yucca Mountain would have negligible short and long-term environmental impacts. DOE recognizes that some radionuclides and potentially toxic chemicals would eventually enter the environment outside the repository. Modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers would keep the release of radioactive materials during the first 10,000 years after closure to very small amounts that would be well within the regulatory limits established by 40 CFR Part 197.

DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. Section 5.2.4 of the EIS describes how DOE dealt with these uncertainties. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Nuclear Regulatory Commission indicates that absolute proof is not to be had in the ordinary sense of the word (see

10 CFR Part 63), and the Environmental Protection Agency finds that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance (see 40 CFR Part 197).

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to assessing the long-term performance of the repository addresses and compensates for important uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.3 (9200)
Comment - EIS002111 / 0001
I'd like to show noncompliance and what should be further research with Yucca Mountain. Number one. Yucca Mountain did not comply with all appropriate regulation Section 40 CFR of -- because of generation of hazardous waste. Due to the corrosion, we're going to have three processes. One, it's generation of heavy metal plume; second, followed by radionuclide; and third is production of mixed waste of heavy metals and radionuclides presume.

Part of the page 528 is there is uncertainty in the EIS which claim the corrosion rate can be very high and very much expectable if this is the correct curve. There are two tables, 5-1 and 5-2, which listed the concentration of heavy metals and activity of radionuclide, and the way I can see it is the least -- no, the worst scenario showing in the risk assessment. The USEPA [Environmental Protection Agency] has a guidelines for complex mixtures, just the complex mixtures, and I listed one, two, three, four, and the latest one is there's a guidelines which addresses the future issue. DOE does not have an official procedure conducted risk assessment or complex mixtures.

There is only very limited information in the literature regarding what is complex mixture, and I'll just elaborate it. One is a Russian work, which was exposure threat to strontium and cesium and they show there was an interaction synergism. The second I presented a paper in 1994 that on heavy metals would show a synergistic effect, the problem which we have associated with risk assessment. Number one, there is no data provided for each if they are alone. Then we don't discuss what happened. Heavy metal would be probably more toxic, radionuclide will generate free radical byproduct to the immune system. There is noncompliance with EPA assessment guidelines for complex mixtures. One is important because if you're taking -- let's assume a 10 to minus EPA for chromium or whatever -- I'm not using this exact -- complex mixture can pose 10 to the minus 3 to 10 to the minus 2 cancer risk.

Response
DOE agrees that there is a likelihood that trace amounts of radionuclides as well as other metals dissolved from waste packages and their inner structural materials could appear in groundwater at some time in the future. The Department also agrees that there is merit in obtaining additional information on whether or not dilute mixtures represent an enhanced – or in some cases perhaps a reduced – risk because of potential negative or positive synergistic effects on toxicity from the presence of multiple metals and radioactive species. The Department feels, however, that this is a basic research issue for those charged with the responsibility for setting environmental protection standards. It is not specific to Yucca Mountain, but could apply as well to any other government, industrial, or natural setting where there are metallic or radioactive elements potentially going into solution that could reach the local water table. Therefore, it is not DOE's responsibility to sponsor research under the Yucca Mountain Project.

7.3 (9382)
Comment - EIS001888 / 0087
In discussing the effect of chemically toxic materials, DOE made the statement that organic materials (additions to the concrete) "could break down completely in response to exposure to high radiation fields for 100 years or more before closure." Does this mean that all of the repository will be open for a minimum of 100 years. In addition if there are high radiation fields, why is radiolysis ignored in the performance assessment calculations?

Response
The updated repository design discussed in the Final EIS does not employ the use of concrete liners. The modeling of the corrosion of waste package materials and other barriers qualitatively included the radiolysis processes. Radiolysis can be estimated through the use of reasonable assumptions about acid formation in nearby water, the primary mechanism for radiolytic influence on corrosion. The natural environment has a minor contribution. Alloy-22 was selected as a container material because it is corrosion-resistant in the ranges of alkaline as well as acidic environments likely inside Yucca Mountain.

Federal regulations (10 CFR Part 63) require that the repository be designed to preserve the option of waste retrieval on a reasonable schedule for as long as 50 years after the start of waste emplacement. Consistent with these requirements, the operational plan for the Yucca Mountain Repository provides for a design and management approach that isolates wastes from the public in the future while allowing flexibility to preserve options for modifying emplacement and retrieving waste. This design would maintain the ability to retrieve emplaced materials for at least 100 years and possibly more than 300 years in the event of a decision to retrieve the waste, either to protect the public health and safety or the environment, or to recover resources from spent nuclear fuel.

7.3 (9392)
Comment - EIS001888 / 0097
The VA [Viability Assessment] waste-package design is not an effective defense-in-depth design. Design options such as use of drip shields that were considered in the VA but not used in the TSPA-VA [Total System Performance Assessment-Viability Assessment] design have potential to significantly improve repository system performance.

Response
After further analysis, DOE came to similar conclusions. The revised design analyzed in the Final EIS includes a drip shield to provide defense-in-depth. The drip shield would be titanium alloy, a different material from those DOE would use in the waste package. Titanium would degrade by different mechanisms and would respond differently to the chemical environment, so it would degrade and fail by different processes from the waste package. Furthermore, the drip shield would provide additional protection of the waste package from rockfall damage.

7.3 (9709)
Comment - EIS002154 / 0006
Now if it contaminates the water, because they're going to have to use water to cool it. When that water drips down into the water system, then the lower part of your body is going to be involved in it. I mean, what kind of thinking is this? Do they have to have it all in one place? That's ridiculous.

Response
The proposed nuclear waste repository at Yucca Mountain is designed to permanently store commercial spent nuclear fuel and high-level radioactive waste. The repository would be constructed in the unsaturated zone several hundred feet above the zone containing groundwater aquifers. The repository is designed such that the configuration of waste packages and underground storage tunnels would naturally distribute the heat load and produce only a minimum heat stress to the surrounding rocks and adjacent waste packages. No water would be used to cool the repository.

Chapter 5 of the EIS points out that if and when waste packages fail, the release of radionuclides to the unsaturated zone and subsequently to groundwater would occur well after the repository had cooled, and would proceed at a very slow rate. Chapter 5 and Appendix I present calculations that show the possible dose to receptors in the Amargosa Valley at several distances from the repository. The calculations show that the dose to the population would present very small risks to human health.

7.3 (9809)
Comment - EIS002070 / 0004
DOE claims to be using "sound science and engineering," e.g. considerable commercial nuclear fuel is having burnups of, e.g., 47,000 MW[megawatt]-days per Metric Ton Uranium, but the key assumption is for much less on average (see p. A-14, Table A-5. ("averages" at 39,560 (PWR [pressurized-water reactor]) and 32,240 (BWR [boiling-water reactor]) Where does the "average" come from????

Oops, your site won't let me retrace my steps through the files so I can't give page number references, but under the spent fuel, TRW report dated (1998), See Appendix A, page A-14 Table 5, reference "a") lists key assumptions including number 039, that concern for criticality control extends beyond 10,000 years" which is appropriate in light of chain reactions in natural uranium ores, the clear infiltration of water into the proposed (politically selected) site as shown by the presence of Chlorine-36, e.g., deep in the proposed site, and the greater enrichment of, and presence of plutonium (fewer delayed neutrons from fission) in "spent" nuclear reactor fuel.

Yet only 10,000 years is selected. Why, when that very page notes a requirement to consider impacts beyond 10,000 years. Certainly the uranium [U], half life over 500 million years for U-235, 4.6 billion years for U-239, and even for Pu-239 [plutonium-239], about 24,000 years, shows that criticality will be of concern for far more than 10,000 years. NCCRG (North Carolina Citizens Research Group] also notes the huge number of assumptions in the "engineering update to EIS file" 3/99 (DOE website on Yucca [Mountain] DEIS), e.g. Section 2.1.1; yet many of these assumptions maybe very difficult to achieve in practice and thus are far from suitable bases for analysis in an EIS or elsewhere. For example, it is assumed that spent fuel is vertically loaded into a container free of liquids, but in practice loading commercial reactor "spent" fuel into a cask almost always leaves some liquid because the loading is done under water. Where is your analysis of how this can be avoided? This is a key issue because water is not only able to facilitate corrosion in many ways, but it also transfers heat well, can provide oxygen to react with zirconium fuel cladding, hydrogen by dissociation (or by Zr-H2O [zirconium-water] reaction) AND provides a means of transport for fission products, uranium and/or TRU [transuranic] elements, and corrosion products of all kinds. Also water turned to steam builds up pressure which can exploit leaks, force liquids and/or gases through cracks, create gaps through thermal expansion, etc.

Response
DOE obtained the average burnup values listed in Table A-5 of the Draft EIS from the cited reference. DOE analyses included spent nuclear fuel with a wide range of burnups, as discussed in Section I.3.1. DOE updated the inventory projections for the Final EIS.

The criticality analyses in support of the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) summarized in Section 5.2.3.6 of the Draft EIS and Section I.2.12 in the Final EIS considered criticality events occurring beyond 10,000 years. Because the waste packages should remain intact for much longer than 10,000 years, the analyses had to assume that consequences for determining the potential for criticalities after waste package degradation necessarily would occur in the longer periods. The analyses showed negligible possibilities for out-of-package criticalities in those long periods (see Section 5.8 of the Final EIS).

With regard to the assumption that waste packages would be free of liquid, Volume 2, Section 6.2.1, of the Viability Assessment (DIRS 101779-DOE 1998) states that wet fuel would be dried before being placed in the waste packages. In addition, dry handling of spent nuclear fuel is an option in the design of the surface facility. Therefore, the spent nuclear fuel would be free of liquid when placed in the waste packages.

7.3 (9811)
Comment - EIS001888 / 0397
[Clark County summary of comments it has received from the public.]

NPTE leakage in Santa Monica, CA. pertaining to the gas leakage in the water, has affected three states - California, Nevada, and Glendale (OH?) and Washington. This leakage has been since 1989 and they have no way of cleaning it up. It has caused cancer in these states and has affected the water and the air. This is my concern with the Yucca Mountain Project a similar situation could arise here.

Response
The commenter's concern relates to historical industrial leakage situations involving liquids and organic volatiles in comparatively short design-life systems. These events have led to organic compounds leaking into groundwater from underground storage tanks and pipelines. The materials that would be stored at Yucca Mountain would be low-solubility solids, many of which would have limited groundwater mobility and are thus not directly comparable to the situations cited by the commenter. Chapter 5 of the EIS provides information on the potential for long-term impacts of the repository via all applicable pathways, including air and water.

7.3 (9883)
Comment - EIS001888 / 0430
[Clark County summary of comments it has received from the public.]

Design measures to mitigate the effects of events and processes (e.g., loss of water resources from contamination) were also requested. Events and processes identified by commenters included: (1) criticality (different kinds of events, multiple and repeated events, events resulting in explosions, events due to different fuel enrichments and plutonium disposal), (2) extreme seismic activity (resulting in pathways for contaminant release), (3) volcanism (volcanic explosions, consideration of "recent" events at Lathrop Wells cone), (4) tectonic events (crustal faulting), (5) meteorological events, (6) hydrological events, and (7) biological events.

Response
DOE evaluated a wide range of factors as part of the long-term performance analysis to determine if the factors would influence repository performance and should be included in the analysis. All the features, events, and processes listed in the comment were considered. Some were screened out either because of low probability of occurrence or because of low consequence (that is, repository performance would not be affected). The EIS and its supporting documents discuss the screening process.

Section 9.2.10 of the EIS discusses mitigation measures related to the long-term performance of the repository. DOE regulations (10 CFR 1021.331) require preparation of a Mitigation Action Plan when mitigation measures are identified in a Record of Decision. Because DOE does not anticipate issuing a Record of Decision, a Mitigation Action Plan might not be prepared. However, the Yucca Mountain site, if approved consistent with provisions of the Nuclear Waste Policy Act, as amended, would be subject to licensing by the Nuclear Regulatory Commission. DOE, in submitting its application to construct and operate the repository to the Commission, would identify relevant commitments and contingencies, including those identified in the Final EIS, to the Commission for its consideration. DOE reasonably expects a comprehensive set of mitigation measures or conditions of approval to be part of the licensing process.

Design measures discussed in the Final EIS would mitigate some of the effects of various events and processes. DOE has included drip shields and updated the waste package to be more robust and longer-lived. Both of these updates would reduce the overall consequences, based on the involved uncertainties, associated with long-term performance.

7.3 (9886)
Comment - EIS001888 / 0434
[Clark County summary of comments it has received from the public.]

Others requested that the analyses consider gaseous pathways for radionuclide release, mineral deposits formed by thermal fluids, thermal overloading, thermal-induced ecosystem affects, thermal expansion and later subsidence, gaseous flux, groundwater heating, thermally induced fracturing affecting fluid flux, increased erosion due to ground surface denudation, local meteorological effects, the quality of the rock below the repository horizon, and radionuclide transport by mineral colloids.

Response
Section 5.5 of the EIS evaluates gaseous releases.

Mineral deposits formed by thermal fluids are included in the Total System Performance Assessment model used to calculate impacts reported in Chapter 5 of the EIS. Mineral deposits would develop as refluxed water drips through fractures and possibly onto waste packages throughout the boiling period. The effects of the salts formed in this process are included in the waste package degradation process modeling supporting the Total System Performance Assessment model.

What this comment means by the term "thermal overloading" is not sufficiently clear for a response, but DOE has considered the long-term performance assessment for a range of thermal load scenarios in the EIS.

Section 5.9 of the EIS considers thermally induced ecosystem affects.

Thermal expansion and later subsidence was considered in development of the Total System Performance Assessment model. The results can be found in CRWMS M&O (DIRS 153246-2000), as referenced in Appendix I of the EIS.

Gaseous flux was not considered in calculating gaseous releases because the DOE conservatively assumed instant transfer of gas-phase radionuclides to the atmosphere so that the flux to the atmosphere would be equal to the release rate from waste packages as a function of time (see Sections 5.5 and I.7 of the EIS).

Groundwater heating was included in the thermal-hydrologic process modeling supporting the Total System Performance Assessment used to produce results for Chapter 5 of the EIS. An overview of the modeling of these processes is contained in Section I.2.3 with details in referenced documents.

Thermally induced fracturing affecting fluid flux was considered in development of the Total System Performance Assessment model. Changes in fracture permeability around an emplacement drift because of thermal-mechanical effects have been calculated. The effects would be primarily within about two drift diameters of the drifts. Since the drift spacing is much larger (about 15 drift diameters), effects on large-scale flow and transport probably would not be significant. In addition, thermal mechanical effects on drift-scale flow (in particular, on seepage into drifts and radionuclide transport out of drifts) were neglected in the Total System Performance Assessment simulations because they are thought to be of little importance (DIRS 153246-CRWMS M&O 2000).

Colloidal transport of plutonium was modeled for the Draft EIS, and the Final EIS contains an expanded model for colloidal transport that extends to other radionuclides and contains a refined approach to the modeled processes (see Sections I.2.6 through I.2.8).

7.3 (9965)
Comment - EIS002311 / 0001
Section 5.7.3 of the 1999 Draft Environmental Impact Statement (DEIS) for the geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada, was arguably incorrect about the statement "Because the waste package would occupy about 40 percent of the space in a drift, a falling rock would have a 40-percent chance of hitting a waste package," because the statement assumes: 1) that the "space" referred to is an area (as opposed to volume), and 2) the size of the rock.

Response
DOE recognizes that the word "space" could be interpreted as an area or a volume. For the analysis in the Draft EIS, the probability of a falling rock hitting a package was estimated based on the surface area of the packages (footprint) and the cross-sectional area of the falling rock.

For the updated analysis in the Final EIS, DOE used the best available information to develop a model based on the rock stresses in the mountain, the drift orientation, the rock fractures, and rock heating and cooling to predict statistically the probability of a rock of a particular size falling on a waste package (DIRS 119414-CRWMS M&O 2000; DIRS 151804-CRWMS M&O 2000). This analysis determined that it would be highly unlikely for a rock larger than 13 metric tons to fall on a waste package. Thus, the waste package has been designed to withstand that size of rockfall without any damage. In addition, the newer design places a drip shield over the waste package that would withstand the rockfall. The combination makes a very robust design that could withstand the rockfall.

Resistance to rockfall would hold true as long as most waste packages and drip shields retain their initial strength. Results for undisturbed degradation show that nearly all packages would be at design integrity for well over the compliance period of 10,000 years; in fact this holds true for well over 50,000 years. Therefore, the effects of rockfall are not part of the long-term performance analysis calculations for the Final EIS since the Total System Performance Assessment model was originally developed for the compliance period of 10,000 years prescribed in 40 CFR Part 197. In the case of long-term peak doses that would occur at 500,000 years, there could be some seismic effects not accounted for because most packages would have been breached by that time. No analysis is available at this time to determine how much this could affect the peak doses.

7.3 (10432)
Comment - EIS002194 / 0006
What this Department of Energy is doing to us is insane.

I am suffering because of what the Department of Energy is doing. Other people are suffering. Thousands and thousands of people are suffering, and I want you to stop.

Again, I'd like an answer what's going to disqualify it, what's going to disqualify Yucca Mountain, and I want to understand.

I would like for you to justify to me -- I'd really like to hear something about what you think you're doing.

Let me flip through this one more second. Okay. Here we go. On page 67072 [64 *FR* 67072], it says here "with respect to qualifying and disqualifying conditions, DOE believes that it is not reasonable or necessary to maintain these conditions in a proposed new rule."

As I read that, that says that if the DOE says it's not reasonable or necessary to find any conditions which will disqualify Yucca Mountain.

I want to know when we're going to get the mountain back. Okay. I want to know when we're getting that mountain back.

When are you going to fill that tunnel back up, get that huge, ugly, disgusting, gross white boring machine out of there -- and it's boring.

Response
The EIS is only one in a series of documents prepared for the Site Recommendation determination for Yucca Mountain. The President and Congress, if necessary, would make the decision to proceed with the project. The goal of these documents is to provide the best available information as input to that decision.

This comment has extracted a quote from the preamble of DOE's proposed Yucca Mountain Site Suitability Guidelines (64 *FR* 67054, November 30, 1999) implying that DOE is dismissing the use of qualifying conditions in the decision process. A more inclusive quote from the guidelines states:

"With respect to qualifying and disqualifying conditions, DOE believes that it is not reasonable or necessary to maintain these conditions in a proposed new rule. DOE proposes eliminating individual disqualifiers, since maintaining them would mask how the system as an integrated whole would function, and would be inconsistent with the NRC [Nuclear Regulatory Commission] proposal. The only appropriate disqualifier is the applicable public health and safety standard."

The prevailing scientific view is that the most appropriate method for evaluating if a site is suitable for a repository is through a Total System Performance Assessment. Under 10 CFR Part 963, DOE would use this method to evaluate if a repository at the Yucca Mountain site would be likely to meet applicable Nuclear Regulatory Commission regulations and, thus, be suitable for development of a repository.

At the time the rule was proposed, DOE pointed out that it was replacing the use of individual disqualifiers with a site suitability evaluation based on total system performance. This is in keeping with a generally accepted approach that has international endorsement. The long-term performance analysis described in Chapter 5 of the EIS uses the same approach as the Total System Performance Assessment referred to in the quote. The analysis compares the Chapter 5 results to appropriate Environmental Protection Agency and Nuclear Regulatory Commission standards developed in companion rules 40 CFR Part 197 and 10 CFR Part 63, respectively. This type of information will be part of the input to the Secretary of Energy, who is responsible for the Site Recommendation, to the President for his consideration in deciding whether to recommend the site to Congress, and to the Nuclear Regulatory Commission, which would have to decide whether to license a repository at Yucca Mountain if the site was recommended by the President and a recommendation is upheld by Congress.

7.3 (10440)
Comment - EIS002194 / 0014
If you're going to do -- if you're going to only go by TSPA [Total System Performance Assessment], then you guys have to, you know, seriously think about the transportation.

Response
Chapter 6 of the EIS evaluates transportation risks as a separate consideration from the impacts evaluated by the Total System Performance Assessment.

7.3 (10441)
Comment - EIS002194 / 0015
I'd really like to see a response as to what will disqualify Yucca Mountain.

Response
Disqualification of the Yucca Mountain site could result from the inability of DOE to provide a reasonable expectation that the long-term repository performance would meet environmental protection standards promulgated by the Environmental Protection Agency at 40 CFR Part 197 and with Nuclear Regulatory Commission licensing requirements specified in 10 CFR Part 63.

7.3 (10494)
Comment - EIS002211 / 0002
It's axiomatic that the underground hydrogeologic domain is naturally ordered as in the state of variable dynamic flux. You knew that from the beginning.

Over the entire term of the geologic time scale continuum from inception through cessation inclusively, it's moving as we speak. This earth is not a bowling ball. It's not a monolithic solid steel sphere or anything of this sort. There's all kind of stuff under there.

There is more tonnage of bio-organisms within the earth than there is on top of it, on the onion's wafer skin surface. Ask any astronaut. It's public, then.

So our domain is rather irrelevant compared to the much broader underground domain.

You're talking about a safety -- deep hydrologic -- what is deep about something that's a depth of 900 feet along a radius of approximately 4,000 miles?

Can you equate that right away? How about 1/32 of a vis -- it's virtually surface, subsurface underground storage.

It shouldn't be there because if you're putting into directly injecting it into the environment, the ambient environment, you know it's going to end up as human accessible somewhere. Maybe Mesquite, maybe Pahrump, maybe Ash Meadows, maybe Death Valley Junction, maybe Lake Mead. Maybe all of them combined.

It will be in the children's milk and in their ice cream. It's a little worse than arsenic.

Consequently, it's impossible to guarantee the safe, secure and human intrusion impervious underground storage of high-level nuclear waste by any combination of natural and engineered barriers and statistical probabilistic modeling and institutional controls over any substantially enduring term, either at Yucca Mountain, Nevada, elsewhere nationally or anywhere on this particular planet.

Billions to find that out and you are not sure of it yet; is that correct? So put the billions back and go do something else, because you apparently don't know how to do this.

Response

DOE acknowledges that the State of Nevada ranks third, behind Alaska and California, in seismic activity. Nevada's reputation as a seismically active state comes from major historic earthquakes in western and central Nevada with magnitudes of 7 or more on the Richter scale. This seismic belt might be an extension into Nevada of the Death Valley-Furnace Creek fault system in southeastern California. The average frequency of earthquakes of magnitude 7 and greater average is about once every 27 years. Yucca Mountain is not in this highly active seismic belt.

This comment refers to bioorganisms in the Earth. The existence of microorganisms is an issue because of the possibility of microbially induced corrosion of metals.

DOE has updated the analysis of microbially induced corrosion for the Final EIS. Such corrosion is one of the waste package degradation processes discussed in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000). Experimental data described in that report show that Alloy-22 is not susceptible to microbially induced corrosion. However, to account for uncertainty, the analysis multiplied the general corrosion rate of Alloy-22 by an enhancement factor that simulates microbially induced corrosion. The *Near Field Environment Process Model Report* (DIRS 153363-CRWMS M&O 2000) describes the analysis of microbes at Yucca Mountain in more detail.

DOE acknowledges that it cannot build a system that can provide perfect containment forever. This EIS provides the Department's best estimate of the impacts that could occur when the containment system inevitably degraded.

The updated analysis in the Final EIS projects that the Proposed Action probably would result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197), which would be due to the very unlikely event of between one and five packages failing due to manufacturing defects.

In addition to the 10,000-year compliance period, DOE has evaluated potential impacts for the period of geologic stability at the repository (that is, 1 million years). This evaluation was performed, consistent with 40 CFR Part 197, to gain insight into the very long-term performance of the repository and thus provide information for the decisionmakers in making both design and licensing decisions. These results show a mean peak dose rate that would be much lower than background levels (see Chapter 5 of the EIS for details).

DOE is aware of the importance of potential releases from a Yucca Mountain Repository entering the food chain, particularly the milk supply, through groundwater pathways. This underscores the necessity of the system of multiple engineered and natural barriers, working together, to keep water away from the waste and to protect human health and the environment for thousands of years. The biosphere pathway model used for the long-term

performance assessment in the EIS explicitly includes dairy farms and milk products in the food chain and potential exposure pathways. In addition, the Yucca Mountain Project and the DOE Nevada Operations Office have conducted environmental surveys to establish baseline concentrations of radionuclides in milk produced in the region.

7.3 (10502)
Comment - EIS002138 / 0009
Page 1-14, table 1-9, why was a performance assessment calculations only modeled to the year 2055 when some of the materials have a half-life of over a million years?

Response
The comment is actually about Table I-9 of Draft EIS Appendix I. That year is only a time chosen to compute the inventory, and is not the time to which the analysis computed long-term impacts. As indicated in Appendix I, the analysis computed impacts for 10,000 and 1 million years after closure.

The wastes listed in Table I-9 are radioactive but do not have a constant activity level over time. A date was therefore assumed for the purpose of establishing a start time and beginning inventory for the performance assessment. DOE chose 2055 to provide the activity level of materials listed in Table I-9.

7.3 (10513)
Comment - 010116 / 0012
Our computer programs have a difficult time predicting the weather one month into the future. Again DOE wants us to believe that they have all the data to predict performance out past 10,000 years. And to be safe, the predictions should go out to one half life of the actinides, that's over a million years.

Response
The EIS discusses estimates of potential behavior, not predictions. These estimates were carried out to 1 million years in the Draft EIS, the Supplement to the Draft EIS, and the Final EIS. The nature of these estimates is to provide input to the decision whether to move ahead with the repository. The decision to close would not occur until as much as 300 years from now, when a great deal of additional data and more advanced analysis techniques would be available. Therefore, the degree of accuracy and level of knowledge in the estimates in this EIS are more than adequate to assist in the initial decision. The standards for weather prediction are far more stringent than those for the long-term predictions in the EIS because weather predictions have an immediate impact.

7.3 (10632)
Comment - 010140 / 0003
Now, on page 3-21, table 3-13, I'm not going to go through all the different ones. That will be in my written report. But one of them, the experimental corrosion data replaces expert judgment. That was the rationale on why the estimated effect would be the decrease in dose up to 10,000 years. And the reason for that was that they claim that there will be no failure of any cask for 10,000 years based on this new alloy that they've had about a year's worth of study on. This is a very interesting piece of data.

DOE has improved the waste package on paper and now admits the waste package will fail before the half-life of plutonium is reached. The nonexistent natural barriers will be all that will be left after 10,000 years. Plutonium and the actinides with one half-life of at least a million years might as well be buried in a hole in the ground.

This entire analysis depends on the very limited corrosion data of Alloy 22. There's conflicting data on the accuracy of this data. And a small variation will result in a significant decrease in the life of the engineered barrier.

Response
DOE based the development of models that predict the performance of corrosion-resistant, nickel-based Alloy-22 in the repository on data from research literature and testing (including long- and short-term tests). The Department conducted long-term tests under expected repository conditions, and short-term tests under both expected repository conditions and very aggressive conditions. The American Society for Testing and Materials codified this approach in a standard procedure (DIRS 105725-ASTM 1998). Analyses of the tests use a suite of tools, including standard microstructural evaluation and atomic force microscopy, which permits the examination of surface films in such

great detail that even very slow degradation rates can be evaluated. Over the next several decades DOE would continue to test samples of Alloy-22 and other alloys that would be exposed in the repository to confirm the results collected to date. In addition, DOE would explore analogs of Alloy-22 to provide confidence in the long-term performance of Alloy-22.

DOE based its selection of materials on input from independent experts and laboratory tests, and from the actual performance of materials in full-size industrial applications. The corrosion tests involve Alloy-22 and other candidate waste package materials subjected to environments that are at least as aggressive as any expected inside Yucca Mountain. DOE would continue these tests during waste emplacement operations to confirm the expected waste package performance.

In the Final EIS, analyses have been refined and include early failures caused by defects in the waste package. The results show a very small dose from these failures. See Section 5.4 of the EIS for more details.

7.3 (10670)
Comment - EIS001966 / 0010
On-site storage at generation plant locations or Part 72 ISFSI's [independent spent fuel storage installations] for any period of time is not an alternative to a well-sited repository. Attached please find a copy of "Report of the Site Advisory Task Force, Goodhue County Dry Cask Storage Alternate Site Project, to the Minnesota Environmental Quality Board." I draw your attention to §8, Task Force Conclusions, including §8.7, Alternate Sites:

"None of the 16 properties proposed as alternate sites by concerned citizens are feasible and prudent for further consideration by the EQB. The permanency issue, public safety concerns involving transportation risks, the uncertainty of long-term exposure to low-level radioactivity, and the apparent lack of derived benefits to the estimated costs of construction and maintenance of an off-site facility are the primary reasons for this outcome. Simply put, there are no risk- and cost-acceptable alternatives to on-site storage. Even on-site storage for an undeterminable period of time is unacceptable."

Because of the obvious difficulties in siting at Yucca, the Task Force regarded potential storage in Florence Township and that established at Prairie Island as de facto permanent storage. The environmental, transportation, and emergency response problems cited in this report were applicable to Florence Township, Prairie Island, and they are applicable to Yucca Mountain. The risks of long-term nuclear waste storage are unknowable, and the risks of catastrophic error are too great to go forward.

Response
Many commenters expressed opposition to the Proposed Action. DOE recognizes both opposition to and support for the proposed Yucca Mountain Repository and the associated analyses in the EIS. Chapter 1 of the EIS describes the need for the repository and the extensive history associated with the selection of the Yucca Mountain location.
In particular, this comment is concerned that the long-term risks associated with the Proposed Action are unknowable. DOE believes that, through the extensive scientific investigations and analyses it has and will continue to conduct, it has determined the possible ranges of the impacts. DOE also believes that the results presented in Chapter 5 of the EIS and the supporting information in Appendix I and the reference documents show that there is reasonable expectation that the repository would meet the appropriate standards for human health and safety over the long term.

7.3 (10742)
Comment - EIS002101 / 0003
Just the other day I was working with some ranchers out of Amargosa Valley that came out to help us out with our well. They farm a thousand acres of hay. Part of their hay is organic hay that they feed the cows there. There's organic dairy there. They -- this one guy's talking about he started there when I was 15 years old. Now he's in his 60s. They turned that land into a place, you know, it was there, people used those springs for thousands and thousands of years before, maybe millions of years before, and now they're growing food for people there. They just want a chance to live, you know, but you just discounted them, you throw them away, and there's some government officials that we hear from, too, that say they want to be compensated. Well, you can't compensate when you destroy a piece of this earth.

Your twelve-mile boundary lines go right through Amargosa. Those are human people, and I work down here at the Federal courthouse doing groundwater remediation work, and I see that, you know, we're just people trying to get by, trying to make a living, want to go out here and see Yucca Mountain go through because it's going to mean a good paycheck for the next five or ten years, but they don't – we're not looking at after that point.

Response
The EIS examines the potential consequences to individuals in the Amargosa Valley from both radioactive and nonradioactive contaminants transported through air, water, soil and food pathways. Chapter 5 presents an evaluation of the long-term environmental impacts of the proposed repository on the people of Amargosa Valley. These evaluations demonstrate compliance with the Environmental Protection Agency environmental protection standards. Therefore, DOE believes adverse health impacts to people in Amargosa Valley would be highly unlikely to occur.

Figure 3-75 of Volume 3, *Total System Performance Assessment of the Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) illustrates the ingestion and direct exposure pathways, including dairy and hay operations, incorporated into the biosphere analyses. Section 3.8.1.3 of the Viability Assessment describes a 1997 survey designed to enable a representation of dietary patterns and lifestyle characteristics of residents within the 80-kilometer (50-mile) radiological monitoring grid surrounding Yucca Mountain. It states in part that Amargosa Valley is primarily rural agrarian, and that agriculture is mainly directed toward growing livestock feed (for example, approximately 1,800 acres planted in alfalfa, 30 acres in oats). Table 3-25 of the Viability Assessment specifies the consumption rates of drinking water and agricultural products estimated from the results of the survey and used in the biosphere model. DOE has created a database of this information for addressing potential impacts to the people of the Amargosa Valley.

7.3 (10885)
Comment - EIS001257 / 0004
There are too many unknown variables as to what effect this potential pollution problem will have on the future. [A] good example of this is the way that plutonium at the test site has traveled one mile from its test crater. It is inconceivable how large an area will be affected over a period of ten thousand years. This is unacceptable.

Response
The situation associated with past underground testing is very different from that of the proposed repository. The plutonium in the repository would be immobilized in ceramic fuel or an immobilized plutonium ceramic, whereas the plutonium at the Nevada Test Site is not. The immobilized plutonium at the repository would then be encased in a very robust engineered container emplaced in a repository system carefully engineered to minimize mobilization and transport. The plutonium from test detonations was forcibly ejected with a tremendous energy at extreme temperatures, which injected the material far into the rock and caused a large region of disturbed (fractured) and altered material.

The models used to project the movement of radionuclides through the rock of Yucca Mountain in the EIS were, however, revised based on another finding at the Test Site. For the Final EIS, the groundwater models have been updated to include consideration of colloidal transport similar to that found at the Test Site.

Even though the modeling now indicates a potential for more rapid movement of plutonium and several other radionuclide species, results of the updated analysis in Chapter 5 of the EIS indicate that these effects would not be important until more than 10,000 years after repository closure when the first significant number of waste package failures would occur. Even so, the results show that the radionuclide species that dominate the potential doses in the earlier tens of thousands of years are high-solubility nuclides that would not benefit from the carrying power of association with colloidal mineral fragments (DIRS 153246-CRWMS M&O 2000).

7.3 (11075)
Comment - EIS000475 / 0017
DOE has [an] obligation to fully address the suitability of the Yucca Mountain High Level Waste Repository site. DOE must consider long term consequences based upon best available technology and scientific knowledge. If DOE has anticipation, based upon agency experience and expertise, that Yucca Mountain will not permanently

isolate high-level radioactive waste from the natural and human environment for time periods of 100 and 10,000 years, DOE has obligation to say so in Final EIS.

Response
DOE agrees that it must consider all aspects of the suitability of the Yucca Mountain site before it submits a License Application to the Nuclear Regulatory Commission to construct and operate the proposed repository. The Department believes that it has used the best available scientific and engineering knowledge and technology to arrive at the environmental impacts described in the EIS. The EIS analyses show that there is a reasonable expectation that the repository would meet suitability and other regulatory criteria for safety during the operational period (more than 100 years) and for as long as 10,000 years after closure.

7.3 (11273)
Comment - EIS001814 / 0008
5.1 to 5.10 Environmental Consequences of Long-Term Repository Performance

The DEIS sections that analyze long-term performance are inadequate because they fail to account for the real possibility of a catastrophic accident due to human intrusion, volcanic activity, or seismic activity. The human intrusion scenario is based on only one future event occurring to intrude into the site. Similarly, the possibility of volcanic activity or significant seismic events are unaccountably minimized despite the fact that Yucca Mountain has a history of earthquakes and the surrounding area is volcanically active. An example of the failure of the DEIS to seriously analyze these real threats to the environment and human safety is found in the discussion of long-term consequences. The DEIS acknowledges that "[p]otential impacts to human health in the far future from a repository at Yucca Mountain would be dominated by impacts from radiological materials in the waterborne pathway under all three thermal load scenarios of the Proposed Action." 5.10. But then goes on to minimize this impact.

Response
The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probabilities and effects of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

One change in the EIS is that now an aerial pathway release from an eruptive scenario is analyzed. The dose rates reported in Chapter 5 are well below the 40 CFR Part 197 environmental protection standards.

DOE has evaluated the long-term geologic stability of Yucca Mountain, including the potential for volcanoes. Volcanic activity has been waning in the recent geologic past and the probability of a volcano that could disturb the repository is very low (see EIS Section 3.1.3.1). Nevertheless, DOE presents an analysis of the effects of both a volcanic eruption, which could release volcanic ash and entrained wastes into the atmosphere, and the intrusion of magma into emplacement drifts, which could damage waste packages and contaminate the underlying aquifer. DOE estimated potential impacts on the nearest population to the south, conservatively assuming wind in that direction. Impacts in White Pine County would be a small fraction of nearby impacts such as those calculated. Sensitivity studies in the Total System Performance Assessment (DIRS 153246-CRWMS M&O 2000) suggest that the probability-adjusted dose from a volcanic, eruptive event at 20 kilometers (12 miles) in the direction of wind transport of an ash plume peaks at a few hundredths of a millirem per year. Because of radioactive decay in the repository there is a very low dose risk at 10,000 years. Therefore, given that White Pine County is considerably farther from the source, there is a negligible risk for dose from volcanism at Yucca Mountain.

DOE continues to include water pathways in its analyses of health risks of the proposed repository. The people of Amargosa Valley are most at risk because groundwater in the saturated zone beneath Yucca Mountain flows in a generally southerly direction into Amargosa Valley. They use water acquired primarily from local wells for household purposes, agriculture, dairy and catfish farms, horticulture, and animal husbandry.

Human intrusion into the repository is an issue because the future behavior of humans cannot be predicted. The Nuclear Regulatory Commission and Environmental Protection Agency have specified the way to analyze human

intrusion in their regulations for Yucca Mountain. The regulations describe a stylized calculation that attempts to minimize the speculation as to why humans would intrude into the repository.

With regard to evaluating a single intrusion event, the National Research Council (DIRS 100018-1995) concluded that one borehole was a good test of system resiliency, and going further was so speculative that it served no purpose useful in judging the robustness of a system. The National Research Council also recommended the assumption of the use of current drilling technology to avoid speculation over future advances in drilling technology. The emphasis was recommended to be on the analysis of the creation of enhanced pathways for radionuclide transport from the repository to the saturated zone.

For the Draft EIS, DOE assumed the intrusion event to occur 10,000 years after closure of the repository. The Department chose this time because it is the earliest that waste packages (under the Draft EIS design) probably would have degraded to the extent necessary to allow penetration without the use of specialized drill bits. However, for the Final EIS, DOE assumed the intrusion event would occur at 30,000 years to simulate an intrusion at a time when the intruder might not detect the waste package because of its weakened state. Over time, as more waste packages failed (and potential doses rose toward a peak dose from the overall system), intrusion would become less, not more, meaningful because the more waste packages that fail, the less the additional waste package failure from drilling would contribute to the overall risk.

Section 5.7.1 of the Final EIS discusses the human intrusion scenario analysis and results.

7.3 (11560)
Comment - EIS002258 / 0004
An adequate discussion is not provided in the Draft EIS relative to whether the proposed repository containments are safe from the occurrence of seismic disturbances; for example, earthquakes are common to this area. The park service is concerned that this possibility alone may lead to a potential release of radionuclides into the environment, specifically the regional underground water system that underlies the proposed repository and downgrading springs, specifically those which discharge within the park.

Response
The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probabilities and effects of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

As discussed in Section 5.2.3.5 of the Draft EIS, the major effect of an earthquake at Yucca Mountain would be ground motion (shaking) rather than direct offset along a fault. The *Disruptive Events Process Model Report* (DIRS 151968-CRWMS M&O 2000) discusses the effect of offset along a fault. Past movement has been along existing faults, and the probability of new faults forming is low. DOE would not emplace waste packages near existing faults, so the probability of shearing a waste package would be very low.

The rockfall analysis discussed in the *Waste Package Degradation Process Model Report* (DIRS 138396-CRWMS M&O 2000) that supports the Total System Performance Assessment (DIRS 151968-CRWMS M&O 2000) and the Final EIS is much more detailed than that in the Draft EIS. DOE based the analysis of the probability of rocks of various sizes falling and damaging waste packages on the rock properties in the repository. Analyses of this new design (DIRS 114171-CRWMS M&O 1999), which includes a drip shield, show that the waste package could withstand the largest potential rockfall. Adding strong drip shields above the waste packages provides a very robust design that would be able to withstand any credible rockfall. This would hold true as long as most waste packages and drip shields retained their initial strength. Results for undisturbed degradation show that nearly all packages would be at design integrity for well over the compliance period of 10,000 years; in fact, this would be true for well over 50,000 years. Therefore, the effects of rockfall are not part of the long-term performance analysis calculations for the Final EIS—since this model was originally developed for the compliance period of 10,000 years prescribed in 40 CFR Part 197. In the case of long term peak doses which occur at 500,000 years there may be some seismic effects not accounted for since most packages have been breached by that time. No analysis is available at this time to determine how much the peak doses might be affected.

DOE's analyses also continue to include water pathways in its analyses of health risks of the proposed repository. The people of Amargosa Valley are most at risk because groundwater in the saturated zone beneath Yucca Mountain flows in a generally southerly direction that then turns to the west into Amargosa Valley. They use water acquired primarily from local wells for household purposes, agriculture, dairy and catfish farms, horticulture, and animal husbandry.

With respect to potential impacts on Death Valley, the DOE acknowledged in Chapter 3 of the EIS that a small amount of groundwater may move beyond the primary groundwater discharge point at Alkali Flat (Franklin Lake Playa) to discharge in the Furnace Creek area of Death Valley. However, even if this were the case, any impacts on the Furnace Creek area would be even less than the low impacts shown in Chapter 5 of the EIS for the discharge location (Franklin Lake Playa) because the impacts decline with distance from the repository.

7.3 (11561)
Comment - EIS002258 / 0005
The park service believes the Draft EIS inadequately assesses possible climatic changes over the next 10,000 years. Increase in precipitation could conceivably result in the transport of radionuclides from the repository to the water table.

Response
The Draft EIS included an evaluation of climate change and its effects on long-term performance. These effects included increased infiltration, increased flux at depth, increased radioactive material transport at depth after waste package failure, and a shortened path to the water table because of changes in water table elevation.

The Draft EIS performance assessment considered three climate scenarios: present day, long-term average (wetter than the present-day climate), and superpluvial (Section I.4.2.4). These scenarios were assumed to occur at short-duration, fixed intervals on a periodic basis during the 100,000-year period after waste emplacement. However, the modeling of climate states was changed for the Final EIS based on the latest research of the U.S. Geological Survey and the Desert Research Institute. As a consequence of this work, pluvial states were expanded to allow short-duration states within them resembling the previously modeled superpluvial states. Superpluvial states are no longer included as separate states based on the results of this continued research.

Models of future climates caused by global warming from increased atmospheric carbon dioxide are speculative, though they are supported by some global climate modeling and the general increase in global temperature noted in the past century. At Yucca Mountain the estimated effect of global warming would increase average precipitation to a level similar to the long-term average climate of the Draft EIS, which resembles the glacial-transition climate in the Final EIS. This estimate, which is based on atmospheric model input, resembles near-continuous El Niño conditions and the near doubling of the precipitation that accompanies these conditions. In other words, DOE considers global warming impacts on future climates to be within the bounds of predicted climate ranges used in the assessment of long-term performance. Chapter 5 of the Final EIS incorporates such climate impacts in the estimates of the environmental consequences of long-term repository performance. These impacts include the effects of global warming and future climate change in general.

Extreme precipitation events are mentioned in Section 3.1.2.2, but would not greatly influence the infiltration rates discussed and used for modeling purposes in Chapter 5 and Appendix I because the subsurface tends to "damp" extreme events (particularly in the Paintbrush nonwelded stratigraphic unit) to produce a nearly uniform infiltration rate with time at depth. If anything, extreme precipitation events are more closely associated with surface runoff events. Locality-based infiltration rates were used (not whole-mountain averages) to derive infiltration rates for repository zones modeled in the performance analysis. The approach to discretizing (dividing the repository into discrete zones) the repository for performance analysis calculations, and the areal infiltration rate applicable to each modeled zone, has been updated for the calculation results reported in the Final EIS (Section 5.4).

7.3 (11610)
Comment - EIS000113 / 0004
Now is DOT allowed to kill Death Valley monument?

Response
DOE assumes the commenter intended to say "DOE" rather than "DOT." Section 5.3 of the EIS discusses potential locations of long-term impacts from the repository. This section states that the general path of water that infiltrates through Yucca Mountain is south toward Amargosa Desert and into and through the area around Death Valley Junction. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, and spring discharge in Death Valley is a possibility. As listed in Table 5-8, the mean peak annual dose to a reasonably maximally exposed individual at the expected discharge location would be about 59 millirem, a very small dose compared to the background. Therefore, doses to reasonably maximally exposed individuals at unexpected discharge points in Death Valley would be even smaller. There is no evidence in the analyses available to DOE that would suggest significant impacts would occur to the Death Valley National Monument. DOE believes that the EIS provides sufficient information on possible impacts to Death Valley National Monument to support current decisionmaking.

7.3 (11829)
Comment - EIS001653 / 0113
5.6 DOE needs to provide a table in Chapter 5 which describes basic assumptions and key performance attributes of the repository system.

Response
DOE agrees with this comment and has included such a table (Table 5-4) as part of Section 5.2.3 in the EIS that is a cross-reference to detailed tables of key assumptions and associated performance-affecting attributes of the repository system. The tables of assumptions and attributes are extremely voluminous and are of an inappropriate level of detail for EIS. The tables can be reviewed in readily available public documents listed in Table 5-4.

7.3 (12037)
Comment - EIS000540 / 0009
Concerned that the DOE Yucca Mountain Safety Strategy allows for radioactive contamination of groundwater, relying on dilution of the waste to limit the radiation dose to nearby residents[10] who use the water for drinking, growing crops, and livestock, and for raising cows on the largest dairy in Nevada to supply the Los Angeles commercial milk market.

[10]US Department of Energy. Repository Safety Strategy: U.S. Department of Energy's Strategy to Protect Public Health and Safety after Closure of a Yucca Mountain Repository. Office of Civilian Radioactive Waste Management, Las Vegas, Nevada, December 1998.

Response
The Environmental Protection Agency (EPA), in promulgating the Yucca Mountain environmental protection standards (see 40 CFR Part 197), recognized that, with the current state of technology, it is impossible to provide a reasonable expectation that there would be "zero" releases over 10,000 years or longer. Therefore, the EPA established standards that it believes provides comparable protections to those of other activities related to radioactive and nonradioactive wastes. These standards do not require complete isolation of the wastes over the compliance period (that is 10,000 years) or the period of geologic stability (1 million years). The goal of a performance assessment for Yucca Mountain is to evaluate whether the repository would be likely to meet these standards. The goal of this EIS is to describe the methods and results of that evaluation.

The performance assessments discussed in the Draft EIS and the Final EIS do not begin with the assumption that the repository would leak. Rather, the performance assessment assigns probability-of-occurrence values (referred to as probability distributions) to various parameter and process features that consider the uncertainty associated with a particular parameter or process. When multiple simulations of repository performance (realizations) are computed, the results indicate which of the various outcomes is more likely to occur (mean values). However, in addition to the most likely outcome, the distributions also show extreme cases (referred to as the 5th and 95th percentile values) that provide a measure of the uncertainty associated with a particular outcome. Although not likely, a number of realizations produced no leakage for extremely long times. The updated analysis in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard

set by 40 CFR Part 197) and would be due to the very unlikely event of between zero and five packages failing due to manufacturing defects.

With regard to the use of dilution factors, DOE does not believe that dilution, in and of itself, is an acceptable method to meet environmental protection standards. However, the EPA has specified the location of the reasonably maximally exposed individual for compliance purposes (40 CFR 197.21), and DOE has used the best available information and generally accepted methods, which include credit for dilution, to estimate potential impacts to this hypothetically exposed individual.

With regard to potential milk contamination, the analysis in the Final EIS projects that the Proposed Action probably would result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure. These estimated releases would result in an annual dose to the reasonably maximally exposed individual of less than 0.0001 millirem, including milk pathways, which is more than 100,000 times less than the individual protection standard set by 40 CFR Part 197.

The EPA also requires a calculation of peak dose (40 CFR 197.30) within the period of geologic stability (1 million years). The EPA requires that DOE include these results and their bases in the EIS as an indicator of long-term performance. This analysis also serves as another source of information for the decisionmakers in making both design and licensing decisions. However, the EPA has recognized the inherent uncertainties associated with these long-term projections and has, therefore, not applied a regulatory standard to the results. Although the analysis in the Final EIS predicts small releases within the 1-million-year period, because of the large uncertainties associated with this prediction, DOE believes that population impacts (for example, those resulting from consumption of contaminated milk) resulting from these releases would be speculative and, therefore, has not included them in the EIS.

7.3 (12071)
Comment - EIS001912 / 0119
Pg. 4-1 Preconstruction Performance confirmation period. How can DOE suggest that performance confirmation will determine with reasonable assurance that the repository would meet performance objectives. Does DOE have a reasonable assurance now? If not why not? Will DOE have a contingency plan in the event that preconstruction performance confirmation activities have negative results? Because DOE cannot guarantee the repository will actually provide containment and that an extended period of performance confirmation will continue, the EIS needs to describe as part of the preferred alternative contingency actions.

Response
The EIS statement about "reasonable assurance" refers not just to the preconstruction period but to confirmation activities that would continue until repository closure. Their purpose would be to continue to build confidence in the system before closure. The information would provide additional assurance for the development of license amendments to proceed with closure sometime after 2110. The decision to close the repository would be very critical and would require the most advanced knowledge available.

The regulations applicable to the proposed Yucca Mountain Repository [see 10 CFR 63.101(a)(2) and 40 CFR 197.14, and 197.20] acknowledge there would be uncertainties, and they require no absolute proof of future performance, but instead require there to be "reasonable expectation" of compliance with safety standards. The challenge to DOE is to show compliance with the regulations while at the same time fully disclosing the uncertainties. The type of assurance needed now must support a decision to proceed to licensing and construction. DOE has to be confident enough in the projected system performance to justify the commitment of resources to this project. The projected range of performance based on current uncertainties must show that the system would likely meet the public health and safety standards set by the Environmental Protection Agency. This EIS is one of a number of documents that will provide input to the determination of whether to proceed with the proposed repository. Additional decision points would occur in the future.

The Proposed Action includes a lengthy program of monitoring, testing, and performance confirmation. This program would continue for perhaps as long as 300 years, through closure of the repository (see Section 2.1.2 of the EIS). It would give future decisionmakers the option to take corrective action if information developed during preclosure or as a result of monitoring, testing, and performance confirmation indicated the need for such actions.

This program would also provide information to support making societal choices on closing the repository or retrieving the wastes.

The details of the postclosure monitoring program would be further defined during the processing of the license amendment for permanent closure, but the types of monitoring that DOE would consider are discussed in Section 2.1.2 of the EIS. Deferring a description of this program until the closure period would enable the identification of appropriate technology, including technology that could become available in the future.

The EIS uses the best available data and analysis techniques to provide estimates of possible impacts. Therefore, testing and monitoring activities and action plans are part of ongoing studies and other documentation that could support licensing and other decisions at various stages of the project. A proposal to close the repository in the next century probably would be supported by a series of comprehensive documents and the experience gained during operations and developed with analytical techniques advanced beyond those in current use.

7.3 (12199)
Comment - EIS001888 / 0436
[Clark County summary of comments it has received from the public.]

Examples cited by other commenters were the potential for humans and the environment to be affected by transport of contaminated groundwater (Death Valley National Park, contamination of regional aquifer), and changes in the vadose zone from the high thermal load alternative. Some commenters questioned whether the EIS could provide information after failure of the waste packages such as mixing of various metals, minerals, isotopes, water, and heat. One commenter requested that a "maximum credible scenario" should be developed for releases from the repository.

Response
As described in Section 3.1.4.2 of the EIS, DOE has conducted an extensive program to characterize the direction and nature of groundwater flow from the Yucca Mountain site. The general path of water that percolates through Yucca Mountain is southward toward the Town of Amargosa Valley, then beneath the area around Death Valley Junction in the southern Amargosa Desert. The groundwater beneath Yucca Mountain merges and mixes with groundwater beneath Fortymile Wash. This groundwater then flows toward, and mixes with, the large groundwater reservoir in the Amargosa Desert. The natural discharge point of this groundwater occurs farther south in Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume may flow south toward Tecopa into the southern Death Valley area. A fraction of the groundwater may flow through fractures in the relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. Potentiometric data indicate that a divide could exist in the Funeral Mountains between Amargosa Desert and Death Valley. This divide would limit discharge from the shallow flow system, but would not necessarily affect the flow from the deeper carbonate aquifer that may contribute discharge to springs in the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Potential Furnace Creek area impacts would be less than the low impacts described in Chapter 5 for Franklin Lake Playa because impacts would decline with distance from the repository.

The long-term performance analysis calculations included changes to the unsaturated (or vadose) zone resulting from the thermal pulse under each of the three thermal loads. Waste package degradation following failure is the subject of detailed process-level modeling, the results of which DOE reported in Chapter 5 of the EIS.

With the regard to the suggestion of a "maximum credible scenario," the EIS presents the long-term performance results in probabilistic terms – mean and 95th-percentile results. This statistical spread reflects the range of possible behavior DOE believes is credible for the repository system based on wide ranges of parameters. As such, the "worst case" is contained within the results. The worst case could be realized as the results approached at the 100th percentile.

7.3 (12310)
Comment - 010321 / 0001
Number one, the first comment is the heavy metals. I don't believe that we have accurate --that nickel will not be released to the environment, particularly when I read both documents -- the Supplement and the engineering science

report *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration*.

I could not find any relation to zeolite absorption. And the question to come, what will happen which will make way first, the heavy metals or the radionuclides. Specifically what's happening is that hard water usually has an affect of absorption of nickel. I'll give an example.

Like in pure water nickel is absorbed about 58 percent, and hard water it's only 50 percent, so there is a question, which leads me to another conclusion that the rate of release which will come through the environment in the biosphere is not accurate.

Another point which I have not seen adequate response is the issue of complex mixtures. There was a question, how are we going to calculate the risk? The President, the Secretary of DOE, officials always say, we're going to use the best science. At this point in time nobody can tell me what is the real risk, because I can cite from the literature professional organization EPA [Environmental Protection Agency] guidelines which address the issue of complex mixtures and others very clear. There is over about 3,000 references which show interactions to various degrees between heavy metals, carcinogen and noncarcinogens and irradiation.

There is even a mathematical model which has been developed by Dr. Suzuki (phonetic) in Japan and never been implemented. I'm asking rhetorical questions why Yucca Mountain does not use the basic developed technology to describe and to predict the risk, because the current methods are incomplete. Specifically I'm talking about physiological and pharmacokinetic testing, which can take into account metabolism, distribution, extrusion, and being used and advocated by EPA to study complex mixtures.

It's advocated by the EPA, and I'm just puzzled why neither EPA or NRC [Nuclear Regulatory Commission] are looking, and specifically when an NRC official said we separated radionuclides from toxic chemicals. In the same document he forget to mention the recent recommendation for studies.

In my professional opinion unless all those studies would be completed, you should put a halt on Yucca Mountain because there are very serious uncertainties. You cannot predict the rate what so happened to the population. I can give an example.

For instance, if you take nickel, carcinogen is enhanced in the presence of chromium hexavalent. This is just an example, or I can give you references. When you irradiate nickel, the embryo tissue culture, nickel x-ray or UV, you get an increase in chromosome aberration, inhibition of repair of the DNA and subsequent genetic toxicity, which can increase the rate of carcinicity, and there is no doubt about it.

I am going to give all this information to Abe Van Luik, my friend, who will continue to argue. And I will challenge them, because when it comes to science you have to use to best science.

Response

The EIS presents the risks of exposure to ionizing radiation and hazardous chemicals separately, where the potential for these exposures could exist. A good scientific foundation for adding the risks of exposure to radiation and chemicals does not currently exist, even if target tissues were the same, because exposure pathways and cellular and molecular mechanisms of cancer induction could differ. The low levels of exposure to radiation and hazardous substances likely to occur from repository operations (Section 4.1) and long-term performance (Sections 5.4, 5.5, and 5.6) would be such that there would likely be no impacts, even though the linear, no-threshold application of risk factors generates fractional impact estimates, such as fractional latent cancer fatalities. Section F.1 contains more information.

7.3 (12317)
Comment - 010242 / 0028
Page 3-19: Section 3.2 - Long-Term Impacts

The Supplement has not, but should consider the impact of the long-term release to the environment of hazardous metals, other than radionuclides, from the repository's engineered components, as was done for the design scenarios in the DEIS.

Response
Section 3.1.12.2 of the Supplement to the Draft EIS mentions that the impacts from the release of hazardous materials would be small. This is further detailed in the Final EIS in Sections 5.6 and I.6. Bounding-case analysis indicates that the concentrations of these materials would be well below regulatory limits in water down-gradient from the repository.

7.3 (12382)
Comment - EIS001888 / 0438
[Clark County summary of comments it has received from the public.]

Commenters requested that the EIS consider the impacts of releases from the repository at the "population level." The EIS should report all dose response models and label each as to whether they are only fatal cancer models or include other health effects. Radon and other gaseous emissions via fracture pathways should also be evaluated. The long-term effects of heat on the ecosystem; and in turn how an altered ecosystem may effect waste isolation, should be analyzed in the EIS. Releases from the repository to the regional groundwater system (specifically Death Valley, Pahrump Valley aquifer, Ash Meadow area), based on a regional aquifer Characterization program, must be considered.

Response
Chapters 4, 5, and 6 of this EIS describe potential population doses to the public for the preclosure activities, postclosure performance, and transportation, respectively, including occupational doses to worker populations for preclosure activities and transportation. The human health impacts primer (Section F.1) describes how radiological doses from exposure to low or chronic levels of radiation convert to health effects. Section F.1.1.5 discusses potential health effects from low-level radiation exposure and their related importance.

In the system model of the proposed repository, gaseous radionuclides, such as radon-222 (which has a half-life of 3.8 days and is a progeny of radium-226) and carbon-14 (half-life of 5,730 years) are considered to be released as waste packages and cladding fails. The atmospheric transport of these gases to the local population is evaluated in Chapter 5.

Section 5.9 of the EIS describes potential local environmental consequences of the closed repository on the ecosystems in the vicinity of Yucca Mountain as a result of heating of the ground surface and of waste migration through groundwater to discharge points. The impacts of temperature increases, radiation exposures, and changes in surface soils and habitat on plants and animals are evaluated. Special attention is given to estimated increases in surface soil temperature that could affect the gender of hatchlings of the desert tortoise – the only species in the repository land withdrawal area that is listed as threatened under the Endangered Species Act.

EIS Section 3.1.4.2 describes the status of the understanding of the regional groundwater flow, based on an understanding of the saturated zone groundwater flow system updated by DOE and Nye County work.

7.3 (12435)
Comment - EIS000426 / 0004
Another problem with this project is the information provided or shall I say not provided. In your environmental impact statement you failed to provide some important information on the surrounding areas of Yucca Mountain. Last time I checked an environmental impact statement, it is supposed to include all potential effects of the designated area for the site. If this is true then why did you fail to mention the impact the Yucca Mountain Site will have on the nearby dairy farm? The milk products coming from this farm, if contaminated, will not only effect the people of that area but also all the people who receive their milk from that region.

Response
The *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) and the biosphere pathways model used for the long-term performance assessment in the EIS explicitly include dairy farms and milk products in the food chain and potential exposure pathways. In addition, the Yucca Mountain Site Characterization Project and the DOE Nevada Operations Office have conducted environmental surveys to establish baseline concentrations of radionuclides in milk produced in the region.

Figure 3-75 of Volume 3 of the Viability Assessment (DIRS 101779-DOE 1998) shows the ingestion, inhalation, and direct exposure pathways, including dairy operations, incorporated in the biosphere analyses. Section 3.8.1.3 of that document describes a 1997 survey designed to permit an accurate representation of dietary patterns and lifestyle characteristics of residents within the 80-kilometer (50-mile) radiological monitoring grid surrounding Yucca Mountain. It states: "Commercial agriculture in the Amargosa Valley farming triangle area includes a relatively large dairy that operates with approximately 4,500 milk cows and employs approximately 50 people." Table 3-25 of the Viability Assessment lists the consumption rates of drinking water and agricultural products, including milk, estimated from the results of the survey and used in the biosphere model. Thus, there is a defensible and traceable basis for addressing potential impacts of contaminated milk products.

The results and interpretation of the biosphere modeling in Section 3.8.3 of the Viability Assessment (DIRS 101779-DOE 1998) indicate that exposure pathways involving drinking water and leafy vegetables are more important than those involving milk.

7.3 (12438)
Comment - EIS001886 / 0003
IEER [Institute for Energy and Environmental Research] applauds and appreciates the fact the DOE evaluated peak doses for up to 1 million years and did not restrict itself to the arbitrary time limit of 10,000 years in the draft EPA [Environmental Protection Agency] Yucca Mountain standard. The 10,000 year limit has been rejected more than once by the National Research Council and by many others, including IEER. This feature of the EIS should be maintained.

Response
DOE appreciates the encouragement to continue to address peak dose in its calculations. The Department has done so in the Final EIS, and will continue to evaluate peak dose hereafter as a means to better understand long-term performance of and to improve the design of the proposed repository. However, DOE also agrees with the Environmental Protection Agency that, because of the large uncertainties, these estimates should not be used to assess compliance with environmental protection standards.

7.3 (12439)
Comment - EIS001888 / 0093
DOE's selection of values for performance parameters was often based on limited data or recommendations from expert elicitations that were conducted in lieu of data. In some cases, such as waste package wall material corrosion rates (discussed in Attachment [to this comment document] B), the base-case expected values used may not adequately represent the potential for radionuclide release and transport.

DOE often selected features for TSPA-VA [Total System Performance Assessment-Viability Assessment] models that would produce high values for radionuclide release and transport. For example, it was assumed that the entire surface of the waste package is wetted when dripped on, that all seepage that contacts a package enters the package when the wall is penetrated, and that all of the waste form is exposed in a fuel rod with breached cladding.

Some performance factors that could contribute to repository system performance, such as in-package dilution, were omitted from the TSPA-VA codes because the basis for characterizing performance parameter values was uncertain.

A key feature of the models and computer codes used for the TSPA-VA analyses was uncoupling of thermal, hydrologic, chemical and mechanical phenomena that are known to be coupled. Coupled effects may be important to performance of a repository with the temperature and heat-load characteristics assumed for the TSPA-VA analyses, but the characteristics of coupling and their effects, and the effect of model uncoupling on the reliability of the TSPA-VA results, are uncertain.

Response
Since the publication of the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) and the Draft EIS, DOE has minimized reliance on expert elicitation and has developed many new models. The waste package degradation model for the Final EIS is based primarily on experimental data, which indicate likely waste package lifetimes of more than 10,000 years.

As noted in the comment, the Viability Assessment and the Draft EIS did not analyze coupled thermal, hydrologic, chemical, and mechanical processes, but stopped with thermal and hydrologic coupling only. The analyses for the Final EIS, as documented in the *Near Field Environment Process Model Report* (DIRS 153363-CRWMS M&O 2000) evaluate thermal, hydrologic, and chemical coupling and thermal, hydrologic, and mechanical coupling. The effects would be small. DOE used the chemical effects directly in the Total System Performance Assessment model. It did not use the mechanical effects because they would have negligible effects on system performance.

The comment also notes that many of the models are conservative and that they neglect many beneficial processes. DOE intentionally incorporates such conservatisms into its analyses to ensure that impacts are not underestimated. This should provide confidence that the repository would protect public health and safety and would be able to comply with regulations, and that actual repository performance would be much better than the calculations of the long-term performance analysis in the EIS.

7.3 (12440)
Comment - EIS001923 / 0002
This document which, at first glance, looks like a document that is the work of unbiased authors. Upon reading this document one very quickly comes to the conclusion that the authors purposely have attempted to confuse the public. The DOE over the past year has attempted to convince the readers and anyone who would listen that the proper way to determine the suitability of this project was the "Total Systems Performance Assessment" [TSPA]. The EIS in Volume 1 presents data that shows that in the eyes of the DOE the project is viable. On page 1-19 volume 1 DOE states that the TSPA is based on the data available in 1998 DOE continues by stating "This EIS summarizes results from the Viability Assessment where applicable and data analysis that continued after the completion of the Viability Assessment." That on the surface sounds like the results can be clearly stated for the Secretary of Energy to easily sign off on the safety of the proposed project. The EIS is supposed to be a document that can be understood by people outside of DOE. On page 1-19, Volume 1 the DOE refers the reader to Chapter 5. Table 5-1 on page 5-5 presents the average radionuclide inventory used for the performance assessment calculations. One can see in this table the 1/2 lives of the material. I focus on this because DOE states that the data used in the computer runs is not an exact match with the inventory data in Appendix A. The values vary by a factor of over 100. Now I do not pretend to know how bad it is but when a simulation is conducted and is the basis of providing the Secretary of Energy the technical input that insure [ensures] him that the project meets all the criteria for safety and health for the environment and humans, I expect that analysis to be the best it can be. When the data used is off by more than a factor of a hundred and this error occurs in a time period that will, (you notice I didn't say can) contaminate the earth and humans after the containers are gone. The assessment must be done with the latest data and clearly spell out why a radiation level of greater than 11 curries [curies] per package will not impact the human race for over a million years after the containers are gone. Would DOE bury that much material in the ground today?

Response
The inventory in Section 5.1 of the Draft and Final EISs is based on an abstraction of the actual inventory (presented in Appendix A). Direct comparison of inventories in Section 5.1 to values in Appendix A cannot be done. The abstracted inventory has been carefully formulated to make it representative of the repository inventory for the purposes of the Total System Performance Assessment modeling. This is explained in detail in Section I.3. Details of the screening analysis for radionuclides are also in Section I.3, and other sources are referenced in Section I.3.

7.3 (12534)
Comment - EIS001078 / 0002
I spent 25 years of my career as a government meteorologist assigned to the Nevada Test Site nuclear underground testing program in the period from the 1960s through early 1980s. One thing that impressed me about the underground testing program was the difficulty in assuring against ventings of nuclear materials during tests. Despite every apparent effort at containment, there were unexpected prompt massive ventings at the time of certain nuclear experiments that more than once literally shut down the test program for months while better containment

procedures and models were developed to try and avoid the unexpected geological and hydrological situations and the shortcomings in test hole backfill procedures that were felt lead [led] to these accidental releases.

The lesson from this as applied to a 10,000 year isolation problem is that mother nature and human shortcomings in methodology will almost certainly deliver up surprises that will result in serious problems of noncontainment sometime in the 10,000 year life of the project. Meteorological predictions have their limitations, but geological predictions have far, far greater prediction uncertainties.

The sad thing about this 10,000 year project is that future generations, perhaps those well beyond the duration of unpredictable civilization changes that have occurred throughout all history since the birth of Christianity, will likely have to contend with these problems. It's anyone's guess as to how well these future generations, these future political systems, future cultures, future population sizes, future densities of population near the storage facility, will be able to cope.

Response
DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency (EPA), and Nuclear Regulatory Commission (NRC) also recognize the difficulty of understanding the behavior of complex systems over long periods. In 10 CFR Part 63, the NRC acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation (consistent with 40 CFR Part 197)." In 40 CFR Part 197, EPA establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. EPA also recognizes the need for expert judgment in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Sciences observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events.

DOE confidence in the disposal techniques is based on defense-in-depth that, for example, places drip shields over waste packages to account for uncertainties. The Department has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components. DOE believes that this process results in a representative estimation of impacts and is sufficient for comparing the relative merits of the various repository scenarios, including the preferred alternative.

DOE continues to evaluate the sufficiency of its approach to dealing with uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

As described in Chapter 1 of the EIS, Congress determined through the passage of the Nuclear Waste Policy Act of 1982 that the Federal Government has the responsibility to permanently dispose of spent nuclear fuel and high-level radioactive waste to protect the public health and safety and the environment. The Act says that the Federal Government needs to take precautions to ensure that these materials do not adversely affect this and future generations. For this reason, EPA has been careful to promulgate environmental protection standards for Yucca Mountain (40 CFR Part 197) that include repository performance criteria that would represent potential risk to future generations no greater than those that present society would be willing to accept. Before recommending development of the proposed repository, the Secretary of Energy must provide a reasonable expectation that the repository would be able to meet these standards.

7.3 (12544)
Comment - EIS001287 / 0002
One of our concerns with the YMP [Yucca Mountain Project] is the effect buried wastes could have over the very long periods during which they will remain radioactive. The EIS uses two time frames of analysis. One is "short-term" -- the next hundred years. The second is "long-term," -- the next 10,000 years. In our fast paced society, where short-term often means the next three months, or the next year, 10,000 years seems an absurdly long-time. But consider the half-life of Plutonium 239, one the radioactive elements proposed to be buried in Yucca Mountain. It has a radioactive half-life of 24,360 years. This means that after that time period, half the radioactivity remains.

After a mere 10,000 years, the plutonium in the repository would be about 80% as dangerous as when it was first buried. After 100,000 years, tens times longer than the "long-term" effects period analyzed in the EIS, one-sixteenth of the radioactivity will remain. This is a quite a lot, considering that plutonium is the most deadly substance known, with one particle lodged in a lung almost certain to result in a cancer. We find it incredible that the EIS does not discuss the radioactive half-life of the elements to be buried at Yucca Mountain. If it had been discussed in the EIS it would beg a question about what "long-term" really means. And the answer would be "much longer than 10,000 years."

What will be left of America in ten thousand years? Will the U.S. Government survive? What about the State of Nevada? Who will be here to reap the deadly harvest of the seeds to be sown in Yucca Mountain? One hundred thousand years may seem an inconceivably long time. But at the end of that period, significant radioactivity would continue to emit inside Yucca Mountain. With some luck it would remain contained there. Consider that in one hundred thousand years, the North American continent is likely to drift 2.5 km or more than 1.5 miles from its present location. I ask, with some seriousness, where will Yucca Mountain be by then? And what will happen to the storage canisters and the still deadly nuclear waste within them? The EIS estimates the probability of volcanic disruption at or near the repository was one in 7000. No doubt the probability over one hundred thousand years is much greater. One hundred thousand years may seem inconceivable, but the EIS must still make some attempt to conceive it, to examine the truly long-term consequences of the burial of this waste.

Response

DOE recognizes that some components of spent nuclear fuel and high-level radioactive waste will pose a hazard after 10,000 years. However, as directed by Congress in the Energy Policy Act of 1992, the Environmental Protection Agency (not DOE) is responsible for establishing the radiation protection standards for the Yucca Mountain repository, and the Nuclear Regulatory Commission is responsible for developing criteria for licensing the repository that are consistent with those standards.

Thus, the projections of impacts to 10,000 years (and beyond) in the Draft EIS were based on a design comprising various engineered barriers and the natural barrier system. The projections were developed in consideration of the proposed Environmental Protection Agency (EPA) and Nuclear Regulatory Commission rules that specified 10,000 years as the period of performance to be evaluated for licensing purposes. The Environmental Protection Agency rule (40 CFR Part 197), which established environmental radiation protection standards for Yucca Mountain, required that DOE demonstrate that there is a reasonable expectation of compliance with the standards specified in the rule for 10,000 years following disposal. If the Department cannot make this demonstration, then the Nuclear Regulatory Commission cannot issue a license pursuant to its criteria (10 CFR Part 63).

EPA also requires a calculation of peak dose (40 CFR 197.30) within the period of geologic stability which, for the Repository, is 1 million years. EPA requires DOE to include these results and their bases in the EIS for Yucca Mountain as an indicator of long-term disposal system performance. This analysis, which includes consideration of disruptive events such as volcanism, also serves as another source of information for the decisionmakers in making both design and licensing decisions. However, the EPA has recognized the inherent uncertainties associated with these long-term projections and has, therefore, not applied a regulatory standard to the results.

As described in Chapter 1 of the EIS, Congress has determined through the passage of the NWPA, that the Federal Government has the responsibility to permanently dispose of spent nuclear fuel and high-level radioactive waste to protect the public health and safety and the environment. The Act goes on to require the Federal Government to take precautions to ensure that these materials do not adversely affect this and future generations.

DOE recognizes that no containment, natural or engineered, can be guaranteed indefinitely. Rather than a goal of "zero leakage," which is unattainable, the repository is being designed to meet those standards for the amount and timing of releases of radioactive materials to the environment. DOE estimates that no individual would receive more than a few millirem (a thousandth of a rem) per year during the preclosure period (see Section 4.1 of the EIS) or more than 0.001 millirem during the 10,000-year period after repository closure (see Section 5.4 of the EIS).

DOE also recognizes that "predicting societal change over the long-term is impossible." As a consequence, the Department has structured conservative assumptions and scenarios taking into account the regulatory guidance provided by EPA and NRC, the National Academy of Science, and other scientific authorities that have provided

review of the Total System Performance Assessment. These assumptions and scenarios attempt to reasonably accommodate the inherent uncertainties with estimating long-term repository performance.

7.3 (12561)
Comment - 010116 / 0009
Nowhere in this report or in the EIS have I found any discussion of the corrosion caused by contact of two dissimilar metals. Is there any possibility of a current flowing through the waste packages? A very low current could cause big problems over periods of time. I was surprised that DOE chose 316 stainless. It's magnetic and corrodes very easily. Has any analysis been conducted on whether the magnetic material can develop a small current?

Response
No credit was taken for the stainless-steel sleeve, which would be only a structural reinforcement before a breach of the Alloy-22. Until the Alloy-22 was breached, the interface would be unwetted and not exposed to oxygen. Therefore, damage to the passive layer would be of no consequence. After the Alloy-22 became breached, corrosion would proceed from the inside, and such things as the presence of stainless steel would be accounted for.

7.3 (12603)
Comment - EIS001957 / 0024
Section 5.7.3 Consequences from Disruptive Events, Seismic Disturbances -- In this section, it is stated that:

"The probability of earthquake occurrence in the Yucca Mountain vicinity is sufficiently high that DOE evaluated potential effects of seismic activity on repository performance. The potential effects of seismic activity would be vibratory ground motion in the repository, causing falling rock to damage waste packages, and a nearby event causing changes in hydrologic properties."

Later in the section, it is stated that:

"Most waste package failures caused by seismic activity probably would occur when the waste package outer wall was completely corroded.… At times greater than 100,000 years after repository closure, damage from falling rocks would be more likely because the waste packages would be corroded. … There is less than a one- percent probability that a falling rock would breach a waste package during the first 10,000 years after repository closure… Over 1 million years, falling rocks could breach about 30 percent of the waste packages in the repository."

The DOE states that waste packages are subject to corrosion. The DOE admits that the probability of seismic events that might breach a waste package in the proposed repository is approximately 10^{-2} during the first 10,000 years, and that after 1 million years, about 30% of the waste packages could be breached. Given that potentially harmful radionuclides with half-lives of well over 1 million years (e.g., Neptunium 237) are to be included in these waste packages, the draft EIS does not address the potential effects of seismic hazards on repository performance, especially the structural integrity of the waste packages, and subsequent effects on down-gradient springs if the packages leak. It is also suggested that the supplemental draft EIS address whether--within an accelerated timeframe for possible radionuclide contamination due to seismic damage-necessary remediation and restoration sciences will be refined sufficiently to respond to impacts which ensue.

Response
The EIS does contain analyses of impacts that could arise from natural catastrophic events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can incorporate them statistically into the risk analysis. Chapter 5 of the EIS contains an assessment of the probabilities and effects of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicates the potential risk, as reported in the EIS.

As discussed in Section 5.2.3.5 of the Draft EIS, the major effect of an earthquake at Yucca Mountain would be ground motion (shaking) rather than direct offset along a fault. The *Disruptive Events Process Model Report* (DIRS 151968-CRWMS M&O 2000) discusses the effect of offset along a fault. Past movement has been along existing faults, and the probability of new faults forming is low. DOE would not emplace waste packages near existing faults, so the probability of shearing a waste package would be very low.

The rockfall analysis discussed in the *Waste Package Degradation Process Model Report* (DIRS 138396-CRWMS M&O 2000) that supports the Total System Performance Assessment (DIRS 151968-CRWMS M&O 2000) and the Final EIS is much more detailed than that in the Draft EIS. DOE based the analysis of the probability of rocks of various sizes falling and damaging waste packages on the rock properties in the repository. Analyses of this new design (DIRS 114171-CRWMS M&O 1999), which includes a drip shield, show that the waste package could withstand the largest potential rockfall. Adding strong drip shields above the waste packages provides a very robust design that would be able to withstand any credible rockfall. Therefore, the effects of rockfall are not part of the long-term performance analysis calculations for the Final EIS.

DOE's analyses also continue to include water pathways in its analyses of health risks of the proposed repository. The people of Amargosa Desert are most at risk because groundwater in the saturated zone beneath Yucca Mountain flows in a generally southerly direction that then turns to the west into Amargosa Desert. They use water acquired primarily from local wells for household purposes, agriculture, dairy and catfish farms, horticulture, and animal husbandry.

With respect to potential impacts on Death Valley, the DOE acknowledged in Chapter 3 of the EIS that a small amount of groundwater may move beyond the primary groundwater discharge point at Alkali Flat (Franklin Lake Playa) to discharge in the Furnace Creek area of Death Valley. However, even if this were the case, any impacts on the Furnace Creek area would be even less than the low impacts shown in Chapter 5 of the EIS for the discharge location (Franklin Lake Playa) because the impacts decline with distance from the repository.

7.3 (12655)
Comment - EIS000475 / 0002
The agency is proposing to construct a facility designed to isolate High Level Radioactive Waste [HLRW] from the human and natural environment based upon a proposed standard which would be in effect for 10,000 years. Human history has little track record with 10,000 year construction projects. In actual fact minus interested party spin doctoring, present day humans have little, if any, knowledge of human construction projects completed and/or attempted 10,000 years in the past in the Nevada desert or elsewhere.

To further compound the lack of scientific coherence, the numbers don't add! Peak doses from the disposed HLRW are anticipated to occur some 200,000 thousand years in the future. "Acceptable" levels of radioactive releases from the Yucca Mountain disposal facility should, according to sound science (and basic logic) be calculated to correspond with the same time frame which scientific calculations indicate peak doses are most likely to occur--some 200,000 thousand years into the future. 1999 or 2000 calendar year best available technology apparently is insufficient to adequately contain the radioactivity of HLRW for 10,000 years, for 200,000 years, and for the half-lives of Plutonium-239 (24,130 years), Technetium-99 (213,000 years), Thorium-232 (14 Billion years), Uranium-235 (7 million years), and Uranium-238 (45 million years). However, the agency has mandate to adhere the standards of protection currently in law rather than rewrite lower standards and "permanently" withdraw 230 square miles of federal land to isolate a site of less than 2 square miles in actual site size.

A maximally exposed individual (MEI) who has the highest exposure within the receptor group is assumed by the agency to be located at the point of maximum concentration of contaminants 24 hours a day, 7 days a week for the period of operations (which is multiple generations of human lifetimes). Regulatory dose limits for individual members of the public as applied to all other sites are currently defined by U.S. EPA [Environmental Protection Agency] and NRC [Nuclear Regulatory Commission] regulations and DOE orders. Safe Drinking Water Act limits (apparent exception for the Yucca Mountain Repository) 4 mrem/yr. [millirem per year] maximum dose from drinking water. Clean Air Act sets maximum dose limit from airborne emissions at 10/mrem/yr. (apparent exception to population and MEI surrounding Yucca Mountain). Dose limitations for all pathways combined is set by DOE Order 5400.5 and NRC regulations 10 CFR 20 at 100 mrem/yr. (apparent exception to Yucca Mountain MEI and surrounding population) (DOE 1999). What "sound science" serves as the basis for agency determination in draft EIS to lower standards currently in regulations and agency order currently adopted as necessary for the protection of the public health and safety? It appears that the agency feels mandated under Nuclear Waste Policy Act to give the Yucca Mountain repository site its stamp of approval by lowering the current public health protection standards, even if the agency required to side-step science and regulations to do so.

Response
The response to this comment is divided into four related parts.

First, DOE agrees there are uncertainties about the efficacy of 10,000-year engineered structures. This EIS discusses those uncertainties at some length (for example, Section 5.2.4 discusses uncertainties associated with consequences of long-term repository performance). The regulations applicable to the proposed Yucca Mountain Repository [10 CFR 63.101(a)(2) and 40 CFR 197.14 and 197.20] acknowledge there would be uncertainties and require no absolute proof of future performance, but instead require "a reasonable expectation" of compliance with safety standards. The challenge to DOE is to show compliance with the regulations while fully disclosing the uncertainties.

The Environmental Protection Agency (EPA) standards for a repository at Yucca Mountain acknowledge that the radioactive waste to be disposed in Yucca Mountain would remain dangerous and, hence, require isolation for longer than 10,000 years. For that reason the EPA standard requires a calculation of potential peak doses, within a million years, in this EIS (see 40 CFR 197.35). These very long-term calculations might be more uncertain than the 10,000-year calculations required for the very exacting licensing process. Thus, the EIS informs the public and decisionmakers that going forward with this project could entail a very far future impact of the magnitude shown.

The anticipated land withdrawal area is large compared to the repository size. This allows for protection of the repository itself, its surface transportation and other handling facilities, its waste packaging facilities, its offices, and its transporter decontamination facilities. Denying unauthorized access to such facilities is standard and a required practice in the nuclear industry as well as at DOE facilities. The current Nevada Test Site boundaries illustrate the historic approach to maintaining large buffer zones between hazardous activities and the public, if the land is available to do so. The approximately 18-kilometer (11-mile) distance prescribed by the regulators for calculating potential doses to hypothetical recipients (the reasonably maximally exposed individual) was not based on the proposed land withdrawal boundary, but was defined as the southern boundary of the Nevada Test Site. The potential dose receptor location was based on estimating the likely future location of a small community of persons and farms, given the physical setting of the potentially affected area, and the depth to water in that setting. After the period of institutional control ceased, persons could live much closer to the Yucca Mountain Repository. But after society loses interest in or knowledge of the repository, if that indeed ever happens, it is still unlikely that individuals would locate their homes, and especially their farms, in an area that is steep, rugged, and more importantly, has a very deep water table.

After closure, DOE would establish and maintain passive and active institutional controls over the repository, as required by the Nuclear Regulatory Commission (NRC) regulations (see 10 CFR Part 63, particularly 10 CFR 63.102). However, consistent with NRC regulations [10 CFR 63.102(k)], DOE believes that active and passive institutional controls would be expected to reduce, but not eliminate, the potential for inadvertent human activities to cause or accelerate the release of radioactive material from the repository. Thus, DOE assumed for purposes of analysis that institutional controls would remain effective only for 100 years after closure, after which time human activities could intrude on the repository. This approach results in an upper estimate of the impacts from an intrusion, because only minimal radioactive decay would have occurred by 100 years after closure. Section 5.7.1 discusses the results of a drilling intrusion analysis.

Finally, with respect to the observation that Yucca Mountain Repository regulations are inconsistent with or different from other regulations, it is not true that the repository system is exempted from Safe Drinking Water Act regulatory limits or other applicable standards and requirements. These limits have been incorporated into the performance standard developed by the EPA specifically for Yucca Mountain (40 CFR Part 197). That standard also explains that airborne releases from the proposed Yucca Mountain Repository would not likely be significant, therefore they are not addressed. During the operational period, however, prior to permanent closure, the system and its facilities have to meet all currently applicable standards, regulations, and DOE orders containing radiological release restrictions applicable to nuclear facilities. This comment refers to dose limitations of 100 millirem per year under DOE Order 5400.5 and NRC regulations (10 CFR Part 20) and suggests there is an "apparent exception to Yucca Mountain reasonably maximally exposed individual and surrounding population." These requirements are for operating facilities such as the repository prior to closure. However, the repository after closure must meet a more stringent standard than 100 millirem per year for the first 10,000 years.

Chapter 11 of the EIS identifies the numerous other statutory and regulatory requirements that could apply to the Proposed Action and includes a list of the permits, licenses, and approvals that may be needed from other Federal and State agencies.

7.3 (12700)
Comment - EIS001632 / 0022
EPA [Environmental Protection Agency] has previously discussed with DOE and NRC [Nuclear Regulatory Commission] the calculations used to determine whether applicable radiation standards are met; determining whether the standard is met requires DOE to project the concentration of radionuclides in the water at the point of compliance. In order to do this, DOE must identify various scenarios for the type and quantity of waste released over time, transport path, and the concentrations predicted for the various options for representative volumes of ground water (e.g. 10 to 1,285 acre feet), at the various distances selected as possible points of compliance. We did not find this data identifiable in the draft EIS and suggest that the final EIS provide a discussion of this information and a summary table.

Response
The Draft EIS reported groundwater concentrations and then compared the results to current Safe Drinking Water Act standards for four points of compliance: 5, 20, 30 and 80 kilometers (3, 12, 19, and 50 miles) from the repository. It reported the concentrations for both the mean and 95th percentile of a set of 100 stochastic realizations of the undisturbed case release scenario, which determines the type and quantity of waste released over time. Chapter 5, Appendix I, and the Viability Assessment (DIRS 101779-DOE 1998) discuss this scenario. The Draft EIS reported results for three thermal load scenarios for the peak occurring within 10,000 years after repository closure.

DOE did not use the concept of representative volume in the Draft EIS because of the nature of the groundwater model, which was the same as that used for the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). This model simulates the saturated zone transport as a series of six parallel tubes that follow the general flow of groundwater south through Amargosa Valley to the surface discharge point at Franklin Lake Playa. These one-dimensional tubes have a concentration identified at the repository footprint (that is, all repository footprint water flows through the tubes), a dilution factor characterizes how much dispersion would occur, and a delay factor accounts for sorption. Thus, at the point of compliance the model assumes that groundwater is repository footprint water with a conservative dilution factor and delay time.

Since publication of the Draft EIS, the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission finalized their environmental protection and licensing criteria regulations (40 CFR Part 197 and 10 CFR Part 63, respectively), which provide an individual protection standard for the proposed Yucca Mountain Repository.

For the Final EIS, DOE used the definition of the Reasonably Maximally Exposed Individual (RMEI) from 40 CFR 197.21, which defines the individual as a hypothetical person who could meet the following criteria:

(a) Has a diet and living style representative of the people who are now residing in the Town of Amargosa Valley, Nevada. DOE must use the most accurate projections, which might be based upon surveys of the people residing in the Town of Amargosa Valley, Nevada, to determine their current diets and living styles and use the mean values in the assessments conducted for Sections 197.20 and 197.25.

(b) Drinks 2 liters (0.5 gallon) of water per day from wells drilled into the groundwater at the location where the RMEI lives.

The location of the RMEI described in 40 CFR Part 197 would be where the predominant groundwater flow path crosses the southern boundary of the Nevada Test Site which coincides with the southern boundary of the controlled area as defined in the regulation. This point is approximately 18 kilometers (11 miles) from the proposed repository. DOE has concluded that it is not necessary to analyze in the Final EIS a hypothetical individual at locations closer

than approximately 18 kilometers to the repository because it is unreasonable to assume that anyone would reside in this area, because:

- An individual would need to install and operate a water well in volcanic rock at more than 360 meters (1,200 feet) deep to reach the water table at costs significantly above (and likely prohibitive) those that would be incurred several kilometers farther south of the repository where the water tables lies less than 60 meters (200 feet) beneath the surface through sand and gravel. and

- Locations closer than 18 kilometers (11 miles) are within the controlled area defined in the EPA standard for a Yucca Mountain repository and therefore not in the postclosure accessible environment defined by EPA.

The updated analysis in the Final EIS estimates potential groundwater impacts reported for the compliance point prescribed in 40 CFR Part 197 [approximately 18 kilometers (11 miles) from the proposed repository]. As part of a comprehensive presentation of impacts, this EIS is charged with providing groundwater impacts for two other important down gradient locations. These are 30 kilometers (19 miles), where most of the current population in the groundwater path is located, and 60 kilometers (37 miles) where the aquifer discharges to the surface (this location is also known as Franklin Lake Playa). This analysis indicates that for the first 10,000 years there would be only very limited releases, attributable to a small number of early waste package failures (zero to three, and possibly as many as five) due to waste package manufacturing defects, with very small radiological consequences (see Table 5-6). For the first 10,000 years after repository closure, the mean and 95th-percentile peak annual individual dose would be thousands of times less than the Environmental Protection Agency standard, which allows up to 15-millirem-per-year dose rates during the first 10,000 years. The peaks would be even smaller at greater distances.

DOE has revised the definitions of the maximally exposed individual and RMEI in the Final EIS. Chapters 4, 6, and 7 now use the term "maximally exposed individual," and Chapter 5 uses "individual." The individual is the "reasonably maximally exposed individual" defined in 40 CFR Part 197.

In addition, the Final EIS updated the groundwater protection analyses consistent with criteria provided at 40 CFR 197.30. The results of these analyses are provided in Tables 5-6 and 5-10 of Chapter 5 of the Final EIS and show that both the mean and 95th percentile estimated radionuclide concentrations during the 10,000 regulatory period are thousands of times less than the regulatory limits.

7.3 (12774)
Comment - 010116 / 0004
DOE is attempting to address the Draft EIS design. Part of the Draft EIS design is to perform subsystems. This report eliminates the subsystem requirement and tests or simulations and instead depends totally on the total system performance assessment. The subsystem simulations addressed specific requirements that are to be done or to be met. DOE cannot disregard these requirements unless higher authority waives them.

Response
The performance of individual subsystems has been studied extensively and reports of individual subsystem performance are cited in Chapter 5 and Appendix I of the EIS, and in the Science and Engineering Report (DIRS 153849-DOE 2001). DOE is not aware of any statutory requirements for subsystem performance. The standard for performance is contained in 40 CFR Part 197.

7.3 (12775)
Comment - 010116 / 0005
Section 2.6 [Page 2-6], Section 2.2.2, sixth line, relative humidity could affect the corrosion rate. By this time in the program DOE should understand this elementary engineering problem, and not say could. I think this is the big red herring in the whole thing. What are you talking about in corrosion rates over greater than 10,000 years?

Response
DOE agrees that the choice of words in the statement cited was not the best. Humidity is an important factor when considering corrosion of the containment system materials. This has been accounted for in the models used to forecast the degradation of these materials. These models are based on detailed testing. While the length of the tests

is short and requires large extrapolations of time, the models are designed to incorporate the large uncertainties involved.

Operation of the repository would include contingency planning for continued performance monitoring and for possible retrieval of the waste if data indicated that the repository would not operate safely. During the period between the decision to construct and operate the repository, through preclosure, research would continue. This period could extend to more than 300 years. It is likely that by the time of closure there would be sufficient information on canister integrity and other components of the repository to confidently support a decision to either permanently close the repository or retrieve the emplaced materials. However, the results to date of research on the performance of these materials under simulated repository conditions provide confidence that they would perform as expected.

7.3 (12776)
Comment - 010116 / 0006
The proposal speaks of 75 years of forced air ventilation to keep the temperature within the design limit. This is page 2-9, last paragraph of Section 2.2.2.2.2. How soon after the ceasing of the forced air due to sensing of contaminants in the exhaust pool to the outside air will the temperature rise above the safe limits of the cask, assume the placement to be the closest spacing? This information should be provided in the EIS, not as a backup document. I take issue with this form of engineering variance that will cause a failure and then thus directly emit into the atmosphere.

Response
The purpose of ventilation is not to just maintain packages within design-limit temperatures but to mitigate various mechanisms that can potentially contribute to release of material. At no time is the design limit of the waste package exceeded. There are substantial safety margins employed so that temperatures are maintained at extremely low conservative levels. In developing the EIS an effort was made to keep the EIS of manageable size by not republishing already available information but rather providing comprehensive references to other supporting documents that are readily available. The body of such information is extremely large and is comprised of hundreds of documents, many of which are quite lengthy.

7.3 (12904)
Comment - 010314 / 0012
Is the DOE claiming that the only radioactive gaseous releases from the repository would be the naturally-occurring radon that would emanate from the exposed rock surfaces surrounding the repository? ("Supplement," pp. 3-3, 3-4) What estimates has the DOE developed for the amount of radioactive fission gases that will continue to be generated from the fuel rods and that may be released from the aging waste packages as they corrode and disintegrate -- such as tritium, xenon, krypton, argon and perhaps other fission gases?

Response
The purpose of the Supplement to the Draft EIS, as its name implies, was to provide information that was supplementary to the Draft EIS. That is, it added information that was new or changed from the Draft EIS. As such, the Draft EIS and the Supplement are companion documents, and not everything in the Draft EIS was repeated in the Supplement. Because the effects of long-term release of radioactive gases did not change significantly, no additional analysis was included in the Supplement. Section 5.5 of the Final EIS provides an updated analysis of the impacts of gaseous materials from the waste.

7.3 (12949)
Comment - 010249 / 0003
NEI [the Nuclear Energy Institute] understands, based on recent DOE presentations to the Nuclear Waste Technical Review Board that DOE will be revising its analysis to postulate 'early failures' of waste packages due to, for example, manufacturing defects. According to these presentations, this new analysis calculates annual doses for the first 10,000 years to no longer be absolute zero, but something less than 0.0001 mrem [millirem] (a level we consider to be 'essentially zero' since it is a million times less than natural background). NEI endorses this change as further evidence that DOE is taking an appropriate, multiple barrier, approach to repository safety. These new results demonstrate that Yucca Mountain's natural systems are capable of protecting public health and safety even if engineered systems do not perform as designed. DOE should clearly communicate in the FEIS that this new

analysis is being added to demonstrate defense-in-depth and that it does not reflect any real decrease in confidence regarding the performance of the repository.

Response
DOE thanks the commenter for the support and confidence for the analyses in the EIS. The inclusion of early failures in the analysis was the result of further studies and the desire to maintain as conservative an evaluation as possible, especially with respect to the first 10,000 years. Defense-in-depth from the inclusion of drip shields and the presence of natural barriers is an important factor for the first 10,000 years and for many more tens of thousands of years. However, the principal reason for the dose being very small during the first 10,000 years is primary containment integrity (protected by the additional defense of the drip shields). The dose would be small because there would be very few early failures. Studies of manufacturing led to the inclusion of a Poisson distribution ranging from zero to five early failures that is sampled for each realization. Fewer than 25 percent of the realizations showed any failures and the total failures rarely exceeded one package. Thus, the dose would be small because the source quantity would be small. The new analysis was added to reflect more conservatively and accurately the possibility of early defects, not to demonstrate defense-in-depth. But defense-in-depth is certainly what limits releases to early failures in the first 10,000 years. This is clearly explained in the Final EIS.

7.3 (13135)
Comment - 010237 / 0004
The site was originally selected due to the lack of groundwater. If the new design indicates the need for drip shields within the storage drifts it is obvious that the site is not as dry as originally thought. If new groundwater impacts and impacts to the site by groundwater have been identified, the site should not be used.

Response
An important factor in the selection of the Yucca Mountain site for study was that a repository could be located in unsaturated rock, far above the water table. This has never meant that there was no water infiltrating through the unsaturated zone.

Additional information about water flow through the unsaturated zone does not disqualify the site as long as a suitable design can be shown to meet the radiation protection standards in 40 CFR Part 197. In fact, DOE did not incorporate the drip shields in the flexible design described in the Supplement to the Draft EIS because of new information on water flow. Data on the water flow in the unsaturated zone has not changed substantially since DOE issued the Draft EIS. DOE added the drip shields primarily as a second line of defense. They would be made of different material than the waste packages, so different processes would drive their degradation. While intact, the drip shields would protect the waste packages from falling rocks as the drifts degraded, and would protect the waste packages from dripping water. The waste packages could be the primary engineered barriers to radionuclide transport. Corrosion of the waste packages would be more rapid if liquid water dripped directly on them. DOE added the drip shields primarily as an additional layer of conservatism for the licensing safety case and to compensate for uncertainties in the corrosion rates of the waste package materials.

7.3 (13170)
Comment - 010243 / 0017
One of the primary reasons for issuing the SDEIS would appear to be to evaluate the performance of a lower temperature repository option. It is not clear to Clark County how this evaluation can be made when some of the near field models used are not coupled and do not consider the critical temperature dependence of coupled chemical hydrological processes and their subsequent effect on corrosion.

Response
Low-temperature performance was not a primary reason for issuing the Supplement to the Draft EIS. In fact, the lower-temperature operating mode is not of great interest in assessing long-term performance. The period of significant heat release would be very short compared to the lifetime of waste packages. Thus, even if the heat was detrimental to waste packages and performance in general, it would be gone before a major amount of waste package failures occurred and would have no real influence on long-term performance. This was shown in the Draft and Final EISs (see Section 5.4). Sensitivity studies, which included a temperature-sensitive model of corrosion, showed improved performance (less than half the mean peak dose reported in the Final EIS) (DIRS 155950-BSC 2001). The fact that there would be improved performance is not surprising because the non-temperature-dependent

model is conservative and uses what is essentially corrosion under all adverse conditions, including high temperature. When the temperature-dependent model was used, the conservatism of always assuming a higher rate was removed, so corrosion after the short heat pulse would be much slower than that of the conservative model. Improved performance would result. Even in the sensitivity studies, the results for the high-temperature operating mode are nearly indistinguishable from those for the low-temperature mode because the period of heat generation would be so short in comparison to package and drip shield lifetimes. For these reasons the Supplement had little to say about this case.

7.3 (13171)
Comment - 010243 / 0018
On Page 3-20 Section 3.2.2 the DOE indicates that the software for the integration of the TSPA [Total System Performance Assessment] has been changed. Even though this is an important and major change from the DEIS no analyses were shown that would indicate the scope and effect of this change on the TSPA.

Response
Golder Associates, Inc., developed both GoldSim (the integrating software used for the Supplement to the Draft EIS and Final EIS) and RIP (the software used for the Draft EIS). GoldSim is a new generation of the RIP program, not an entirely different program. The differences have more to do with user interface convenience and the mechanics of data handling than with the actual modeling. Nevertheless, as part of the production, delivery, and documentation of GoldSim, Golder Associates validated that program against RIP by running similar cases in both. Thus, differences in the integrating software caused no differences between the Draft EIS, the Supplement to the Draft EIS, and the Final EIS.

7.3 (13229)
Comment - 010244 / 0028
DOE projects there would be zero individual radionuclide doses in the first 10,000 years and a 120-[millirem] release at 20 km [kilometers] after that period and peak dose at 550,000 years after closure. DOE provides no substantiated proof that the waste packages will not fail before 10,000 years as projected in the Supplement, which would again alter DOE's projections.

Response
The Final EIS includes an analysis of possible early failures brought on by defects in the waste package. The results show a very small dose from these failures (see Section 5.4).

7.3 (13230)
Comment - 010244 / 0029
The range of operating modes would result in post closure repository temperatures that could vary from the above boiling point of water to an average waste package surface temperature below 85ºC. The heat could affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn would influence the flow of ground water and the transport of radionuclides for the engineered and natural barrier systems. The Supplement does not mitigate the consequences of temperatures above the boiling point of water and the ability of the engineered and natural barrier systems to isolate the emplaced waste from the human environment.

Response
The results of long-term performance analyses reported in the Supplement to the Draft EIS and in the Final EIS accounted for all of the prevailing conditions expected in the repository, especially temperature. The newer models used for the Supplement and the Final EIS were able to account for the coupled effects of heat and water flow compared to the models used for the Draft EIS. The latest evaluations show that the design features of the repository would mitigate the effects of these conditions to the extent that the repository is expected to have performance far below the established standard set by the Environmental Protection Agency for the compliance period and have all-time mean peak doses that are less than normal background. Therefore, the design is demonstrated to adequately isolate the waste materials from the human environment.

7.3 (13248)
Comment - 010328 / 0002
I realize it's going to be real hot and the water will probably be boiled out of the mountain around the waste, yet it does indicate that on section -- page 2-25, section 2.3.4.1 it says that water dripping on the waste packages, and I quote, increases the likelihood of corrosion. So you got waste in there, and it's sitting in there for 300 years and then the drip shields go in, but there's rain, not all the time but it's not like we're in Oregon, but often enough that the waste packages could get wet.

And we're talking about waste packages with a 20-year old metal. I hope everybody here understands Alloy 22 is 20 years old. I mean, I understand it's under peer review right now, but this is a 20-year old metal that's supposed to protect us, protect us for at least 10,000 years. Come on. This isn't three-card monte. This is our lives we're talking about.

So the drip shields, concerns with the drip shields, I didn't see it adequately addressed in this document, how the plans -- I mean, I guess the temperature, the heat, but it didn't -- it just didn't do it for me.

So again I don't have a reference page for you on this one, but if no quantitative evaluation was done on the impacts of, I'm getting technical here, the impacts of the variable drift spacing, and these are probably your words, how does the DOE know that the effects would be less than the effect of waste package spacing?

So basically what I'm saying, the drifts, if the drifts are further apart, what's the difference in that between the actual packages being further apart? I didn't see that really addressed.

Response
All of the issues raised in this comment are addressed in detail either in the Final EIS or its referenced source documents. The long-term performance analysis includes a comprehensive evaluation of the processes mentioned including uncertainty evaluations. Two cases for waste package spacing are reported in the Final EIS.

7.3 (13279)
Comment - 010231 / 0012
Page 3-20, Section 3.2.2. Following Table 3-12 is a statement that the integrating software for the Total System Performance Assessment has changed from that used for the original DEIS to GoldSim(c), and that "GoldSim(c) incorporates much the same performance assessment calculational approach, but with substantial improvements in the user interface and data handling." The final EIS should provide support for this statement because changing the software which integrates the many programs which are used in the Total System Performance Assessment (TSPA) introduces uncertainty into the comparison of previous results.

Response
Golder Associates, Inc., developed both GoldSim (the integrating software used for the Supplement to the Draft EIS and Final EIS) and RIP (the software used for the Draft EIS). GoldSim is a new generation of the RIP program, not an entirely different program. The differences have more to do with user interface convenience and the mechanics of data handling than with the actual modeling. Nevertheless, as part of the production, delivery, and documentation of GoldSim, Golder Associates validated that program against RIP by running similar cases in both. Thus, differences in the integrating software caused no differences between the Draft EIS, the Supplement to the Draft EIS, and the Final EIS.

7.3 (13280)
Comment - 010231 / 0013
Page 3-21, Table 3-13. This table lists a change in the "Unsaturated zone flow" as "Coupling between thermal, hydrologic, and chemical effects." What is the status of the modeling and research on these coupled processes?

Response
The modeling for the Supplement and the Final EIS for long-term performance analysis includes improved coupling of these processes over the essentially uncoupled versions used for the Draft EIS. Section I.2.3 of the Final EIS and the documents referenced in that chapter discuss these models.

7.3 (13346)
Comment - 010296 / 0006
Nye County has not seen any reference to the environmental effects and impacts of the corrosion products. Although DOE claims that the material used are corrosion resistant, the amount of metal that is exposed in the facility is so large that a risk analyses will need to be performed to demonstrate that the drinking water standards will not be exceeded at any time. Also, it is not known whether the metal surfaces will be clean or treated with some protective substance. The solubility of the substances used on both the canisters and the drip shields should be evaluated and, if present, health risk analyses performed. Similarly, the potential impact of the steel sets should be presented. Unlike the heavy metals (uranium and other radioactive material) that are protected by the waste package cladding and other protective layers, the steel sets and other metals used are subject to degradation from the instant they are placed underground.

Response
The Final EIS analysis has been refined and includes analysis of possible early failures brought on by defects in the waste package. The results show a very small but not-zero dose from these failures (see Section 5.4).

The Final EIS contains a new analysis of non-nuclear toxic materials based on the new design of the repository and waste packages. The analyses show that even under very conservative and bounding assumptions, toxic materials have no significant impacts during the compliance period (see Sections 5.6. and I.6).

7.3 (13362)
Comment - 010182 / 0010
The SDEIS fails to analyze if the change in the emplacement of the waste would pose any problems. The proposed action indicates that as many as 6,000 additional canisters would be placed in Yucca Mountain.

Response
The NWPA only allows the Proposed Action to emplace 70,000 metric tons of heavy metal of waste (MTHM) in the proposed repository. Additional legislation would have to be passed to allow any additional MTHM in the repository. Therefore, the additional canisters are not a planned action but rather a possible future action evaluated as a cumulative effect. Cumulative impacts were presented in the Draft EIS but not discussed in detail in the Supplement to the Draft EIS because the amount of change from the Draft EIS would be similar to the reported changes in the Proposed Action. However, the Final EIS details these cumulative effects in Chapter 8.

7.3 (13363)
Comment - 010182 / 0011
The SDEIS should analyze potential juvenile failures of the canisters.

Response
Section 5.4 of the EIS analyzes the consequences of early failures caused by defects in waste packages. The results show there would be a very small dose from such failures.

7.3 (13364)
Comment - 010182 / 0012
It does not consider the potential for the Yucca Mountain geologic formation to accommodate spent fuel in amounts beyond that considered within the DEIS due to the closer spacing to be achieved through the flexible design. The SDEIS should provide a new estimate of the total potential spent fuel and other high-level radioactive waste that could be emplaced in Yucca Mountain. Although "DOE did not perform a quantitative evaluation of the environmental impacts of variable drift spacing due to a design trade-off" (Page 2-31, para 4), a quantitative analysis of variable drift spacing should be performed.

Response
The current law only allows the proposed action to emplace 70,000 metric tons of heavy metal of waste in the proposed repository. Additional legislation would have to be passed to allow any additional canisters in the repository. Therefore, the additional canisters are not a planned action but rather a possible future action evaluated as a cumulative effect. Cumulative impacts were presented in the Draft EIS but not discussed in the Supplement to the Draft EIS because the amount of change from the Draft EIS would be similar to the reported changes in the

Proposed Action. However, the Final EIS details these cumulative effects in Chapter 8. With regard to variable drift spacing, the text quoted in the comment gave the reason why variable spacing was not analyzed: It is no longer part of the design basis for the Proposed Action.

7.3 (13365)
Comment - 010182 / 0013
Furthermore, the SDEIS should consider what effect, if any, closer spacing of waste packages would have if a volcanic dike encountered one or more waste packages.

Response
The Final EIS contains detailed discussion of the analysis of such events and other related disruptive events in Section 5.7.2. Effects of igneous intrusion were evaluated for both the higher- and lower-temperature operating modes and the results are essentially identical. This is because while the wider spacing for the lower-temperature mode case would decrease the probability that an intrusion would intersect a waste package, the wider spacing also increases the repository footprint thus increasing the likelihood that an igneous intrusion would intersect the repository.

7.3 (13453)
Comment - 010296 / 0039
On page 4 38, the S&ER states that the USGS has conducted evaluations of three climatic conditions, the current climate, an interglacial monsoon climate, and a glacial-transition climate. While these studies did in fact evaluate average annual precipitation and the corresponding average infiltration rates, they did not evaluate the extremes of climate for the present, interglacial, and glacial-transition climates. The studies did not look at the increase in extreme precipitation events and the consequences of those events on l00-year floods, probable maximum floods, recharge or other events. Recharge occurs in response to precipitation events that exceed a given threshold and occurs as pulses follow a given event, typically the period of snowmelt or rarely, during the rare periods when rainfall occurs for several days or more. The threshold at which recharge begins to occur varies with season, antecedent moisture conditions, elevation, aspect, slope, vegetation, and a number of other factors. None of these factors were considered in the evaluations of future climate; only the average values were evaluated. The lack of extreme event evaluations is considered a deficiency in the S&ER. The S&ER and TSPA should be revised to include an analysis of the effects of extreme events on infiltration rates, recharge, flooding and repository performance using the Nogales, Hobbs, and Beowawe analogue stations as the basis for the extreme events. Consideration of these effects could result in a significant difference in the calculation of releases from the repository and the effects of such releases on potential receptors.

Response
As mentioned in the Science and Engineering Report (DIRS 153849-DOE 2001), such extremes were evaluated using the Nogales, Hobbs, and Beowawe analogue stations. More details on this are in the *Total System Performance Assessment – Site Recommendation* (DIRS 153246-CRWMS M&O 2000). Extreme lower and upper bounds were established for each climate state. In the case of the Monsoon Climate, the Nogales and Hobbs stations were used for upper-bound states. The Beowawe station was used for an extreme lower bound for the Glacial-Transition Climate. In the Total System Performance Assessment modeling, each climate state was represented by a probability distribution with a low, medium, and high value. In most cases, the distribution spanned a range of infiltrations in which the low and high values differed by factors of 10 to 100 (DIRS 153246-CRWMS M&O 2000). In this EIS, DOE expanded the climate model to six climate states with a similar treatment of extremes (DIRS 153246-CRWMS M&O 2000). These extremes are often manifested as significant changes in the annual dose from groundwater. This can be seen as large spikes in the dose history curves (see Section 5.4 of the EIS).

7.3 (13454)
Comment - 010296 / 0040
A worldwide search can no doubt identify analogue models of almost any type of condition. The use of such analogues in lieu of site- or region-specific data for Yucca Mountain is not considered adequate for the purposes of characterizing flow, transport, and seepage at Yucca Mountain. The DSEIS should be revised to fairly state that there are locations within the region that show the transport of water at depth. In the case of the Spirit Cave mummy and the pack rat middens, the analogue approach is particularly misleading. The Spirit Cave mummy and pack rat middens occur very near the surface in caves or small voids in surface slopes, not at depths of more than

1,000 meters in a tunnel, mine, or deep cave. Again, analogues are selected and discussed that are favorable while the many analogues that would lead to quite different conclusions were not selected and evaluated.

Findings in caves (page 2-31) analogous to deep geological repository support the idea that the environment of a naturally ventilated underground system, could under certain conditions preserve materials several thousand years old. The reference to DOE 2001a, Sec. 2.1.5.4 is in the SR Consideration, and refers to cave paintings in southeastern France and a mummy found in Spirit Cave near Reno. For example, there are preserved cave bear skulls, paws, teeth, etc. in the Ural Mountains, etc. A comparison of what has been destroyed under similar conditions would also provide useful information. How many caves have had smashed or destroyed artifacts, skeletons, paintings, etc.? How many bodies were not mummified. The analogues are weak, and more work should be done in this area.

Response
There was no intent to use analog information "in lieu of site- or region-specific data," but rather to supplement site data with analogs for subsystems, especially using examples that represent periods that cannot be investigated at the site. The discussion cited in the comment is an abbreviated discussion of analog information and, as such, might not adequately convey the intended information. The point of mentioning Spirit Cave was not that it is a good analog to a deep underground tunnel, but rather how well even biological remains can be preserved if they remain dry. Packrat middens were mentioned because they must remain dry to be preserved. Although not stated here, they exist in hundreds of caves in the desert Southwest. Thus, the ability of caves to protect delicate remains is a common feature.

This comment correctly notes that evidence of destroyed remains is difficult to evaluate. This question is addressed to a degree in Stuckless (DIRS 151957-2000). However, even with no intent to do so, ancient man left easily destroyed artifacts that have lasted tens of thousands of years.

The comment also correctly notes that ventilation might be an important variable. Nye County representatives and the U.S. Geological Survey have strongly suggested the consideration of long-term ventilation. This option is evaluated in Final EIS. While there are some advantages for various methods to reduce heat content, changes in the heat pulse for a higher-temperature to lower-temperature operating mode would have only about a 30 percent effect on total dose results for postclosure performance, even with a highly temperature-sensitive model for corrosion. However, there are many other possible advantages for the lower-temperature operating mode.

The comment suggests that more work needs to be done on analogues. This EIS is only one among many documents that will provide input to the phases of the project from site recommendation through licensing to closure. The EIS and its supporting documents contain sufficient information for an appropriate level of decision. If the site was recommended and the project continued, DOE would perform more work in this area to support subsequent phases.

7.3 (13457)
Comment - 010296 / 0043
DOE needs to consider potential for condensation of vapor in LTOM design. Peak dose of zero, seems to indicate that no corrosion is assumed to occur in the first 10,000 years. Surface temperature of all the waste packages should be considered when making such assumptions. To assume that the repository will perform uniformly or with predictability of 100% is to be overoptimistic. Variation in canister and drip shield surface temperature may occur due to uncontrolled or unpredicted conditions of the waste package or the host rock interactions. The probability of condensation occurring during some period of time in some location of the repository is high, regardless of the operational mode of the repository. The closer the packing of the canisters and the smaller the repository, the more uniform and predictable the temperature of the surface of the waste canister will be.

Response
The analysis assumed that Alloy-22 corrosion would proceed under the drip shields. It assumed that the bulk rate of corrosion would be the same before and after drip shield failure. Other corrosion mechanisms were added when there would be significant dripping on the packages after drip shield failure. The simulations in the Final EIS show early failures before 10,000 years (unlike those reported in the Supplement to the Draft EIS). Using different models and data sets, the analysis found that the long-term performance would be essentially insensitive to heat

loadings and operation modes, primarily because the time of the heat pulse would be so short in comparison to package lifetimes and the period over which materials would be released.

7.3 (13459)
Comment - 010296 / 0045
Table 3-13 Changes to the TSPA model lists 17 changes and their estimated effects. Of these, there are far more increasing than decreasing. The FEIS should explain the causes of these differences.

Response
Many of the changes to the Total System Performance Assessment model were made for conservatism and, therefore, increased the impacts. However, some changes resulted in decreasing the dose, which was much more significant than the combined effect of several increasing effects. For example, the effect of refined solubility models, which consider the formation of secondary phases, accounts for a decrease approaching a factor of 4 while the effect of many other increasing changes (such as the increase in the number of radionuclides considered) would be only a few percent. Section I.2 of the EIS and the referenced supporting document discuss the model components. In addition, the introduction to Chapter 5 discusses changes since the publication of the Draft EIS.

7.3 (13474)
Comment - 010372 / 0004
Page 3-21 indicates that waste packages will remain intact for 10,000 years. Any design options DOE proposes would be acceptable because the waste canister is the most important containment mechanism. If DOE continues to rely upon this rationale, there does not appear to be any need to continue to strive for improved repository performance because as long as the containers stay intact it would appear that all designs would meet performance requirements. As we have asked repeatedly, DOE needs to consider under what conditions the repository would fail to meet performance standards.

Response
The Final EIS analysis has been refined and includes analysis of possible early failures brought on by defects in the waste package. The results show a very small but not-zero dose from these failures (see Section 5.4).

All credible features, processes, and events have been accounted for in the TSPA. Therefore, it has been shown that under no credible conditions would the repository fail to meet performance standards.

7.3 (13475)
Comment - 010372 / 0005
Page 3-22 Table 3-14 please explain what causes the peak mean dose of the S&ER design be lower but occur sooner than the DEIS thermal load scenarios. The supplement only reports the results of the performance assessment but provides no explanation as to the differences in performance among the various thermal designs.

Response
Details of the analysis are in the referenced supporting document, the Science and Engineering Report (DIRS 153849-DOE 2001). The various model changes listed in Table 3-13 of the Draft EIS contributed in a variety of ways to the outcome. The reduced result is due largely to the revised solubility models. The difference in time is partially due to refinements in the climate cycles over the 1 million years. Several changes were made in the climate cycle based on further research. The time change and amount of peak mean dose are influenced by changes in the waste package degradation model, among several other things. These trends continue to show in the updated results reported in the Final EIS.

7.3 (13536)
Comment - 010305 / 0008
The affected area contains the Beatty dump and U.S. Ecology in the huge Amargosa Valley. Have the 7,500 dairy cows or their feed been tested for radionuclides or chemical poisons?

Response
The Milk Surveillance Network consists of 11 sampling locations within 300 kilometers (190 miles) of the Nevada Test Site, which includes the Yucca Mountain Site (DIRS 104544-CRWMS M&O 1999). In 1997, samples were

collected from 10 locations only. The network includes family-owned cows and goats and commercial dairies. In 1997, the estimated radiation dose associated with drinking this milk was 0.011 millirem per year, primarily from naturally occurring radionuclides along with small quantities of manmade fallout-derived radionuclides (strontium-90 and cesium-137). These results are consistent with data from previous years and indicate little or no change.

Deer and cattle forage was collected from both near- and far-field locations. A total of 143 near-field deer forage samples were collected from 32 sampling locations between 1990 and 1995. In addition to deer, cattle graze on public grazing allotments near the Yucca Mountain Site. Seven cattle forage sampling locations were established in 1993, five in the Razorback grazing allotment and two in the Mt. Sterling allotment, from which 14 samples were collected and analyzed. Only very small amounts of fallout-derived radionuclides (strontium-90, cesium-137, and plutonium-239) were detected in the samples.

Although the available radiological data suggest that radioactivity reported at the Yucca Mountain Site is higher than average because of naturally occurring radionuclides in the soil, no evidence of above-normal manmade radioactivity has been found.

7.3.1 THERMAL LOAD SCENARIOS

7.3.1 (185)
Comment - 55 comments summarized
Since the Draft EIS was issued, DOE has continued work on the repository design. Several commenters cited studies including drip shields, a modified waste package design, and a reduced thermal load scenario. Some commenters noted that some intermediate considerations, such as the use of backfill, were not incorporated into the current design. Commenters felt that the EIS must evaluate long-term performance of these other design considerations. One commenter expressed the opinion that DOE should explain the role of the EIS in future design evolution. One commenter was concerned that the major changes currently contemplated for the License Application design would invalidate the performance assessment. Another commenter felt the EIS must evaluate a nearly final design and asked why DOE abandoned the high thermal load scenario described in the Draft EIS.

Several commenters made observations on the thermal load scenarios and expressed opinions on the relative merits of a hot or cold repository. Some commenters favored the low thermal load because they believed a cooler design would be easier to model. Some commenters felt that a hot repository would have fewer implications for groundwater flow and chemistry because of the potential to boil off groundwater infiltrating through the mountain. According to the commenters this would delay the transport of contaminated liquids into the saturated zones. Other commenters felt that a hot repository could accelerate contamination of the saturated zone because of accelerated waste package disintegration.

Response
DOE stated in the Draft EIS (in Section 2.1.1.5, for example) that the designs analyzed were preliminary and were likely to evolve in various ways. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001). This design focuses on controlling the temperature of the rock between waste emplacement drifts (as opposed to areal mass loading), but the basic elements of the Proposed Action to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged. DOE evaluated the flexible design in the Supplement to the Draft EIS, which was released for public review and comment in May 2001.

For the analyses performed for the Supplement to the Draft EIS, DOE developed analytical scenarios to estimate the range of environmental impacts that could result from the Proposed Action. These scenarios include the low, intermediate, and high thermal load scenarios presented in the Draft EIS, as well as the higher- and lower-temperature repository operating modes of the flexible design. The low, intermediate, and high thermal load scenarios presented in the Draft EIS were not carried forward to the Final EIS. Section 2.2.1 of the Supplement summarizes the operational parameters for the three thermal load scenarios analyzed in the Draft EIS and the two repository operating modes analyzed in the Supplement. Section 2.2.2.2 describes the operational parameters for the

higher- and lower-temperature repository operating modes. DOE developed these scenarios and operating modes to accommodate and maintain flexibility for the future evolution of the design of the repository. So as not to underestimate the impacts that could result from future design evolution, these scenarios and operating modes incorporate conservative assumptions. Sections 2.2.1 and 2.2.2 of the Supplement discuss the design and operational evolution, respectively.

The Supplement to the Draft EIS evaluates the potential environmental impacts of the Reference Design higher-temperature repository operating mode, which is the design focus of the *Yucca Mountain Science and Engineering Report* (DIRS 153849-DOE 2001). In addition, the Supplement evaluates the impacts of the lower-temperature repository operating modes that embrace a range of operational parameters, as described primarily in Section 2.1.5 of the Science and Engineering Report. In the Supplement, the term "flexible design" refers to design features that are common to both the higher- and lower-temperature repository operating modes. The differences between these modes deal with the highest postclosure temperatures of the waste package surfaces, the temperature of the emplacement drift rock walls, and the overall temperature of the repository rock. Section 2.3 of the Supplement describes the design modifications including the addition of drip shields and refined waste packages. DOE is not currently considering backfill in the emplacement drifts.

The Final EIS addresses all aspects of the Proposed Action, including the flexible design. DOE acknowledges in the EIS that the flexible design could be further modified or refined during the License Application process, if the Yucca Mountain site was approved for development. DOE believes that the information on the impacts that could result from either the Proposed Action or the No-Action Alternative complies with the NWPA requirements for a Final EIS to accompany any recommendation by the Secretary of Energy to the President to approve Yucca Mountain for development as a repository. This belief is based on the level of information and analysis, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts that could occur, and the use of bounding assumptions if information is incomplete or unavailable or where uncertainties existed.

Concerning the comments related to a hot versus cold repository, the flexible design discussed in the Final EIS shows that both higher- and lower-temperature operating modes would be in compliance with environmental protections standards at 40 CFR Part 197 (see Tables 5-6 and 5-10 in Chapter 5 of the Final EIS for results). Thus, from the standpoint of long-term repository performance, the operating temperature of the repository would not be the sole deciding factor. The flexible design described in the Supplement and the Final EIS allows for a range of operating temperatures by varying such operational parameters as waste package spacing, surface aging, and extended periods of ventilation.

7.3.1 (611)
Comment - EIS000150 / 0002
When I look at the thermal load modeling, and I see all of the modeling is based upon the fact that it's just heat in that environment, and in fact that heat is coming from somewhere. My own personal knowledge of nuclear physics states that it's probably coming from either beta decay or the emission of free neutrons which creates a radioactive environment which could lead to significant embrittling of the storage containers far before their projected lifetime. And I don't really see any radiological studies that are connected with the thermal loading studies. Obviously I believe at least that that environmental site at Yucca Mountain when it's loaded is going to be an operating low-level nuclear reactor with the radiation levels.

Response
No reaction of the type found in a nuclear reactor would occur under the Proposed Action, and analyses documented in the *Waste Package Degradation Process Model Report* (DIRS 151624-CRWMS M&O 2000) indicate that radiolysis would have no impact on waste package performance.

In a nuclear reactor, radiation affects the metals because there are a large number of high-energy free neutrons. The decay heat in the proposed repository would be due to a combination of alpha, beta, and gamma decay as well as neutron emission. The fission products would be mostly beta and gamma emitters and the actinides would be alpha emitters. The number of free neutrons would be small because the rate of spontaneous fission of the actinides would be extremely small. Materials such as the fuel itself, its cladding, and high-level radioactive waste glass and the pour canister would stop alpha and beta particles. Gamma rays could pass through the materials, but their

interaction with the metal lattice would be small. The energy of the particles and gamma rays and the rate of emission would be low enough that they would not affect the waste package metal.

7.3.1 (1623)
Comment - EIS000498 / 0001
The EIS indicates that thermal loading may be a concern of the design of this repository. The previous viability assessment indicates that the surface facility is going to repackage the utilities' spent fuel assemblies underneath a cool water environment possibly to blend the hotter and cooler fuel assemblies so they can even out the temperatures.

It's been observed that industrial mishaps happen more frequently the more times you manipulate items. My comment is a very direct focused comment: To improve the EIS is to improve what discussions or agreement are in process between the DOE and the utilities to reduce the amount of spent fuel handling activity at the surface repository facility.

One possibility is staging or sequencing the delivery of hot and cold fuel so they don't have to assemble and mix and match them at the Yucca Mountain area.

Another way is to use the utility to mix and match the hot and cold fuel assemblies so that they don't have to disassemble these shipping casks or containers at the repository itself under water.

Response
As discussed in Section 2.2.2.2.2 of the Supplement to the Draft EIS and Section 2.1.1.2.2 of the Final EIS, commercial spent nuclear fuel would be the major contributor of heat in the repository. It would have a wide range of thermal outputs. The thermal output of the waste packages could, however, be reduced by varying waste package loading. Commercial spent nuclear fuel waste package loading could be varied by (1) placing low-heat-output (older) fuel with high-heat-output (younger) fuel in the same waste package (fuel blending), (2) limiting the number of spent nuclear fuel assemblies to less than the waste package design capacity (derating), (3) using smaller waste packages, or (4) placing younger fuel in a surface aging area to allow its heat output to dissipate so it could meet thermal goals for later emplacement. Section 2.3.2.1 of the Supplement to the Draft EIS and Section 2.1.1.2.2 of the Final EIS describe the fuel blending process further. Reducing the thermal output of the waste package through any of these means would achieve lower waste package and drift wall temperatures. DOE would consider surface aging as much as 40,000 metric tons of heavy metal of commercial spent nuclear fuel during a 50-year period.

Blending would involve some additional handling of the commercial spent nuclear fuel, the only waste form DOE would blend. Blending is merely the selective loading of disposal containers to control waste package temperature. Accidental assembly drops during handling and loading operations is evaluated in Appendix H of the EIS and impacts from such accidents are provided (see Section H.2.1.5). Releases from assembly drop accidents in the pool would be mitigated by retention in the pool water, and all accidents within the confines of the Waste Handling Building would be mitigated by the ventilation system, which controls the flow of any radioactive release and filters any airborne discharge to the atmosphere. Misloading of a waste package could occur, and such events could result in excessive temperatures. The possibility of such events has been considered, and it is expected that disposal container loading procedures would be developed based on thermal analyses of the various waste package configurations such that sufficient margin would be available to ensure that temperature criterion would not be violated for any credible misload (DIRS 150198-CRWMS M&O 2000).

The flexible design for the repository allows flexibility in the types of commercial spent nuclear fuel that DOE would receive. However, the estimated receipts are based on DOE projections of actions that would be taken by utilities to deliver spent nuclear fuel for disposal and are independent of the repository design. Instead, they are based on the terms of DOE's *Standard Contract for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste* contained in 10 CFR Part 961 and the generation and storage characteristics of each generator site (see discussion of CALVIN computer code in Section J.1.1.1 of the EIS). Therefore, DOE believes that the flexible design, including the blending facility, would accommodate fuel that would be shipped to a Yucca Mountain repository based on the terms of the Standard Contract.

DOE has no final plans for surface aging, although it is considering many options. Both blending and surface aging would be areas of active inquiry in the years just before the receipt of the first waste after 2010, if the President and Congress, if necessary, approved the site and the Nuclear Regulatory Commission issued a construction authorization in response to the License Application.

7.3.1 (4484)
Comment - EIS001430 / 0005
The repository layout for the low thermal load scenario (Figure 2-16 on page 2-26) has not been adequately addressed in Section 3. I suggest that Figures 3-7 and 3-8 (p. 3-22 and 3-23) be modified to include the low thermal load footprint and that additional discussion be added as necessary.

Response
The purpose of Chapter 3 is to describe the existing environmental conditions for the proposed repository and the region of influence. Chapter 2 describes the Proposed Action, including repository design and operating modes. Figure 3-7 provides general information on bedrock geology within the repository horizon. This is a complex figure, which DOE has modified to show fault lines. Because it is already complex, DOE has not included more features, such as the repository footprint, to the figure. Figure 3-8 is an updated elevation drawing that shows the approximate location of the repository within Yucca Mountain.

7.3.1 (4843)
Comment - EIS001340 / 0004
In Thermal Output Chapter A.2.3.5.4 - Current planning calls for blending by years 2013-2016 of certain types of waste materials which would make the batches of waste much hotter in canisters at maximum allowable watts. If such mixtures have not been experimented with for long periods, who's to say the temps allowed were not more than the canisters wall thickness could handle? And what if such canisters being prepared for shipment were miss marked or canisters began to leak during shipping? It could be missed for miles spewing death in its path across these many states.

Response
Commercial spent nuclear fuel would dominate the thermal, or heat, output of the nuclear waste that DOE would dispose of in the Yucca Mountain Repository. The heat output of this fuel would depend on the time the fuel spent in a reactor (the burnup) and the time the waste cooled before emplacement in the repository.

The repository design in the Final Environmental Impact Statement includes blending of commercial spent nuclear fuel assemblies. The purpose of such blending would be to constrain waste package temperatures by placing cooler (longer-cooled) spent nuclear fuel assemblies into the waste packages.

DOE would use a stringent quality control program during the packaging of wastes for shipment to the repository to ensure that there was no mismarking of waste packages. Transportation casks would be manufactured, loaded, and closed to ensure they were sealed. In addition, high-level radioactive waste would be in solid form and could not leak in the unlikely event of a transport cask penetration.

7.3.1 (5034)
Comment - EIS001520 / 0001
The final EIS should be based on an updated repository design and should include the updated performance assessment results that the DOE plans to produce to support a possible recommendation that the site be developed as a geologic repository.

The repository design that was assumed when preparing the draft EIS already has evolved and may change further before the final EIS is prepared. The Board recommends that the final EIS be based on the most advanced design concepts available at the time the final EIS is prepared.

Response
The Draft EIS evaluates the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for repository facilities and disposal containers (waste packages). It also evaluates the plans for the construction, operation and monitoring, and closure of the repository. DOE

recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any Nuclear Regulatory Commission licensing review. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

For these reasons, for the analyses performed for the Supplement to the Draft EIS, DOE developed analytical scenarios to estimate the range of environmental impacts that could result from the Proposed Action. These analytical scenarios include the low, intermediate, and high thermal load scenarios in the Draft EIS, and the higher-temperature and lower-temperature repository operating modes described in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation* (DIRS 153849-DOE 2001). Section 2.2.1 of the Supplement summarizes the operational parameters for the three thermal load scenarios analyzed in the Draft EIS and the two repository operating modes analyzed in the Supplement. The three thermal load scenarios presented in the Draft EIS were not carried forward to the Final EIS. Section 2.2.2.2 of the Supplement describes the operational parameters for the higher-temperature and lower-temperature repository operating modes. DOE developed these scenarios and operating modes to accommodate and maintain flexibility for the future evolution of the design and plans for the repository. So as not to underestimate the impacts that could result from future design evolution, these scenarios and operating modes incorporate conservative assumptions. Sections 2.2.1 and 2.2.2 of the Supplement discuss the design and operational evolution, respectively.

The Supplement to the Draft EIS evaluates the environmental impacts of the higher-temperature repository operating mode, which is the design focus of the Science and Engineering Report (DIRS 153849-DOE 2001). The Supplement also evaluates the impacts for the lower-temperature repository operating mode (which embraces a range of operational parameters, including 300 years of extended ventilation. In the Supplement, the term *flexible design* refers to design features that are common to both the higher-temperature and lower-temperature repository operating modes. The differences between these modes deal with the highest postclosure temperatures of the waste package surface, the temperature of the emplacement drift rock walls, and the overall temperature of the repository rock. Section 2.3 of the Supplement describes the design modifications, including the addition of drip shields and waste package design changes.

7.3.1 (5038)
Comment - EIS001520 / 0007
The estimates of long-term repository performance for the proposed action of the draft EIS are essentially the same as those used by the DOE to prepare its 1998 Viability Assessment of a Yucca Mountain repository. After reviewing the Viability Assessment, the Board stated its belief that identifying important sources of uncertainty, estimating the magnitude of those uncertainties, reducing critical uncertainties, and evaluating the effects of residual uncertainties on expected repository performance are essential for supporting a technically defensible site suitability determination. The Board concluded that a significant amount of additional scientific and engineering work will be needed to increase confidence in a site-suitability determination. The Board recommended that the DOE evaluate alternative repository designs that have the potential to reduce uncertainties in projected repository performance, thereby reducing the scope of additional necessary scientific study. Because the draft EIS relies on essentially the same performance assessment capabilities as those used to prepare the Viability Assessment, the Board believes that these conclusions and recommendations are equally applicable to the draft EIS.

The performance assessment models and data used to project the long-term performance of a Yucca Mountain repository are very similar to those used by the U.S. Department of Energy (DOE) to prepare its 1998 Viability Assessment of a Yucca Mountain repository. The Board has previously commented on the Viability Assessment[(1)] and those comments would also apply to the draft Yucca Mountain EIS. The DOE intends to refine its models and collect additional data before the final Yucca Mountain EIS is prepared. The Board recommends that the final EIS include the updated performance assessment results that the DOE plans to produce to support a possible recommendation that the site be developed as a geologic repository.

[(1)]U.S. Nuclear Waste Technical Review Board, Moving Beyond the Yucca Mountain Viability Assessment, Washington, D.C., April, 1999.

Response
DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years into the future. Consistent with National Academy of Science observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events.

DOE confidence in the disposal techniques is based on defense-in-depth (for example, placing drip shields over waste packages to account for uncertainties). DOE has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components. The bases of the approach are summarized as follows:

1. Site description is based on extensive underground exploratory studies and investigations of the surface environment.

2. Reference design is based on laboratory investigations and conceptual engineering studies.

3. Features, events, and processes that could affect the long-term safety of the repository are identified.

4. Evaluation of a wide range of exposure scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical, and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as use of water supply wells, irrigation of crops, exploratory drilling; and low-probability events such as volcanoes, earthquakes, and nuclear criticality.

5. Development of alternative conceptual and numerical models to represent the features, events, and processes of a particular scenario and to simulate system performance for that scenario.

6. Parameter distributions to represent the possible change of the system over the long term and use of conservative assessments that lead to over estimating of impacts when there is insufficient information for use of a probability distribution.

7. Performance of sensitivity analyses.

8. Extensive peer review and oversight.

DOE believes this process results in a representative estimation of impacts and is sufficient for comparing the relative merits of the various repository scenarios, including the preferred alternative.

DOE continues to evaluate the sufficiency of its approach of dealing with uncertainty at the process level (scientific) as well as the system level (modeling). DOE has organized a task force to review and outline further work to be completed on uncertainties before the time of license application, should Yucca Mountain be recommended as a suitable site for a repository.

The Draft EIS evaluates the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for repository facilities and disposal containers (waste packages). It also evaluates the plans for the construction, operation and monitoring, and closure of the repository. DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any Nuclear Regulatory Commission licensing review. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

For these reasons, for the analyses performed for the Supplement to the Draft EIS, DOE developed analytical scenarios to estimate the range of environmental impacts that could result from the Proposed Action. These analytical scenarios include the low, intermediate, and high thermal load scenarios in the Draft EIS, and the

higher-temperature and lower-temperature repository operating modes described in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation* (DIRS 153849-DOE 2001). Section 2.2.1 of the Supplement summarizes the operational parameters for the three thermal load scenarios analyzed in the Draft EIS and the two repository operating modes analyzed in the Supplement. Note that the three thermal load scenarios presented in the Draft EIS were not carried forward to the Final EIS. Section 2.2.2.2 of the Supplement describes the operational parameters for the higher-temperature and lower-temperature repository operating modes. DOE developed these scenarios and operating modes to accommodate and maintain flexibility for the future evolution of the design and plans for the repository. So as not to underestimate the impacts that could result from future design evolution, these scenarios and operating modes incorporate conservative assumptions. Sections 2.2.1 and 2.2.2 of the Supplement discuss the design and operational evolution, respectively.

The Supplement to the Draft EIS evaluates the environmental impacts of the higher-temperature repository operating mode, which is the design focus of the Science and Engineering Report (DIRS 153849-DOE 2001). The Supplement also evaluates the impacts for the lower-temperature repository operating mode (which embraces a range of operational parameters, including 300 years of extended ventilation. In the Supplement, the term *flexible design* refers to design features that are common to both the higher-temperature and lower-temperature repository operating modes. The differences between these modes deal with the highest postclosure temperatures of the waste package surface, the temperature of the emplacement drift rock walls, and the overall temperature of the repository rock. Section 2.3 of the Supplement describes the design modifications, including the addition of drip shields and waste package design changes.

7.3.1 (5363)
Comment - EIS001887 / 0081
Page 2-23; Section 2.1.2.2 - Repository Subsurface Facilities and Operations (Including Waste Packages)

The low thermal load repository would include Area 5 in order to provide sufficient underground emplacement area. Area 5 has not been the object of site characterization and, therefore, should not be included in the Draft EIS or repository planning until it has been characterized. According to the NWPA, the Secretary's site recommendation is to be made at the completion of site characterization. In the case of the low thermal load alternative design, site characterization has not been started, much less completed, in a portion of the area included in the Proposed Action. If the low thermal load alternative is to be considered a reasonable alternative, the Draft EIS should be deferred until characterization of Area 5 is satisfactorily completed.

This is especially important in light of currently developing information regarding saturated zone flow and transport. Essentially nothing is known about groundwater flow beneath Area 5 and how it might be influenced by the Solitario Canyon fault and other faults known and unknown. (See page 3-52 that states, "West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.") This introduces a new and major uncertainty in the performance assessment of the repository, to the extent that it precludes any certainty regarding flow paths along which radionuclides would travel from a significant portion of the repository. The Proposed Action is fatally flawed under these circumstances, as is the credibility of the impact analysis in the Draft EIS.

Response
DOE believes the EIS is consistent with National Environmental Policy Act requirements. The level of information and analyses, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts that could occur, and the use of bounding assumptions if information was incomplete or unavailable or if there were uncertainties, provide a meaningful assessment of environmental impacts consistent with the regulations. DOE acknowledges that the results of analyses often have associated uncertainties and has described such uncertainties throughout the EIS.

For the low thermal load scenario described in the Draft EIS, DOE extrapolated information for Area 5 from neighboring regions. DOE believes that the natural uncertainty and variability in the models for the other regions encompass the properties of Area 5 (see Section I.4.2.3 of the Draft EIS and Section I.4.4.2 of the Final EIS).

7.3.1 (5723)
Comment - 010073 / 0012
Page 2-6 and 2-7 - The SDEIS should consider what, if any, effect closer spacing of waste package has upon the probability and consequence of a volcanic dike encountering one or more waste packages.

Response
The Final EIS contains detailed discussion of the analysis of such events and other related disruptive events in Section 5.7.2. Effects of igneous intrusion were evaluated for both the higher- and lower-temperature operating modes and the results were essentially identical. This is likely because while the wider spacing for the lower-temperature operating mode would decrease the probability that an intrusion would intersect a waste package, the wider spacing also increases the repository footprint thus increasing the likelihood that an igneous intrusion would intersect the repository.

7.3.1 (6147)
Comment - 010229 / 0001
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.

Response
In considering the points in this comment, it is important to focus on a fundamental idea: The period of significant heat release would be very short compared to the lifetime of waste packages. Thus, even if the heat were to be detrimental to waste packages and performance in general, heat output would be dramatically reduced before any significant amount of waste package failures occurred and thus would have no important influence on long-term performance. This was seen in the Draft EIS case and also in the Final EIS case (see Section 5.4).

Sensitivity studies, which included a temperature sensitive model of corrosion, showed improved performance (less than half the mean peak dose that is reported in the Final EIS) (DIRS 155950-BSC 2001). The fact that there is improved performance is not surprising because the non-temperature-dependent model is conservative and actually uses what is essentially corrosion under all adverse conditions including high temperature. When the temperature-dependent model is employed, the conservatism of assuming a constant, higher rate is removed so that corrosion after the short heat pulse is much slower than that of the conservative model. Improved performance then results. Even in these sensitivity studies the higher-temperature repository operating mode results differ by about 30 percent from the lower-temperature repository operating mode (DIRS 154659-BSC 2001) because of the fundamental fact that the period of heat generation is short compared to package and drip shield lifetimes.

After consideration of the a large body of study and analysis, DOE does not believe that general lowering of repository temperature would not improve the overall long-term performance of the repository.

7.3.1 (6414)
Comment - EIS001632 / 0006
Page 2-6, final two paragraphs of 2.1.1: The repository performance and dose assessments in the draft EIS are based on models and assumptions in the DOE Viability Assessment Report (DOE/VA - DOE/RW-0508) that are now outdated. For example, the draft EIS analyzes the Module I & II inventory increases which were not part of the DOE/VA. Also, the DOE/VA examined the performance of a waste package design that is now obsolete. The

assessments in the final EIS should describe/assess the new EDA II design, particularly those aspects of the new design that modify the performance assessment.

Response
The Draft EIS evaluates the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for repository surface and subsurface facilities as well as disposal containers (waste packages). It also evaluates the plans for the construction, operation and monitoring, and closure of the repository. DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review of the repository by the U.S. Nuclear Regulatory Commission. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

As described in the Supplement to the Draft EIS and incorporated into the Final EIS, the waste package has been redesigned to include a thick outer shell of corrosion-resistant high-nickel alloy (Alloy-22) and a thick inner shell of stainless steel for strength. This newer design resists corrosion far better than the design described in the Draft EIS, and has improved the predicted performance of the repository and reduced uncertainties associated with that performance. A description of the flexible design waste package can be found in Section 2.3.4.1 of the Supplement to the Draft EIS and Section 2.1.2.2.2 of the Final EIS.

The type and amount of neutron absorber necessary for a specific waste package design would be determined by DOE prior to receipt of a license from the Nuclear Regulatory Commission to receive and posses spent nuclear fuel and high-level radioactive waste. This would have to be done consistent with a criticality analysis methodology that has been accepted by the Commission. The specifics of that methodology are presented in Disposal Criticality Analysis Methodology Topical Report, which DOE submitted to the Commission in January 1999.

7.3.1 (6593)
Comment - EIS001632 / 0066
Pages 9-12 through 9-16, Section 9.2.8: The design alternatives discussed in this section are outdated with the Department's adoption of the EDA II design. The final EIS should discuss the new design of the engineered barrier components (e.g., elements designed to minimize water contact with the packages, increase containment lifetime, or retard radionuclide movement out of the repository); it should also discuss the operational choices (e.g., a prolonged retrievability period) that dictated the design changes and reduced uncertainties in assessing performance of the system.

The final EIS should also contrast significant changes in the engineered barrier performance assessment with the assessments for the older design. For example, the DOE/VA design assumed a juvenile package failure at 1,000 years, a major contributor to the dose calculations within 10,000 years. Estimating the rate and timing of juvenile failures is very difficult since the failure mechanisms are hard to predict. With the addition of drip shields, this uncertainty is effectively eliminated since releases would only occur if a drip shield is breached over a package with a juvenile failure -- a very low- probability event.

The performance assessment of the new design should describe the string of processes and events needed to release radionuclides, e.g., the probability that a drip shield would prematurely fail, the probability that a waste package would prematurely fail, the probability that these failures would be co-located, and the probability that a ground water seep would be located over the failed drip shield. A presentation in the final EIS that describes the new design in terms of its expected performance can help justify the design change, support the bounding argument for the older design, and increase confidence in the repository assessment.

Response
As the Environmental Protection Agency notes, the Draft EIS evaluated the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS-101779-DOE 1998) for repository surface facilities, and disposal containers (waste packages). It also evaluated the plans for the construction, operation and

monitoring, and closure of the repository. DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review of the repository by the U.S. Nuclear Regulatory Commission. The design evolution is evaluated in the Supplement to the Draft EIS and integrated into the Final EIS. The Supplement to the Draft EIS incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies. Section 2.3.4 of the Supplement describes the design modifications (engineered barrier designs) including the addition of drip shields and refined waste packages.

With regard to the design process, DOE is moving forward with a final design but acknowledges, as noted above and as documented by the Supplement to the Draft EIS, the design could further evolve. The updated design information presented in the Supplement was carried forward to the Final EIS. However, DOE believes the design has progressed to a point that it provides a reasonable basis for estimating the range of potential short- and long-term impacts that would likely result from any final design.

7.3.1 (6699)
Comment - EIS001632 / 0090
Page 2-58, Section 2.1.4.3: This discussion does little to help the reader understand the design features and alternatives that affect operations and cost. We note that DOE intends to "evaluate the environmental impacts associated with the updated design in the final EIS." This section should be revised to clarify the discussion.

Response
As noted in the comment, DOE indicated in the Draft EIS its intention to evaluate updated designs in the Final EIS. Design updates were first presented and evaluated in the Supplement to the Draft EIS issued in May, 2001 and then integrated into the Final EIS. The Supplement to the Draft EIS presents new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

With regard to the design process, DOE is nearing a final design but acknowledges, as noted above and as documented by the Supplement to the Draft EIS, the design could further evolve. However, DOE believes the design has progressed to a point that it provides a reasonable basis for estimating the range of potential short- and long- term impacts that would likely result from any final design.

7.3.2 UNCERTAINTIES

7.3.2 (216)
Comment - 83 comments summarized
Commenters generally criticized the adequacy of the uncertainty discussions in the EIS. Commenters cited concerns with unavailable data, modeling, and the chaotic nature of the processes being evaluated. In addition, commenters noted expert disagreement and the length of time involved in the process as contributing to the level of uncertainty. As one commenter summarized, long-term impacts are based on arguably incomplete data fed into largely untested models. Several commenters expressed concerns that because of the scientific uncertainties and lack of data, DOE cannot determine with any certainty the long-term impacts of the repository, nor support the preferred alternative. The uncertainties call to question the claims of likely compliance with containment requirements.

Several commenters indicated that the uncertainty discussions were obscure, lack a systematic treatment, and should address a meaningful performance measure. Commenters suggested that real work, experimental work, would be better then testing compliance issues with computers. One commenter specifically criticized the use of the Monte Carlo sampling approach suggesting that any approach that produces a different answer with each calculation constitutes "criminal negligence."

Similar to the expressions of concern over uncertainty, several commenters expressed lack of confidence in long-term scientific projections, in general. Commenters suggested there was an insufficient basis for having any confidence in either the 10,000-year or 1-million-year potential dose calculations. One commenter asked for "a hundred percent confidence beyond a reasonable doubt."

Response

DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency, and Nuclear Regulatory Commission also recognize the difficulty of understanding the behavior of complex systems over long time periods. In 10 CFR Part 63, the Nuclear Regulatory Commission acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." In 40 CFR Part 197, the Environmental Protection Agency establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. The Agency also recognizes the need for expert judgment in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Science observations, DOE has designed performance assessments on a combination of mathematical modeling, natural analogs, and the possibility of remedial action in the event of unforeseen events.

Since publication of the Draft EIS, the Science and Engineering Report (DIRS 153849-DOE 2001) has been published that supported the Supplement to the Draft EIS with the results of a comprehensive quantitative analysis of the possible future behavior of a Yucca Mountain repository. This analysis, known as the *Total System Performance Assessment – Site Recommendation* (DIRS 153246-CRWMS M&O 2000), combined the results of detailed conceptual and numerical models of each of the individual and coupled processes in a single probabilistic model that can be used to assess how a repository might perform over long periods of time. The *Total System Performance Assessment – Site Recommendation* was a next-generation analysis after the *Total System Performance Assessment – Viability Assessment*, used for analysis of long-term performance in the Draft EIS. This new analysis was the result of some significant design changes to the proposed repository and also some further advancement in knowledge from on-going research activities.

Despite the extensive scientific studies described in the Science and Engineering Report, DOE has always recognized that significant uncertainties will remain in any assessment of the performance of a repository over thousands of years, as discussed in the Science and Engineering Report (DIRS 153849-DOE 2001). These uncertainties are attributable to a variety of causes, ranging from uncertainty regarding the fundamental processes that could affect radionuclide migration to uncertainty related to the design and operation of the proposed repository. For this reason, one part of the DOE approach to dealing with uncertainty relies on multiple lines of evidence that may contribute to the understanding of the performance of the proposed repository. Another part of the DOE approach is a commitment to continued testing, monitoring, and analysis beyond the possible recommendation of the site.

One important aspect of the Total System Performance Assessment – Site Recommendation model was a variety of unquantified uncertainties. These are uncertainties for which a realistic distribution of parameters is not identified but rather a very conservative bounding value or bounding range is chosen. Additional studies have been conducted to investigate affects of unquantified uncertainties and sensitivities in the model. Part of the additional studies was to add several features to the Total System Performance Assessment to better quantify uncertainties and the affected processes. An additional report, known as the *FY 01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001), was prepared discussing this additional research and describing the modifications to the Total System Performance Assessment model. (See Section I.2 for more detailed discussion of the evolution of the Total System Performance Assessment model and application to this EIS.) This section summarizes areas in which the Supplemental Science and Performance Analysis model benefited from these additional uncertainty studies. Full details of the studies can be found in the *FY 01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001).

DOE confidence in the disposal techniques is based on defense-in-depth that, for example, places drip shields over waste packages to account for uncertainties. DOE has adopted an assessment approach that explicitly considers the spatial and temporal variability and inherent uncertainties in geologic and biological components, and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment

2. Consideration of features, events and processes that could affect repository performance over the long-term

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario

5. Parameter distributions that represent the possible change of the system over the long term

6. Use of conservative assessments that lead to an overestimation of impacts

7. Performance of sensitivity analyses

8. Use of peer review and oversight

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

DOE continues to evaluate the sufficiency of its approach of dealing with uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

In response to the comment on the Monte Carlo technique, Monte Carlo is a widely accepted technique that randomly samples a range of input variables to produce different answers until enough results exist for a meaningful interpretation. These interpretations involve the application of accepted statistical tests and provide mean values as well as values for less likely outcomes.

7.3.2 (361)
Comment - EIS000043 / 0002
A number of design alternatives and options are described and their impacts evaluated. DOE's expectation is that whatever design is finally selected, its impacts will have been bounded by the analysis of the alternatives and options. The range of possible impacts, however, is wide, and they all lead to releases of radionuclides from the repository that contaminate a groundwater source currently used for drinking water and agricultural purposes in Nye County. What we don't know, and can't know from this Draft EIS, is how much is released, how fast it is released, and how soon it is released. In simple terms, this Draft EIS does not tell us what future risks of the proposed repository are to people and the environment.

Response
The long-term impacts resulting from the Proposed Action are summarized in Chapter 5 of the EIS. Additional detail related to assumptions and methodology used to estimate these impacts has been provided in Appendix I.

The Draft EIS evaluates the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). It also evaluates the plans for the construction, operation and monitoring, and closure of the repository. DOE recognized before it published the Draft EIS that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review by the U.S. Nuclear Regulatory Commission. The design evolution is evaluated in the Supplement

to the Draft EIS and integrated into the Final EIS. The Supplement incorporates new information, including an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. The design will continue to evolve in response to additional site characterization information, technological developments, and interactions with oversight agencies.

The updated analysis in the Final EIS projects that the Proposed Action would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197) and are due to the very unlikely event of between zero and five packages failing due to manufacturing defects.

In addition to the 10,000-year compliance period, DOE has evaluated potential impacts for the period of geologic stability at the repository (that is, 1 million years). DOE performed this evaluation, consistent with 40 CFR Part 197, to gain insight into the very long-term performance of the repository and thus provide information for decisionmakers in making both design and licensing decisions. These results show a mean peak dose rate that would be much lower than background levels (see Chapter 5 for details).

7.3.2 (1090)
Comment - EIS000217 / 0002
Because of grave uncertainties with regard to performance over the long term, it is important to build several layers of redundancy into any geologic storage program. For example, not only do analyses show the ineffectiveness of Yucca Mountain's geology in containing waste, serious questions exist as to whether the canister will perform as projected and even whether the performance of the canister can be characterized with any degree of certainty. A DOE peer review panel criticized the canister containment in this 1998 report:

"Alloy C-22 is susceptible to localized corrosion only when wet in a critical temperature range. If C-22 remains passive in this range, its anticipated life, prior to penetration, is thousands of years. If it is not passive, then its life, prior to penetration, is as little as a few tens of years."

Chris Whipple et al Yucca Mountain Total System Performance Assessment Third Interim Peer Review Panel Report, 1998, pp. 20-22.

Response
The goal of geologic disposal is for engineered and natural barriers to work together to isolate the waste and allow only slow release to the environment to protect the public health and safety.

The waste package would be a principal barrier and its slow corrosion would be an important feature of the design. As noted by the commenter, factors such as critical temperature and chemistry would be crucial in determining the performance of the waste package. Experiments show that Alloy-22 (the waste package material) is not susceptible to localized corrosion in the conditions reasonably anticipated in the repository. The repository design as described in the Final EIS (which includes lower temperatures than described in the Draft EIS) would keep the waste packages cool enough so they would not be susceptible to localized corrosion. The updated analysis in the Final EIS projects the very unlikely event of between zero and five packages failing due to manufacturing defects. This small number of package failures would likely result in extremely small releases of radioactive contamination to the environment in the first 10,000 years after repository closure (more than 100,000 times less than the individual protection standard set by 40 CFR Part 197).

Concerns about uncertainty expressed by the Peer Review Panel and others led to the design presented in the Final EIS. This design includes use of Alloy-22 for the outer rather than the inner layer of the waste package, the addition of titanium drip shields, and the consideration of a lower repository temperature resulting from fuel aging and other operational features.

7.3.2 (5660)
Comment - EIS001887 / 0279
Page 5-21; Section 5.2.4.3.3 - Uncertainty and the Proposed Action

The Draft EIS should compare the "lumped" performance analyses to the discrete analyses with each type of uncertainty isolated. This would provide information on the relative importance of each type of uncertainty so a value assessment can be made of various types of uncertainty reductions. For example, it would be important to know the relative importance of conceptual model uncertainty in the saturated zone flow model.

Response
The EIS contains estimates of the future environmental impacts of operating and closing a repository. The descriptions of these estimates include statements about the uncertainty in them. The EIS discusses uncertainties that existed at the time the analysis was performed, but does not address the estimates if these uncertainties were modified or reduced. Documents referenced in the EIS, such as the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) and the *Yucca Mountain Science and Engineering Report* (DIRS 153849-DOE 2001), investigate uncertainty and sensitivity in performance more fully. These documents and, in turn, their referenced technical documents (such as Process Model Reports and Analysis Model Reports) contain extensive detail on a large number of sensitivity and uncertainty analyses that studied the individual contribution of specific uncertainties.

In response to this and other comments on the Draft EIS, DOE has organized an internal task force to evaluate the sufficiency of the treatment of uncertainty at the process (scientific) and system (modeling) levels. The EIS discussion of uncertainty and its treatment in the supporting documents have benefited from this review.

7.3.2 (5661)
Comment - EIS001887 / 0280
Page 5-22; Section 5.2.4.3.5 - Confidence in the Long-Term Performance Estimates

This section of the Draft EIS concludes with the statement, "The EIS performance assessment represents a 'snapshot in time' and ongoing work will refine that snapshot." In fact, the performance assessment is not analogous to a "snapshot" at all. A snapshot implies a reasonable representation of reality. The Yucca Mountain performance assessment represents a compilation of incomplete data, buttressed by assumptions and guesswork, and analyzed using models of questionable validity in order lend an illusion of accuracy to its conclusions.

Response
DOE conducted iterative long-term repository performance assessments in 1991, 1993, 1995, and 1998 based on Yucca Mountain site and design information available at each of those times. The performance assessment described in the Draft EIS was based on the state of knowledge at the time as described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). The long-term performance described in the Final EIS reflects advances in understanding of repository performance since that time. DOE will continue to collect data, refine designs, upgrade models, and conduct iterative assessments as it proceeds to License Application, construction, operation, and monitoring. Over time, with advances in knowledge and understanding, the iterative Total System Performance Assessment process helps to reduce but not eliminate uncertainty in the predicted repository performance.

DOE acknowledges that it is not possible to predict with certainty what will occur hundreds or thousands of years in the future. The National Academy of Sciences, Environmental Protection Agency, and Nuclear Regulatory Commission also recognize the difficulty of understanding the behavior of complex systems over long time periods. In 10 CFR Part 63, the Nuclear Regulatory Commission acknowledges that "proof that the geologic repository will conform with the objective for postclosure performance are not to be had in the ordinary sense of the word because of the uncertainties inherent in the geologic setting, biosphere and engineered barrier system. For such long-term performance, what is required is reasonable expectation." In 40 CFR Part 197, the Environmental Protection Agency establishes "reasonable expectation" as a test of compliance, with diminished "weight of evidence" with time. The Agency also recognizes the need for expert judgment in assigning scenario probabilities, selecting simulation models, and assigning parameter distributions. Consistent with National Academy of Science observations, DOE has designed performance assessments on a combination of mathematical modeling, natural

analogs, and the possibility of remedial action in the event of unforeseen events. DOE believes this process results in a representative estimation of impacts and is sufficient for comparing the relative merits of the various repository scenarios, including the preferred alternative.

DOE continues to evaluate the sufficiency of its approach of dealing with uncertainty at the process level (scientific) as well as the system level (modeling). A task force is reviewing and outlining further work to be completed on uncertainties before the time of License Application, should the repository be recommended as a suitable site.

7.3.2 (7345)
Comment - EIS001106 / 0023
NEPA [National environmental Policy Act] is meant to assure achievement of high environmental quality far into the future. The full range of uncertain adverse impacts of the YMP [Yucca Mountain Project] that are meaningful in the context of future generations is missing from the YMP DEIS and must be corrected to meet NEPA's purpose for sufficient EIA [environmental impact assessment]. This applies in particular to the interactions between global climate change and future releases of radionuclides into the regional and global environment from the YMP.

Response
The regulations of the Council on Environmental Quality (40 CFR Parts 1500 to 1508) direct Federal agencies to use the process established by the National Environmental Policy Act to identify and assess reasonable alternatives to the proposed actions that could have effects on the quality of the human environment. DOE has prepared this EIS pursuant to those regulations and 10 CFR 1021. Additionally, DOE has adhered to the directions of the NWPA.

While DOE has taken steps to consider the pertinent long-term impacts of its action, uncertainties remain and are discussed (pursuant to 40 CFR 1502.22) in Section 5.2.4 of the EIS. With regard to the specific issue of climate, climate change was included in the long-term performance assessment calculations used to estimate environmental impacts from the repository. These impacts and the specifics of the projections are reported in Chapter 5, 8, and Appendix I of the EIS.

7.3.2 (7402)
Comment - EIS001957 / 0021
Section 5.1 Environmental Consequences of Long Term Repository Performance, Inventory for Performance Assessment Calculations -- Table 5-1 lists the average radionuclide inventory of waste packages to be emplaced at the proposed repository. The table lists nine radionuclides. Other than carbon 14, which has a half-life of 5,700 years, the radionuclides that comprise the proposed waste packages have half-lives that range from 24,000 years (Plutonium 239) to 16,000,000 years (Iodine 129). Neptunium 237, a key radionuclide that is thought to play an important role in human health risk, has a half-life of 2,100,000 years.

Section 5.2.4 Uncertainty Associated with Models and Model Parameters -- The draft EIS states:

"The total system performance model used to assess the impacts from groundwater migration includes a very large number of submodels and requires a large amount of input data to estimate the performance of the system."

In a contrasting article published in the Journal of Ground Water of the Association of Ground Water Scientists & Engineers, July-August 1999, by Konikow and Ewing, entitled: "Is Probabilistic Performance Assessment Enough?", it is stated that:

"The U.S. Department of Energy has just released the congressionally mandated 'total systems performance assessment' as part of the viability assessment of the proposed nuclear waste repository at Yucca Mountain. The linking of multiple complex, deterministic models in the PA approach makes it difficult to find and analyze weaknesses in the underlying conceptual models or even errors generated by faulty linkages and inconsistent assumptions among various submodels. We urge extreme caution before accepting the probabilistic outcomes generated by the PA approach. In summary, we offer a quote from Ansel Adams: "There is nothing more disturbing that a sharp image of a fuzzy concept.'"

There is excessive imprecision in the uncertainty analysis for the proposed repository at Yucca Mountain, due to the coupling of various models, each of which employ many assumptions. The degree of uncertainty in the analysis of

long term environmental consequences is not and cannot be adequately assessed, due to the coupling of these various models, each of which has inherent uncertainty.

Response
The long half-lives of some of the radionuclides to be disposed of in the Yucca Mountain Repository (if it is approved) are why DOE continues to perform evaluations of the peak dose, up to a million years into the future. Regulatory concern exists over attempting to use calculations into the very far future in a licensing setting and therefore these evaluations to peak dose are outside the licensing setting. The uncertainties over the details of the unknowable future would quickly make it impossible to implement these evaluations in a rigorous licensing process.

The Total System Performance Assessment analyses in the EIS is not intended to be a definitive prediction of repository behavior With any impact estimate, there is a level of uncertainty associated with the forecast, especially when estimating over thousands of years. DOE recognizes that uncertainties exist from the onset of an analysis; however, forecasts are valuable in the decisionmaking process because they provide insight based on the best available information and scientific judgements available. Section 5.2.4 of the EIS addresses uncertainty related to total system performance analysis.

7.3.2 (7801)
Comment - EIS001653 / 0004
The FEIS needs to contain a strong worst-case scenario analysis. Currently, there are too many uncertainties in the performance assessment process. It is highly likely that even at the conclusion of the licensing process many uncertainties will still exist. DOE needs to include a worst-case scenario examining the conditions under which the repository waste containment would not achieve regulatory standards. This analysis should describe the probability of occurrence, the likely consequences, and the inherent weaknesses of the performance assessment process used in the DEIS. The FEIS should also clearly identify the progress and or improvements of the performance assessment since the issuance of the DEIS.

Response
The EIS presents the long-term performance results in probabilistic terms – a mean and 95th-percentile result. This statistical spread reflects the range of possible behavior DOE believes is credible for the repository system based on wide ranges of parameters. As such, the "worst case" is contained within the range of results. The worst case could be realized as the results approached at the 100th percentile.

The Draft EIS evaluated the preliminary design concept described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for repository surface facilities, subsurface facilities, and disposal containers (waste packages). It also evaluated the plans for the construction, operation and monitoring, and closure of the repository. DOE recognized that plans for a repository would continue to evolve during the development of any final repository design and as a result of any licensing review by the Nuclear Regulatory Commission. In May 2001, DOE issued a Supplement to the Draft EIS providing information on the evolving design. Section 2.2.1 of the Supplement describes the new performance assessment results. Further updates to the results are described in Sections 2.4 and 5.4 of the Final EIS. Table 5-1 of the Final EIS describes the changes to the models since the Draft EIS.

7.3.2 (9885)
Comment - EIS001888 / 0433
[Clark County summary of comments it has received from the public.]

Still others requested the EIS to adopt "excessive conservatism" to compensate for the magnitude and broad range of uncertainties in projecting analyses of the future.

Response
The use of probabilistic modeling accounts for the wide range of uncertainties in the calculations. The 95th-percentile results (which means 95 percent of the analyses would produce a smaller potential impact than that shown) represent a very conservative case. If there was sensitivity and uncertainty, the analysis often biased input distributions with "pessimistic" values. If there was uncertainty about the appropriate model for a process, DOE generally used the model that produced the least favorable result. DOE believes that these analyses present an

appropriately realistic case (the mean value results), and a very conservative case (the 95th-percentile case). DOE believes these results, in conjunction with other information, are sufficient to allow decisionmakers to decide whether to approve the site for development as a repository.

7.3.2 (11403)
Comment - EIS002251 / 0001
I appreciate the opportunity to ask a question earlier. I feel like it wasn't thoroughly answered, but the answer I did get that the science errs to the side of conservatism tells me that it is not science being used to study Yucca Mountain, and that it is influenced by the scientists. Because if it wasn't, the answer should have been that it is science. There's no possibility of either erring conservatively or otherwise.

Response
Science is a disciplined way of studying nature. However, every aspect of applied science requires some judgment by the scientist. Science is not always as exact and definitive as a scientist could hope. Scientific problems often require judgment and interpretation using the insights gained from similar processes observed in nature and compiling and judging evidence from the past. Because there is uncertainty in the science applied in the study of the proposed Yucca Mountain Repository, the scientists have provided, where possible, ranges of possible conditions and results, rather than a single most likely value. Where there is insufficient data to provide this range, a single conservative estimate is used, so as to err on the side of overestimating consequences rather than underestimating.

Yucca Mountain scientists have carefully documented the bases for their judgments so that others can follow the development of their data and modeling. External and internal reviews by subject-matter experts have been conducted. These reviews have resulted in the evolution of the repository design.

7.3.2 (12109)
Comment - EIS001887 / 0408
Apprehension for future environmental quality has been aroused by concerns such as global warming and accumulations of radioactivity. Adverse consequences of increased environmental perturbations, however, have not always been recognized by the public. Government agencies should educate the public rather than fostering further development at the risk of unexpected environmental impacts. Accomplishing this is a role of the federal government. Means must be found to bring the political will and the missions of agencies closer to implementing the values expressed in NEPA's [National Environmental Policy Act] intent. NEPA is meant to assure achievement of high environmental quality far into the future. The full range of uncertain adverse impacts of the YMP [Yucca Mountain Project] that are meaningful in the context of future generations is missing from the DEIS and must be corrected to meet NEPA's purpose for sufficient EIA [environmental impact assessment]. This applies in particular to the interactions between global climate change and future releases of radionuclides into the regional and global environment from the YMP.

Response
The regulations of the Council on Environmental Quality (40 CFR Parts 1500 to 1508) direct Federal agencies to use the process established by the National Environmental Policy Act to identify and assess reasonable alternatives to the proposed actions that could have effects on the quality of the human environment. DOE has prepared this EIS consistent with those regulations and 10 CFR 1021. Additionally, DOE has adhered to the directions of the NWPA. As part of that process DOE has hosted public scoping meetings, informational sessions, and solicited comments. While DOE has taken steps to consider the pertinent long-term impacts of its action, uncertainties remain and are discussed (pursuant to 40 CFR 1502.22) in Section 5.2.4 of the EIS.

The potential long-term impacts presented in Chapter 5 and Appendix I of the Draft EIS do account for future climate change. However, DOE improved the future climate model for the Final EIS to reduce the uncertainty in climatic effects on the repository. The climate change scenarios are provided in reports referenced in the EIS. The impacts estimated for a 1-million-year period after closure of the repository were based on a careful evaluation of any releases of radionuclides as well as other hazardous materials. The range of possible impacts reported is based on probabilistic analyses.

The commenter indicates that further development should not be fostered at the risk of unexpected environmental impacts. The situation, however, is that the materials that would be placed in the proposed repository exist now.

The requirement for an ultimate permanent solution to the waste problem would remain even if the Proposed Action was not carried out. Chapter 7 of the EIS discusses the potential environmental impacts of the No-Action Alternative.

7.4 Repository Accidents

7.4 (41)
Comment - 3 comments summarized
Commenters stated that human error is a common initiator for accidents, citing examples of the recent nuclear accident at the Tokaimura nuclear fuel plant in Japan and past accidents in Russia and elsewhere. Commenters suggested that DOE has completely ignored human error as an accident initiator for any stage of repository construction, operation, monitoring and closure.

Response
DOE agrees that human error is a potential accident initiator and has considered human error in the EIS in the analyses of potential accidents. Appendix H of the EIS documents an analysis of potential accidents that could happen at a repository. The range of accidents considered includes events that could be initiated from both human error (for example, fuel assembly drop accidents) and external events (for example, earthquakes and volcanoes). Appendix H and its references describe the applicable analyses and the results. The results of a set of 10 potential accidents (based on screening described in Appendix H) are shown in Tables 4-36 and 4-37 of the EIS. Impacts to any member of the public resulting from the complete spectrum of credible events (those having an annual probability of 1 chance in 10 million or greater) would result in a radiation dose of no more than a few millirem even if no action was taken to avoid exposure after an accident occurred. Spent nuclear fuel handling and transportation operations would be designed so that the consequences of accidents caused by human error are limited and localized. For example, during transfer operations, lifting heights would be limited so that accidental drops of radioactive material would not be expected to result in an uncontained release of radioactive material.

7.4 (67)
Comment - 3 comments summarized
Commenters expressed concern over the selection of older fuel for accident analysis in the DEIS and the fact that the Supplement did not consider transportation analysis.

Response
As a result of similar comments on the Draft EIS, DOE has reevaluated the fuel characteristics used for the base case accident analyses based on a hazard index approach as described in Section A. 2.1.5. The revised fuel used for the analyses in the Final EIS is younger than the fuel used in the Draft EIS. For example, the pressurized-water reactor fuel now used in the accident analyses ("representative" fuel) is 15 years old rather than 26 years old as assumed in the Draft EIS. DOE has also performed sensitivity analyses to determine the relationship between accident impacts and fuel characteristics. These studies indicate that the hottest fuel to be received at the repository (5 years old) would produce impacts about 3 times higher than the representative fuel selected for the analysis. Accidents involving transportation casks and waste packages would not involve only the hottest fuel because licensing limitations preclude loading these containers with only the hottest fuel.

Transportation analysis is beyond the scope of the Supplement to the Draft EIS. As indicated in Section 1.2 of the Supplement, the scope was limited to changes in the proposed repository design and operating modes. The transportation analysis has been extensively revised for the Final EIS to incorporate the new fuel characteristics and other relevant information (See Chapter 6 and Appendix J).

7.4 (87)
Comment - 10 comments summarized
Commenters were concerned about the potential impact of catastrophic accidents at Yucca Mountain. Such catastrophic event cited included seismic events, a nuclear meltdown, meteor strikes, and impact from aerospace objects originating from proposed launch facilities at the Nevada Test Site. Some commenters stated that the impacts of such events would be compounded by concentrating the nuclear waste at one repository as opposed to scattered storage locations.