APPENDIX K

SUMMARY OF RECENT INFORMATION RELEVANT TO THE PRELIMINARY PRECLOSURE SAFETY ASSESSMENT INPUTS

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SUMMARY OF RECENT INFORMATION RELEVANT TO PRECLOSURE SAFETY ASSESSMENT INPUTS

1. INTRODUCTION

This white paper contains a summary of recent test results and other additional information that are relevant to the preclosure safety assessment inputs used to support the *Yucca Mountain Science and Engineering Report* (DOE 2001a) and the *Yucca Mountain Preliminary Site Suitability Evaluation* (DOE 2001b). The U.S. Department of Energy (DOE) released these two documents for public review in May and August, respectively, of this year.

The white paper focuses on the results of those field and laboratory tests and other additional information that became available after the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* (BSC 2001a) was completed to support the preparation of the *Yucca Mountain Science and Engineering Report* (DOE 2001a) and the *Yucca Mountain Preliminary Site Suitability Evaluation* (DOE 2001b). The summary of this recent information is being used to conduct an impact review, in accordance with AP-2.14Q, *Review of Technical Products and Data*, to determine if this additional information has an impact on the technical analyses supporting the *Yucca Mountain Science and Engineering Report* and the *Yucca Mountain Preliminary Site Suitability Evaluation*. The documentation of the additional information in this white paper is only an interim step, and primarily used to support this impact review. This information is expected to be formally documented in subsequent Project technical reports, as appropriate.

To assist in the impact review, this white paper briefly describes the preclosure safety assessment inputs that were used to support the *Yucca Mountain Science and Engineering Report* (DOE 2001a) and the *Yucca Mountain Preliminary Site Suitability Evaluation* (DOE 2001b), provides a summary of the recent test results and other additional information, and discusses the potential implications of this additional information on the preclosure safety assessment inputs.

2. SUMMARY DESCRIPTION OF THE PRECLOSURE SAFETY ASSESSMENT INPUTS

The *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* (hereafter termed PPSA) (BSC 2001a) comprises a structured and comprehensive examination of potential hazards and event sequences that could result in releases of radioactivity to the environment or radiological exposures to workers. The analysis is limited to the operations and storage in the period before permanent closure of the potential monitored geologic repository. Section 5 of the PPSA (BSC 2001a), "Hazard and Design Basis Event Analysis", (BSC 2001a) describes the processes and respective results associated with identifying hazards, developing event sequences, and evaluating associated consequences. Principal inputs to the "Hazard and Design Basis Event Analysis" are described in Section 3, "Site Characteristics," and Section 4, "Facility Description," of the PPSA (BSC 2001a). This white paper identifies test results and additional information that could potentially affect the inputs to these sections. In addition, additional information specific to the likelihood of initiating events and the reliability of equipment are identified such that the potential impact can be evaluated.

The preclosure safety assessment is initiated with hazards analyses to identify, respectively, the natural phenomena and man-made hazards that could potentially initiate an event, or an event sequence, that results in the release of, or exposure to, radioactivity. Lists of potential hazards are subjected to screening analyses to identify those hazards that have one chance in 10,000 of occurring before permanent closure based on final 10 CFR Part 63 (66 FR 55732) performance criteria.

The criteria for determining which structures, systems, and components (SSCs) are important to safety are based on the performance requirements of final 10 CFR 63.111 (66 FR 55732), which specifies dose objectives for the public and repository workers according to the frequency category associated with an event sequence initiated by either a human induced or natural event. One parameter that effects the calculation of the dose received is the atmospheric dispersion factor (χ/Q), which is influenced by the meteorological conditions near the potential site.

Using guidance from the hazards and event sequence analyses, nuclear safety design criteria were developed in the System Description Documents to ensure that SSCs important to safety, as appropriate, will be designed to (1) withstand natural phenomena without loss of safety functions, or (2) ensure sufficiently low probability of failure such that the event sequences are prevented or mitigated to within regulatory performance criteria. Potentially, information from geological tests and ongoing meteorological measurements could influence the design criteria or the specific values of parameters that are input to the facility design.

To ensure that the SSCs important to safety are able to withstand the natural phenomena, the design process applies methods based on regulatory precedents from the commercial nuclear industry. For each natural phenomenon applicable to the monitored geologic repository, initiating events are defined (e.g., earthquakes, floods, winds, and tornadoes) by design input parameters that represent the energy that could be transmitted to a given SSC. Such design parameters include the peak ground accelerations for the bounding earthquakes, maximum wind velocity, tornado missile spectra (mass and velocities), and level of the Probable Maximum Flood. The characteristics of the design basis natural phenomena are specific to the potential repository site and are subject to site-specific tests and measurements. Using regulatory precedents and policies of the Nuclear Regulatory Commission (NRC), however, design methods and input parameters for natural phenomena are prescribed from generic or regional information to conservatively bound site-specific parameters.

The seismic design bases for SSCs important to safety have been established through *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (YMP 1997), otherwise known as "Seismic Topical Report No. 2." This topical report defines two earthquakes termed Frequency Category 1 and Frequency Category 2. The purpose of the recently acquired geotechnical data at the proposed site and the ongoing analyses of these data is to establish improved estimates of vibratory ground motion for the respective earthquakes. The ground motion estimates, to be documented in the forthcoming Seismic Topical Report No. 3, will be applied in the design of SSCs that must withstand these respective earthquakes. The role of preclosure safety analysis is to identify which SSCs important to safety must withstand the respective Frequency Category 1 or Frequency Category 2 earthquake. The results from the preclosure safety analysis are used to determine if Frequency Category 1 or Frequency Category 2 earthquake design criteria are required for individual SSCs. The designer then must

apply the seismic parameters appropriate to the criteria (e.g., the ground accelerations for the appropriate earthquake).

Although wind-speeds have been measured for the proposed site as part of a continuing meteorological program, the NRC has prescribed methods for bounding extreme wind speeds, maximum tornado wind speeds, and tornado missile characteristics. Therefore, continuing measurements of wind speeds are not expected to affect the design input. Instead, the additional data are expected to corroborate that the current design bases are bounding. Similarly, the current Design Basis Flood (the Probable Maximum Flood) for the site is based on regional climatological data processed in accordance with NRC precedents.

The analysis of human-induced hazards external to the monitored geologic repository applied screening criteria to identify event sequences having one chance in 10,000 of occurring before permanent closure. Analyses of aircraft crash probability, documented in the *MGR Aircraft Crash Frequency Analysis* (CRWMS M&O 1999a), have been performed in accordance with the *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* (NRC 1987), taking into account potential crashes of commercial, private, DOE, and military aircraft. The military aircraft from the Nellis Air Force Base were shown to be the dominant contributor to the probability of a crash on the surface facilities. However, the probability of this event was shown to not have one chance in 10,000 of occurring before permanent closure by the performance objectives of final 10 CFR Part 63 (66 FR 55732). In Section A4.2 of the PPSA (BSC 2001a), the conservatism that was used in that analysis are presented.

The probabilities of internal hazards evaluated in the preclosure safety analysis are, with one exception, independent of the site. The identified potential radiological release scenarios involve equipment failure and/or human errors in handling or processing the waste forms. Estimates of probabilities of such events are derived from equipment databases and/or industry reports. The only site-related internal event identified is associated with the possibility of a large rock (keyblock) falling onto one or more waste packages during the preclosure storage in the emplacement drifts.

The probability of a keyblock fall is influenced by the joint properties of the host rock. Extensive mapping of joint properties has been conducted in the lithologic units of the potential repository. Probabilistic keyblock analyses have been performed to quantify the number of potential keyblocks that may occur per unit length of emplacement drift and the probability distribution of keyblock masses. These results were presented in the *Drift Degradation Analysis* (BSC 2001b). The probability of a radioactive material release scenario initiated by a rockfall, however, includes not only the probability distribution of keyblocks but also the probability of failure of the ground support system (i.e., steel sets and rock bolts), the probability of striking a waste package, and the probability of waste package breach, as reported in *Update to Waste Package DBE Rockfall Analysis* (BSC 2001c). Historical information has been collected on ground support systems (steel sets and rock bolts) that have been installed to date as part of the Exploratory Studies Facility. This information was used in the analysis of ground support system reliability. Analyses have been performed to quantify the probability of a rockfall that exceeds the design basis of a waste package, as reported in *Preclosure Design Basis Events Related to Waste Packages* (CRWMS M&O 2000) and the *Update to Waste Package DBE Rockfall Analysis* (BSC 2001c). Results reported in the PPSA (BSC 2001a) indicate that such an

event does not result in sequences having one chance in 10,000 of occurring before permanent closure for cases involving preclosure periods lasting 50 to 125 years.

A 6 MT rock was used as the size of the key block for the design basis of the waste package analyzed as part of the rockfall event in the PPSA (BSC 2001a). The design basis for the monitored geologic repository ground support is to prevent a 6 MT rock or larger from falling on the waste package during the preclosure period. Historically, this design basis was based on analyses that assumed an idealized, perfectly spherical and unyielding, rock mass impinging on the side of a horizontally oriented waste package. This assumption leads to maximum potential damage to a waste package.

3. SUMMARY OF RECENT TEST RESULTS AND OTHER ADDITIONAL INFORMATION

This section summarizes recent activities that may provide information relevant to preclosure safety assessment inputs. The tests, data, and other sources of information that could impact inputs to preclosure safety assessments include the following.

1. Meteorological and climatological measurements
2. Preclosure rockfall analyses
3. Seismic parameters
4. Aircraft activity in the proposed site vicinity
5. Risk of heavy load drops.

Because of the recent nature of the information provided in this section, much of it is unpublished and, therefore, some source references have been provided where appropriate, but others could not be provided. However, this information is currently documented in the principal investigators' scientific notebooks, if applicable, in accordance with the Project's quality assurance procedure AP-SIII.1Q, *Scientific Notebooks*.

3.1 METEOROLOGICAL AND CLIMATOLOGICAL MEASUREMENTS

The current meteorological monitoring program is continuing to document meteorological conditions in the vicinity of Yucca Mountain to satisfy a variety of purposes. The data are used for environmental compliance, site operations health and safety concerns, engineering design and repository licensing requirements, and performance confirmation. The meteorological program continues to be operated as a quality-affecting program collecting "Q" data.

Four stations measure a broad range of conditions, including wind, temperature, humidity, barometric pressure, solar radiation, precipitation, and atmospheric dispersion conditions. Five more stations measure precipitation, temperature and humidity, and three more stations only measure precipitation. The stations range from upper Yucca Wash north of Yucca Mountain through Midway Valley and Yucca Mountain to NTS Gate 510 in Amargosa Valley. In addition to basic averaging, various statistical parameters such as gust wind speed values are also recorded for engineering applications. Six of the sites recently had radio telemetry added to enhance utilizing current information for health and safety purposes and to increase the efficiency of checking station operations.

Data collected in the on-going program are summarized for environmental compliance reports. The data are also submitted to the Technical Data Management System for use in updating engineering design information, such as extreme rainfall events. However, there has been no analysis performed on the data since publication of *Engineering Design Climatology and Regional Meteorological Conditions Report* (CRWMS M&O 1997). That data were used as input to *MGR Design Basis Extreme Wind/Tornado Analysis* (CRWMS M&O 1999b), which demonstrated that tornado wind speeds based on NRC precedents bounds the site-specific maximum wind speed.

Rainfall data also continue to be collected. However, there has been no analysis performed on the data since publication of *PMF (Probable Maximum Flood) Study for Nevada Nuclear Waste Storage Investigation Project* (Bullard 1986). The estimate of the Probable Maximum Flood for the site is based on conservative NRC precedents. The most recent climatological information corroborates the conclusion that estimates of the Probable Maximum Flood are bounding.

Additionally, new meteorological information could potentially affect the analysis of the atmospheric dispersion factor (χ/Q) used in the consequence analysis in the PPSA (BSC 2001a). A preliminary examination of the routine meteorological information, however, indicates no significant differences from the information used to develop the values of χ/Q used in the input to the PSSA. The input values of χ/Q used in the PPSA (BSC 2001a) are documented in *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c).

3.2 PRECLOSURE ROCKFALL ANALYSES

There has been no new mapping of joint properties in the lithologic units of the potential repository relevant to the keyblock analysis. Therefore, the probabilistic keyblock analyses that have been performed to date, and which supported the PPSA (BSC 2001a), remain valid. This information, reported in *Update to Waste Package DBE Rockfall Analysis* (BSC 2001c), is used as input to the analysis, currently in progress, to quantify the probability of a rockfall-initiated breach of a waste package.

The analysis of the probability of a waste package breach initiated by a rockfall has been continuing since the completion of *Preclosure Design Basis Events Related to Waste Packages* (CRWMS M&O 2000). The current analysis has a modified reliability model for the preliminary ground support system design in lithologic units where steelsets and rock bolts are, or are not, used concurrently. This analysis supports the design by evaluating the performance of the ground support in meeting the design basis of preventing a 6 MT rockfall or greater during the preclosure period. The results of this ongoing analysis does affect the estimate of probability of the rockfall scenario by changing the probability that the ground support system fails to prevent the fall of a keyblock. This information is used to refine the preliminary design features of the ground support.

3.3 STUDIES OF SEISMIC PARAMETERS

Analyses are being completed to provide design input parameters for SSCs and to support publication of Seismic Topical Report No. 3 (see the white paper or disruptive events—

volcanism and seismicity, Appendix I). Analyses to develop seismic design inputs using the expanded set of geotechnical data have not yet been completed. A number of factors contribute to the effect of the upper 300 m (1,000 ft) of rock and soil on the site-specific ground motions (e.g., the magnitude and depth of impedance contrasts associated with the velocity profile, the linearity of variations in dynamic properties as a function of shear strain). Thus, it is not possible to estimate with confidence the integrated effect of the additional data relative to previous results without carrying out the actual analyses. The expanded geotechnical data set and the ongoing analyses are expected to result in added confidence in the ground motion estimates.

3.4 AIRCRAFT ACTIVITY IN THE VICINITY OF THE POTENTIAL REPOSITORY SITE

The Yucca Mountain Site Characterization Project is continuing to collect information on flight frequencies and pathways for Nellis Air Force Base and other aircraft activity in the vicinity of the proposed monitored geologic repository site. Recent information indicates that the average number of flights (based on 2 additional years of recorded information) has increased from 12,717 flights per year approximately 17,394 flights per year over the Nevada Test Site. Additional information was obtained for flights in an area centered on the proposed monitored geologic repository site. The area is approximately 11 km by 11 km (7 mi by 7 mi). The number of flights in this area was 1,726 flights per year, based on information collected over 1 year. Approximately 10 percent of the total flights over the Nevada Test Site are over the 11-km by 11-km (7-mi by 7-mi) area (1,726/17,394 or 0.10) centered on the potential repository site based on this limited data.

3.5 INFORMATION CONCERNING THE RISK OF HEAVY LOAD DROPS

An NRC draft report, titled *Technical Assessment Generic Issue 186: Potential Risk and Consequences of Heavy Load Drops in Nuclear Power Plants* (Lloyd 2001), which became available in 2001, presents an analysis of the risk of heavy load drops that updates the estimates of crane failures beyond the information used in the PPSA (BSC 2001a). This draft report, derived from actuarial experience from nuclear power plants from 1980 to October 1999, provides information on causal factors, effects of "single-failure proof" ratings, and probability of load drops.

The draft report (Lloyd 2001) provides an estimate of the frequency of heavy load drops at nuclear plants:

> "For very heavy loads occurring at plants having an operating license there were no load drops of any consequence. To be conservative, one load drop was assumed to occur during the period of interest. Assuming that the number of very heavy load lifts was approximately 47400, the load drop frequency (drops/number of lifts) was calculated to be approximately 2×10^{-5} (1/47,400 lifts)."

This estimate has been made for loads greater than 30 tons.

4. IMPLICATIONS OF RECENT TEST RESULTS AND OTHER ADDITIONAL INFORMATION

The previous section identified tests and additional information that are directly or indirectly related to preclosure safety inputs that has been generated since the preparation of the PPSA (BSC 2001a). In this section the implications of recent test results and other additional information on the preclosure safety analysis inputs is described.

4.1 METEOROLOGICAL AND CLIMATOLOGICAL MEASUREMENTS

A qualitative evaluation of the rainfall, windspeed events, and atmospheric dispersion factors collected since the PPSA (BSC 2001a) was issued concluded that the data do not vary significantly from meteorological and climatological data collected in previous years. Data collected in the ongoing program are summarized for environmental compliance reports. The data are also submitted to the Technical Data Management System for use in updating engineering design information, such as recent extreme rainfall events. These events have not exceeded the maximum estimated values provided in previous reports. The implication of meteorological and climatological measurements are that the PPSA (BSC 2001a) dispersion factors and selection of external events remains appropriate.

4.2 PRECLOSURE ROCKFALL ANALYSIS

There has been no new mapping of joint properties in the lithologic units of the potential repository relevant to the keyblock analysis. Therefore, the probabilistic keyblock analyses that have been performed to date, and which supported the PPSA (BSC 2001a), remain valid. For the base case scenario loaded with 70,000 MTHM, a rockfall equal to or greater than 6 metric tons is expected to not have one chance in 10,000 of occurring before permanent closure. The ground support design meets the design basis of prventing a 6 MT rockfall or greater during the preclosure period.

However, for other repository scenarios, rockfall greater than 6 metric tons has one chance in 10,000 or greater of occurring before permanent closure. The ground support design basis is not met for some scenarios. The draft calculation (BSC, in preparation) recommended further investigation of ground support reliability/design to improve the performance of the preliminary ground support design. In addition, the draft calculation suggests that the design mass of 6 MT used for the rockfall could be changed to a higher value. The implication of the updated rockfall analysis is that ground support reliability or other design optimizations should be considered to reduce the frequency of rockfall such that the monitored geologic repository design basis requirement for the ground support is met for all flexible design scenarios (DOE 2001a).

4.3 SEISMIC PARAMETERS

While ongoing seismic analyses incorporating the expanded geotechnical data set are expected to result in added confidence in the seismic design basis inputs, the final inputs are not expected to change the conclusions in the PPSA (BSC 2001a) concerning compliance to the performance criteria. The amount of uncertainty incorporated into site-specific ground motions for the repository block, based on limited velocity data available in 1999, appears to be more than is warranted based on the additional data. Higher ground motions resulting from uncertainty,

therefore, should be reduced. The estimation of the earthquake parameters used to define Frequency Category 1 or 2 earthquakes become design parameters for SSCs important to safety. The implication of ongoing seismic analyses is that earlier uncertainty was too large and that ground motions should be reduced.

4.4 AIRCRAFT ACTIVITY IN VICINITY OF SITE

The mean number flights estimate in *MGR Aircraft Crash Frequency Analysis* (CRWMS M&O 1999a) is 12,717 flights per year. The number of flights per year is used to estimate the aircraft hit frequency at the site. Two models were used to estimate this frequency. The crash hit best estimate frequencies range from 1.59×10^{-7} per year using the Uniform Overflight Density Model to 2.8×10^{-7} per year using the model in the *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* (NRC 1987). The additional information indicates that the number of flights over the Nevada Test Site has increased over the period information was collected as compared to the period analyzed in *MGR Aircraft Crash Frequency Analysis* (CRWMS M&O 1999a). The average number of flights per year have increased to an average of 17,394 flights per year over the total period that information has been collected. Based on the increase in flight counts, the mean aircraft crash frequency will increase by approximately 37 percent. The implication of the new flight information is that the aircraft hit frequency used on the PPSA (BSC 2001a) has increased, but remains below one chance in 10,000 of occurring before permanent closure. The conclusion in the PPSA (BSC 2001a) concerning aircraft crashes remains unchanged.

4.5 RISK OF HEAVY LOAD DROPS

The estimate of heavy load drops at nuclear power plants made in the draft NRC report, *Technical Assessment Generic Issue 186: Potential Risk and Consequences of Heavy Load Drops in Nuclear Power Plants*, (Lloyd 2001) indicates that for cranes the drop frequency is estimated to be 2×10^{-5} drops per lift. The estimated failure rate for heavy lift cranes used to estimate event sequences in the PPSA (BSC 2001a) was 1.4×10^{-5} drops per lift. The estimate from the draft NRC report (Lloyd 2001) is a factor of 1.4 higher than used in the PPSA (BSC 2001a). The use of a higher frequency estimate for heavy loads drops would increase the frequency of event sequences in the PPSA (BSC 2001a). However, the use of a more realistic statistical model (such as the Bayesian statistical model) results in a drop frequency of 1.1×10^{-5} drops per lift (based on 47,400 lifts with no drops of any consequence). This drop frequency is smaller than the value used in the PPSA (1.4×10^{-5} drops per lift) (BSC 2001a). Therefore, no significant implications are expected to the conclusions reached in the PPSA (BSC 2001a) based on the recalculation of the heavy load drop frequency using data from the NRC draft report.

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