# Department of Energy

Washington, DC 20585

JAN 2 7 1997

MEMORANDUM FOR MARIO P. FIORI
MANAGER
SAVANNAH RIVER OPERATIONS OFFICE

FROM: Alvin L. Alm
Assistant Secretary for Environmental Management

SUBJECT: H-Canyon Seismic Issue and Nuclear Material Stabilization Activities

I have reviewed the attached December 1996 Supplement Analysis on the ability of H-Canyon to survive a severe seismic event in accordance with applicable Departmental standards and orders as well as your November 27, 1996, memorandum and their relation to completed National Environmental Policy Act (NEPA) documentation. I have approved the Supplement Analysis and have concluded that the new information related to the H-Canyon seismic issue does not affect the quality of the human environment in a significant manner or to a significant extent not already considered in the Interim Management of Nuclear Materials (IMNM) Final Environmental Impact Statement (EIS). The new analyses demonstrate that the ability of the H-Canyon facilities to survive a severe seismic event is equal to or better than that calculated in the existing Safety Analysis Reports and the IMNM EIS. Therefore, I have determined, in accordance with 40 CFR 1502.9(c) and 10 CFR 1021.314(c), that a supplemental EIS is not required.

Attachment

U.S. Department of Energy

# SUPPLEMENT ANALYSIS OF SEISMIC ACTIVITY ON H-CANYON

APPROVED [signature]

Alvin L. Alm
Assistant Secretary for
Environmental Management

DATE 27 January 1997

# SUPPLEMENT ANALYSIS OF SEISMIC ACTIVITY ON H-CANYON

December 1996

## PURPOSE AND SCOPE

The Department of Energy (DOE) issued a *Final Environmental Impact Statement on the Interim Management of Nuclear Materials at the Savannah River Site* (IMNM EIS) in October 1995 (DOE/EIS-0220). DOE has issued three records of decision based on the IMNM EIS regarding stabilization of certain nuclear materials in the canyon facilities, including H-Canyon. Recently, new information became available related to the seismic safety analyses contained in the IMNM EIS.

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA), 40 CFR 1502.9(c), direct federal agencies to prepare a supplement to an environmental impact statement (EIS) when an agency "makes substantial changes in the proposed action that are relevant to environmental concerns, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts."

DOE regulations for compliance with NEPA (10 CFR 1021.314) direct that, when it is unclear whether a supplemental EIS is required, DOE is to prepare a supplement analysis to assist in making that determination. This supplement analysis evaluates new information regarding the effect of a severe earthquake on H-Canyon at the Savannah River Site (SRS), and compares the potential earthquake accident impacts based on the new information with the evaluation of earthquake accident impacts presented in the IMNM EIS.

## SUMMARY

In October 1995, DOE issued the IMNM EIS regarding the interim management of certain nuclear materials at the SRS. As described and analyzed in the EIS, DOE proposed to stabilize some of these materials by processing them in the canyon facilities, including H-Canyon. As part of the analysis, the EIS estimated the amount of radioactive material that could be released from H-Canyon into the environment as a result of a severe earthquake[1].

[1] The earthquake used in the accident analysis of the IMNM EIS was an event with a response spectrum (a profile of ground acceleration over a range of frequencies of motion) and peak ground acceleration (a fraction or multiple of the acceleration of gravity measured in "g's") as defined by J.A. Blume & Associates Engineers (Blume) for the SRS in the early 1980's. A frequency of occurrence (or return period) of once every 5000 years was assigned to correspond to the Blume earthquake.

The EIS's estimate of how H-Canyon would perform structurally during such an earthquake was based on data contained in existing Safety Analysis Reports (SARs) (Safety Analysis -200 Area Savannah River Plant H-Canyon Operations DPSTSA-200-10 Supplement-5 and Safety Analysis -200 Area Savannah River Plant HB-Line Operations DPSTSA-200-10-2) that, in turn, relied on information developed in the 1980s. While the Westinghouse Savannah River Company (WSRC) was reviewing safety documentation for the H-Canyon at the Savannah River Site, it discovered that the seismic analyses performed in the early 1980s were based on assumptions that were inconsistent with the as-built condition of H-Canyon (e.g., the degree of overlap of reinforcement steel was in some cases less than assumed for the EIS analysis).

The issue presented by the new information under NEPA was whether the as-built condition of H-Canyon would result in significantly greater radioactive releases due to building degradation as a result of a severe earthquake than are estimated in the IMNM EIS. For DOE to be able to resolve this issue (and the related issue of whether new radioactive materials should be introduced into H-Canyon for stabilization), WRSC had to complete its on-going seismic analysis. In completing its analysis, WSRC not only considered the as-built condition of the Canyon, but also incorporated the most current information available about the probable size and frequency of a severe earthquake in the region where the Savannah River Site is located (WSRCa).

The new seismic analysis was prepared by WRSC with input from its consultants. The engineers and scientists involved in the preparation of the seismic evaluation are experts in their respective fields, and in many cases are nationally recognized for their contributions to the science of seismic and structural analysis.

Incorporating up-to-date seismic data, WSRC completed a detailed evaluation of the likelihood of a severe earthquake and the estimated resulting structural damage of H-Canyon. This evaluation indicated that a severe earthquake capable of producing structural damage comparable to that described in the IMNM EIS would not occur more frequently than once in 5500 years. That is less frequent than the severe earthquake occurrence assumed in the IMNM EIS (1/5000 years). Within the frequency range for which the canyon is most susceptible to damage from ground motion (i.e., about 0.35 to 0.85 Hz), the response spectrum associated with the 5500 year earthquake was determined to be about the same or slightly greater than the Blume spectrum.

Two other comparisons were also made. First, based on the new WSRC structural analysis building models, an estimate was made of the probability of structural failure[2] at the Blume response spectra (i.e., the as-built H-Canyon was subjected to the same magnitude earthquake as analyzed in the IMNM EIS). This probability of failure ranged from about 8 percent to 41 percent, which would indicate that a lower level of structural damage would result compared to that estimated in the IMNM EIS (equivalent to 50% probability of failure) for the same Blume earthquake. Second, an estimate was made of the probability of failure for an earthquake estimated

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[2] Throughout this document the term "failure," when applied to the new seismic analysis work of WSRC, does not mean building collapse. It means the onset of cyclic strength degradation in the important load-bearing joints of the structure. The onset of cyclic strength degradation is the point where the strength of the structural elements begins to degrade significantly as a result of the cyclic earthquake motion.

to have a 5000 year return period based on the new WSRC structural analysis. In the case of the current 5000 year earthquake, the new WSRC structural analysis building models indicate that the probability of failure is about 40% percent, a lower level of damage than considered in the IMNM EIS. These two comparisons indicate that the as-built condition of H-Canyon would sustain a similar (or slightly lower) level of damage for both the current 5000-year earthquake and Blume response spectra than that predicted in the IMNM EIS.

Collectively, the new and more detailed analyses indicate that irrespective of the comparison (i.e., severity of earthquake needed to produce the same level of damage to H-Canyon described in the IMNM EIS; the level of damage produced by the same Blume earthquake; or the level of damage produced by the revised 5000-year earthquake), the seismic risk at H-Canyon would be less than that indicated in the EIS. As a result, the potential release of radioactive materials to the environment during a severe earthquake, and thus the resulting health effects (expressed in latent cancer fatalities), are expected to be no greater than those described in the IMNM EIS.

Current DOE safety requirements specify that facilities like H-Canyon must be able to withstand an Evaluation Basis Earthquake[3] (EBE) of a 2000-year frequency (which would be less severe than the earthquake associated with the Blume spectra used in the IMNM EIS). The WSRC analysis demonstrated that the probability of failure for H-Canyon in an EBE was about 1%. Thus, the probability of structural damage from an EBE event would be very low.

The WSRC seismic analysis was evaluated by a team from the DOE Savannah River Operations Office and the DOE Office of Environmental Management (DOEa). This team consisted of federal engineers with expertise in the area of seismic and structural evaluations, and consultants from the Earthquake Research Center at the City College of New York. They concluded that the WSRC work met the requirements established by DOE for seismic evaluations and that the H-Canyon structure met DOE seismic performance criteria.

Upon request by the Under Secretary, an independent review of the WSRC analysis was performed by the DOE Office of Environment, Safety and Health (DOEb). This review team consisted of federal and contract support engineering staff with specialties in structural analysis, and consultants who are nationally recognized experts in the areas of seismic hazard estimation, geotechnical analysis, structural analysis and failure probability and fragility analysis. The team concluded that the WSRC analysis was based on accepted engineering practices and principles and judged the WSRC analyses to be conservative (i.e., tending to overstate the risks). The team determined that the results of the WSRC failure analysis met applicable DOE seismic criteria.

On this basis, DOE has determined that the new seismic analyses based on the as-built condition of H-Canyon do not constitute significant new circumstances or information relevant to environmental concerns, and therefore no supplement to the IMNM EIS need be prepared.

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[3] An evaluation basis earthquake is the earthquake an existing facility must be able to withstand to be in compliance with the requirements of applicable DOE Orders and Standards.

## BACKGROUND

### A. Description of H-Canyon

Building 221-H, called H-Canyon, is located in the H-Area of the Savannah River Site (SRS). The building was constructed of reinforced concrete in the early 1950's and consists of four interior floor levels and a roof, which is the fifth level. The bottom of the 5' thick base-mat (or foundation) is located 20' below grade and the building extends to a height of about 51' above grade to the top of the fifth level. The building is about 850' long and 120' wide and is composed of 18 separate sections, each about 43' long (except section 1, which is about 90' long). Each of the 43' sections weighs about 12,000 tons. The exterior walls are over 4' thick at the base of the structure and over 2.5' thick at the roof. The roof slab thickness varies from 2.5' to 3.5'. The interface between each section is an expansion joint which is 1/2" wide. The expansion joints are keyed to fit into one another and are sealed with a pre-molded fill similar to asphalt. In the 1980's a penthouse structure, called HB-Line, was added on top of H-Canyon. The HB-Line consists of a two-story reinforced concrete frame structure over sections 2 through 6 of H-Canyon. The HB-Line structure is about 215' long, 70' wide and 40' high, and was constructed in 43' long sections to match the H-Canyon below.

Initially, the primary use of the H-Canyon was to chemically dissolve spent nuclear fuel from the SRS production reactors and recover the highly-enriched uranium. These activities ceased in the early 1990's and the facility is now being used to stabilize nuclear material left over from the era of nuclear weapons production. HB-Line was used primarily to produce plutonium-238, used by the National Aeronautics and Space Administration as a power source for deep space probes. The plutonium-238 production mission was completed in mid-1996 and now HB-Line, like H-Canyon itself, is used for nuclear material stabilization activities.

### B. Previous Seismic Evaluations

In 1979, E.I. Dupont De Nemours and Company (DuPont), the DOE contractor operating the site, hired Engineering Design and Analysis Company (EDAC) to prepare a seismic/structural evaluation of various facilities at the SRS, including H-Canyon/HB-Line. The purpose of this evaluation was to determine how these existing structures would perform in a severe earthquake. Seismic input for the H-Canyon/HB-Line analysis was provided by URS/John A Blume & Associates, Engineers (Blume) in the form of peak ground acceleration (pga) (the largest ground acceleration that would be expected to be measured in the earthquake) and response spectrum (a profile of ground acceleration over a range of frequencies of motion). The input was developed after review and analysis of available geologic, seismologic and seismotectonic data relating to the SRS and the surrounding region within a radius of 200 miles. Blume used data from the 1886 Charleston, South Carolina, earthquake to provide the basis for evaluating the SRS seismic hazard and to determine the appropriate level of ground motion in terms of peak ground acceleration (pga) and the appropriate response spectra.

Blume determined that the level of ground motion that could be expected in a severe earthquake at the SRS, the peak ground acceleration, was 0.2g. Blume also reported that, based on a probabilistic analysis, the estimated average (mean) annual rate of exceedance of the 0.2g peak ground acceleration was about $10^{-4}$. In other words, Blume indicated that the 0.2g pga would be exceeded on average about once in 10,000 years.

The Blume response spectrum was prepared using statistical analyses of ground motion data that matched both SRS geologic conditions as closely as possible, as well as epicenter distance and magnitude for near (within about 25 km of the SRS) and far (within about 145 km of the SRS) events. However, no return period (frequency of occurrence) was assigned by Blume to this theoretical earthquake. The response spectrum and the 0.2g pga were used as input for the EDAC structural evaluations of H-Canyon and HB-Line.

The Blume study adequately represented the state of knowledge in the early 1980s. However, the Blume response spectrum is now acknowledged by seismic experts to be biased toward low frequencies as a result of the use of western U.S. data so that the higher frequencies of the response spectrum are not adequately represented. Moreover, the Blume ground motion estimates did not account for any site-specific soil or rock data from the SRS.

At about the same time (circa 1984) that the Blume input was being developed, probabilistic seismic hazard curves (a statistically based prediction of ground motion) were being developed for all DOE sites. These curves showed that at SRS a peak ground acceleration of 0.19g was associated with a probability of occurrence equal to $2x10^{-4}$ per year, i.e., an earthquake which generates a peak ground acceleration with a frequency of occurrence of once every 5000 years.

Using the seismic information assembled by Blume, EDAC performed a structural analysis to determine the performance of the buildings during the Blume earthquake. For the purposes of EDAC's structural analysis, the seismic performance criteria for the structure would be met if no local or global collapse mechanism was formed or there would be no loss of support from any critical structural member. The performance criteria permitted the yielding, but not collapse, of structural supports. In the EDAC analysis, a "mechanism" was defined as the physical situation where there was yielding at a sufficient number of locations that the structure would absorb energy beyond the elastic range or beyond the point at which the structure would return to its original shape and integrity. A "collapse mechanism" was defined to occur when excessive lateral force caused allowable ductility ratios (ratios that describe the capability of materials to deform without failing) in reinforced concrete members to be exceeded, causing the displacements of the structure to become excessive such that collapse was possible. The EDAC analysis concluded that localized points of failure could occur, but the structure would marginally meet this no-collapse criterion. In other words, the structure would marginally stay within the inelastic response region defined by the allowable ductility ratios for the materials of construction. Although the EDAC analysis does not define the term "marginally," based on EDAC's definition of "collapse mechanism," the level of ductility reached in the structure, and the material strength, it is reasonable to conclude the Blume earthquake would induce the onset of cyclic strength degradation in H-Canyon, i.e., a loss of strength to the first critical joint of the structure. The EDAC analysis predicted the damage would include the sagging of some floor slabs and localized crushing of some columns. The predicted damage could also include concrete cracking at the locations where ductility ratios exceeded 1, such as canyon interior and exterior walls. Additionally, EDAC postulated that the keyed expansion joint between each canyon section could be damaged. The current analysis has assumed that this description of damage is consistent with a 50% probability of failure. This assumption is conservative, considering that the 50% probability of failure in the current analysis is the point where the first joint significantly degrades, but well before the point that the building would collapse.

In 1986, DuPont prepared safety analysis reports (SARs) for H-Canyon and HB-Line to describe facility design and operation and to define the radiological impacts to the workers and the public which could occur from a range of accidents associated with facility operations. The impact to the public was described in terms of risk, which was the product of the accident consequences and the frequency of the event. Among the accidents analyzed in the SARs was an accident precipitated by the Blume earthquake. The results of the EDAC analysis were used to help derive accident consequences. EDAC's statements of potential damage to the structure were considered in determining whether the canyon could provide radioactive material confinement in the event of a severe earthquake. For the purposes of the SAR, the frequency of the earthquake was taken from the new seismic hazard curves developed in 1984. Thus, the frequency of the Blume event (both spectra and pga) was assigned to correspond to a frequency of once in 5000 years.

### C. IMNM EIS

In 1995, DOE prepared the IMNM EIS to evaluate alternatives for stabilizing nuclear materials which are in storage at the Savannah River Site. Among the alternatives evaluated was the operation of H-Canyon and HB-Line to stabilize various solutions and other materials (e.g., plutonium scrap). The evaluations included an estimate of the impacts from earthquake accidents involving H-Canyon and HB-Line. The basis for the earthquake impact estimates in the EIS was the radioactive material release mechanism described by each facility SAR (which was based, in part, on information from the EDAC analysis). On December 12, 1995, DOE issued an Interim Management of Nuclear Materials Record of Decision (ROD) to stabilize some nuclear materials using the H-Canyon/HB-Line facilities. A second ROD, issued February 8, 1996, selected the F- and/or H-Canyon facilities for the stabilization of additional materials (i.e., Mark-16/22 spent nuclear fuel and other aluminum clad targets). A third ROD, issued September 16, 1996, selected F-Canyon facilities for the stabilization of some of the H-Canyon nuclear material solutions (i.e., plutonium-239 and neptunium-237).

## DISCUSSION

### A. Chronology of Events

In the Fall of 1995, WSRC began work on a new structural analysis for H-Canyon to support the preparation of an updated H-Canyon Safety Analysis Report. The purpose of the structural analysis was to determine the performance of the canyon using a site-specific earthquake developed in accordance with the latest DOE criteria and state-of-the-art seismic and structural analysis models. HB-Line was included in the analysis since it is located atop the H-Canyon.

WSRC reviewed the EDAC analysis and the seismic criteria established by the Blume study and determined that a new analysis was required, principally because DOE had issued a new natural phenomenon hazards mitigation Order (and associated Standards). The new Order and the Standards specified more prescriptive requirements for seismic evaluations than were applicable at the time of the EDAC and Blume studies. These requirements are contained in DOE Order 420.1, "Facility Safety," and a series of five DOE Standards. In accordance with these new requirements, H-Canyon and HB-Line were classified as performance category 3 (PC-3) structures for the purpose of seismic evaluations. Based on this classification, DOE requirements specified that the EBE would be a once in 2000-year earthquake, and the target performance goal would be a once in 10,000-year earthquake (hereafter referred to as the seismic margin event or SME). Additionally, the earthquake ground motion was to be described by probabilistically-derived site-specific seismic hazard curves. In other words, the EBE and SME would use ground motions based on site characteristics.

By January 1996, a conservative preliminary analysis by WSRC had determined that canyon performance in the event of a postulated site-specific earthquake might be less favorable than expected. These preliminary results prompted WSRC to review the EDAC analysis because it had concluded that canyon performance in a severe earthquake would marginally meet the EDAC criteria. On February 29, 1996, WSRC notified DOE of the potential inadequacy of the structural analysis that supported the authorization of activities to be conducted in both F- and H-Canyons. Specifically, WSRC determined that some of the building joint capacity assumptions in the EDAC analysis were not supported by actual building design details (e.g., the embedment and splice lengths of the reinforcing bar into the concrete was less than assumed). WSRC expected to resolve the question by completing new structural analyses.

On March 15, 1996, then-Assistant Secretary for Environmental Management Thomas P. Grumbly approved a staff recommendation to continue stabilizing material already in F-Canyon and H-Canyon while awaiting the results of the WSRC analysis work, but to prohibit the introduction of any new material into the canyons for stabilization purposes until new seismic analyses were completed and determinations made as to what further environmental review, if any, was required under the National Environmental Policy Act. The decision to suspend the movement of additional nuclear materials into the canyons was reiterated in a June 5, 1996, memorandum from Mr. Grumbly to the Savannah River Operations Office Manager.

On June 4, 1996, Mr. Grumbly, now the Under Secretary, requested a review of the WSRC seismic analysis by the Office of the Assistant Secretary for Environment, Safety and Health (EH). On June 21, 1996 the Assistant Secretary for Environment, Safety and Health directed a team of EH personnel and expert consultants to accomplish a detailed review after completion of the WSRC analysis.

Similar analyses and reviews for the SRS F-Canyon facilities were undertaken to evaluate the impact of the potential seismic analysis inadequacies. The results from these reviews indicated that the F-Canyon facilities meet DOE's seismic performance standards and criteria. Under Secretary Grumbly approved the Supplement Analysis of Seismic Activity on F-Canyon on

August 20, 1996, and authorized the introduction of nuclear materials into the F-Canyon facilities to resume on August 26, 1996.

WSRC's first step toward completing its new seismic analysis for H-Canyon was to define the ground motion for the EBE and SME. WSRC accomplished this by defining the bedrock motion expected to be caused by each of the two hypothetical earthquakes and analyzing how this bedrock motion would be transmitted to the surface through soil columns with properties based on empirically-derived soil data (i.e., from actual soil tests at SRS). The bedrock motion was derived using probabilistic seismic hazard assessments conducted by the Electric Power Research Institute (for commercial utilities) and Lawrence Livermore National Laboratory (for the U.S. Nuclear Regulatory Commission), that were specifically applicable to the SRS. The seismic hazard data from these studies were averaged and revised to derive uniform hazard spectra (UHS) (i.e., prediction of ground acceleration over a range of frequencies of motion) for bedrock at the SRS at annual probabilities of $5x10^{-4}$ (1/2000 years) and $1x10^{-4}$ (1/10,000 years). The spectral shapes (ground motion curves) were developed for the 1/2000 year EBE, and the 1/10,000 year SME, for H-Canyon and HB-Line. As a final step in developing rock motion data, a check was performed to ensure that the probabilistically-derived EBE was adequately conservative for historical earthquakes within 200 km of the SRS (e.g., the Charleston earthquake of 1886).

With the ground motion defined, the last part of the seismic evaluation was to perform a structural analysis of the facilities. For an existing facility such as H-Canyon or HB-Line, DOE Standard 1020-94 specifies that the facility could be evaluated either against current design or "code" requirements, even though the facilities in this case were already built and were designed to earlier code requirements, or by determining the facility's seismic adequacy (i.e., the inherent strength) in its as-built condition. In the code based assessment, the general acceptance criteria require that the facility remain elastic at the EBE. In the seismic adequacy assessment, the acceptance criteria require that the structure not fail with a specified degree of certainty, i.e., less than a 10% probability of failure, after the EBE's effect on the structure has been increased by a factor of 1.5.

The seismic adequacy assessment method was applied to the evaluation of H-Canyon and HB-Line. The code assessment method was not applied since it is based on design specifications that did not exist as code requirements at the time of original construction. The H-Canyon and HB-Line were also evaluated against the performance goal established by DOE Standard 1020-94. This Standard specifies a mean annual probability of failure of $1x10^{-4}$ for facilities like H-Canyon, but allows for a slight increase (i.e., to $2x10^{-4}$) in the average or mean probability of failure when an existing facility is close to meeting the performance goal.

In order to perform the H-Canyon and HB-Line structural evaluation, WSRC used the same building structural model developed in the F-Canyon seismic analysis. This was possible because the design of the two canyons is essentially the same. In fact, the model used for the F-Canyon analysis was actually based on H-Canyon structural details. A review by WSRC showed section 6 of H-Canyon to be controlling (i.e., the section most vulnerable to damage in an earthquake); thus the final results discussed below are based on the analysis of that section. WSRC performed the structural evaluation using non-linear dynamic analysis methods (methods that account for inelastic structural behavior) to determine the effect of the EBE and SME on the H-Canyon and HB-Line. Actual material strengths, based on samples from the structures, were used in the calculations.

The objectives of the analysis were to evaluate the capability of the structures at the EBE and to determine the mean probability of failure of the structure in terms of maximum lateral drift (i.e., the relative displacement between the roof of the structure and the foundation), the ground motion for these drifts and the probability of the onset of cyclic strength degradation. The maximum lateral drift was established by relating drift with the amount of rotation allowed at structural joints in the buildings. The results from this work were then used to compare the performance of the building against the DOE Standard 1020-94 criteria.

WSRC concluded that the structure met the criteria established in DOE Standard 1020-94 for an existing facility. The building drift (as calculated for comparison to the first DOE acceptance criterion) was 2.9 inches. This corresponded to about 1% probability of failure, which was well within the DOE requirement that existing buildings must have less than a 10% probability of failure in the event of the EBE. In order to evaluate facility performance against the second criterion (a mean annual probability of failure equal to $2x10^{4}$), analyses were performed to develop a fragility curve, i.e., a prediction of failure probability versus the severity of an earthquake. This curve was constructed based on the failure probability and performance information associated with the EBE and SME. The results of this work indicated the mean annual probability of failure for the H-Canyon would be equal to $1.8x10^{4}$. This equated to an earthquake return period of about 5,500 years. WSRC noted that the estimate of the probability of failure for H-Canyon was conservative and likely could be reduced by a minimum of 20%, i.e., to a probability of failure at least as low as $1.4 \times 10^{4}$ (WSRCb), equating to a return period of about 7,100 years.

WSRC estimated that the potential building lateral drift was about 6" at the mean annual probability of failure. WSRC determined that, at this lateral drift, horizontal cracking could develop in the concrete at each exterior wall-to-roof joint and at each exterior wall at about the first-level ceiling elevation in the canyon. The cracks would be irregular and would not form line-of-sight pathways through the walls since the cracks would be under compression from the weight of the structure. Additionally, there was the potential for limited failure at three of the 17 canyon expansion joints, i.e., between sections 1 and 2, sections 4 and 5, and sections 17 and 18. Each canyon expansion joint was constructed so that the section-to-section interface was an interlocking saw tooth design across the thickness of each wall. The thickness of the exterior walls ranged from 30" to 52" on the west side and from 36" to 58" on the east side of the canyon. The saw tooth design provided the strength to make adjacent canyon sections move together in the transverse direction during an earthquake and prevent further degradation of expansion joint seals. At the three joints that could experience limited failure, WSRC calculated thatthere would be no relative displacement (in the transverse direction) between the sections at a wall elevation of about 7' above ground level, and that the relative displacement would increase with the height of the wall to a maximum of 6" at the roof. The affected joints would still restrict air flow out of the structure since the maximum displacement would be 5 to 10 times less than the thickness of the exterior canyon walls. In fact, WSRC estimated that the integrity of the other canyon expansion joints combined with the limited failure of three expansion joints could reduce actual leakage estimates about 40% below the estimate used in the existing earthquake accident analysis and IMNM EIS impact estimates.

Two additional analyses were conducted by WSRC to relate current estimates of structural damage to that assumed in the IMNM EIS. First, WSRC performed a study using time-histories (a prediction of ground acceleration over time) with acceleration response spectra that closely matched and typically exceeded the Blume response spectra. These time-histories were run through the same structural analysis models used to evaluate the site-specific earthquake. The results showed that the maximum building roof displacement from the Blume spectra was less than that calculated using the site-specific spectra, and that the probability of failure for the Blume related time-histories was between 8% and 41%. The results for the Blume spectra indicated that the Blume earthquake was slightly less severe than the 5500-year earthquake used by WSRC in the new analysis of H-Canyon and HB-Line, and that these facilities have essentially the same seismic survival capacity as assumed in the IMNM-EIS. Additionally, based on the estimated displacements for a 5000-year earthquake, and using the structural fragility curve and analysis techniques, the probability of failure associated with a once in 5000-year earthquake was determined to be about 40%, which indicates that a slightly lower level of damage would occur at this return period than was estimated in the IMNM EIS (where the probability of failure was assumed to be about 50%).

On July 12, 1996, a joint DOE-Savannah River Operations Office and Office of Environmental Management (EM) review team completed an evaluation of the WSRC analysis [DOEa] for H-Canyon. The review team had established 17 acceptance criteria for its evaluation based on DOE Order 420.1, "Facility Safety," and associated Standards. The review team determined that all acceptance criteria were satisfied and concluded the following: H-Canyon would have relatively small displacements at the EBE with a very low probability of failure; the 5500-year earthquake was, in effect, about the same severity as the Blume response spectra (used in the original analyses); the mean probability for failure of the structure was $1.8x10^{4}$ per year; and from a building collapse perspective, the H-Canyon met the criteria established in DOE-STD-1020-94 for an existing facility. The review team did not identify any technical issues that required resolution before the resumption of H-Canyon stabilization activities.

In December 1996, the Office of Environment, Safety and Health issued its evaluation (EH review) of the WSRC seismic analysis calculations (DOEb) for H-Canyon. The EH review was conducted in four technical areas: 1) seismic hazard analysis, 2) geotechnical analysis, 3) structural analysis, and 4) fragility and probabilistic analysis. The review team was comprised of federal personnel and nationally recognized experts in each of these four areas. After an initial review of the overall WSRC work, the team concentrated its efforts on the approach WSRC used to model the slip of reinforcing bar in concrete and the performance and validation of structural analysis models. The team also carefully reviewed the treatment of the expansion joints at each building segment and reviewed the fragility and probabilistic analyses. In addition, the team conducted independent structural modeling and calculations. This activity produced results for building drift that were similar to the WSRC results. In performing its independent review, the team noted conservatisms in the WSRC calculations. In particular, the team noted that the WSRC estimates of H-Canyon soil column height (i.e., the depth from building foundation to bedrock) may have been too great, resulting in an overestimation of the building drift that would actually occur in an earthquake. The team concluded that the WSRC analysis was based on accepted engineering practices and principles, and judged the results to be conservative. The team determined that the results of the WSRC failure analysis met applicable DOE seismic criteria

**B. Comparison of Analysis Results to IMNM EIS**

The IMNM EIS earthquake accident analysis impacts were based on the amount of radioactive material that could be released from H-Canyon/HB-Line as predicted in the existing Safety Analysis Report for these facilities. The following accident sequence was analyzed: the earthquake occurred during operations that involved transfers of radioactive solutions involving ten of the largest tanks inside the canyon. The force of the earthquake caused the transfer piping to leak and the contents of the tanks to be pumped out onto the canyon cell floor. A portion of the spilled material evaporated inside the canyon and some of the airborne material (estimated to be 10%) made its way outside to the environment through cracks in the canyon structure caused by the earthquake. The material released outside the canyon was then assumed to be blown off-site to the general population. This scenario is very conservative because it tended to overstate the risk in several respects. For example, it assumed that an earthquake with a projected frequency of once every 5000 years would actually occur during the remaining operating life of the facility. Additionally, the scenario assumed that an earthquake powerful enough to crack the walls of the canyon and rupture stainless steel piping would not interrupt steam or electrical power, therefore allowing the contents of 10 tanks to be pumped to the canyon floor (an interruption in steam and electrical service would disable pumping capability). Also, the scenario assumed that all of the material released from the facility was accumulated at essentially one point outside the facility and that it was blown off-site in a narrow plume. The plume was assumed to have maintained essentially a straight line that extended from the release point to the nearest off-site location (a distance of several miles). During the transit off-site, there was assumed to be effectively no deposition or dispersion, so that the concentration was essentially undiluted. The amount of material released in the accident analysis for the IMNM EIS was estimated to be 10% of the airborne radioactive material in the building. It should be noted that it is extremely unlikely that all of these conditions would actually occur.

The level of damage to the walls would affect the amount of radioactive material that could be released outside the facility. The level of damage predicted for the earthquake accident, as indicated in the IMNM EIS, was based on descriptions of damage in the EDAC report, i.e., sagging of some floor slabs and localized crushing of some columns. It could also be concluded that concrete cracking would be expected at locations where ductility ratios exceeded 1, such as canyon interior and exterior walls. Additionally, it was postulated that the keyed expansion joint between each canyon section could be damaged. Thus, the damage state associated with the EDAC analysis is a significant amount of cracking, but not structural collapse.

The new WSRC analysis indicated that an earthquake slightly more severe than the Blume event would cause a level of damage to H-Canyon similar to that indicated in the analysis for the IMNM EIS. In both the original and new analysis, the cracks in the walls were considered to be irregular and would not form line-of-sight pathways for direct leakage. As a result, it was reasonable for the new WSRC analysis to conclude that the amount of material assumed to be released would be no greater than that released under the original analysis. As an additional check, WSRC performed a calculation to estimate the volume of canyon air loss (in percentage) that could be expected to be released as a result of the damage predicted from the most severe earthquake associated with the new analysis. WSRC calculated the air loss to be about 7% (compared to the 10% release of airborne radioactivity estimated in the EIS). Since the volume of air released is a reasonable surrogate for the amount of airborne radioactive material which could be released, the WSRC analysis shows that less radioactive material would be released in a severe earthquake than indicated in the IMNM EIS analysis.

The IMNM EIS provided health impact information for the earthquake accident scenario in terms of both consequence and risk. Consequence was described in terms of the number of increased latent cancer fatalities that could be expected from public or worker exposure to the radioactive material released during the accident. The potential health impacts (i.e., consequences) associated with the new analyses would not be greater than those estimated in the IMNM EIS because no more radioactive material would escape than previously estimated. Risk in the IMNM EIS was derived by multiplying the frequency of the earthquake by the calculated consequences from the accident. The earthquake frequency in the IMNM EIS was assumed to be a one in 5000-year event ($2x10^{-4}$ per year). Risk would not be increased, since the frequency of the new earthquake (for the level of damage described) was a one in 5500-year event ($1.8x10^{-4}$ per year). The lower frequency multiplied by the same consequence results in slightly less risk.

## CONCLUSIONS

The earthquake accident consequences presented in the IMNM EIS continue to be representative of potential impacts since the canyon structural integrity, based on the as-built condition of H-Canyon, would be equal to or better than that calculated in the IMNM EIS accident analysis. That is, based on the new, more detailed analyses, the structure would achieve the same (or better) level of radioactive material confinement than that estimated in the earthquake accident analysis for the IMNM EIS. Earthquake accident consequences in the EIS are a function of the structural confinement capability. Since the confinement capability has been determined not to be less than that estimated in the IMNM EIS, the consequence from the accident would not increase. Indeed, the new seismic analysis indicates that potential releases from an earthquake of the magnitude of the one analyzed in the EIS would be smaller than those predicted in the EIS.

The earthquake risks presented in the IMNM EIS continue to be representative of the potential impacts that would be calculated using the new canyon structural response information. The severe earthquake used in the IMNM EIS analysis was predicted to occur no more than once every 5,000 years, while the new analysis predicted an earthquake which causes a similar level of damage would occur at a frequency which was slightly less, i.e., once every 5,500 years. The risk associated with impacts from earthquake accidents in the IMNM EIS was the product of earthquake frequency and potential consequences. Since the consequences (i.e., the number of latent cancer fatalities) would be no greater and the frequency of the severe earthquake is about the same, the recalculated risk would be no greater than those currently represented in the IMNM EIS.

The new information associated with the structural response of H-Canyon and HB-Line does not depart significantly from the information contained in the IMNM EIS. This new information also does not present a seriously different picture of environmental consequences than those projected in the EIS. Accordingly, the new seismic analyses based on the as-built condition of H-Canyon do not constitute significant new circumstances or information relevant to environmental concerns, and therefore no supplement to the IMNM EIS need be prepared based on the new seismic data.

**REFERENCES**

DOEa. H-Canyon Seismic Analysis Supplemental Safety Evaluation, November 1996.

DOEb. DOE/EH-0538, Independent Review of the Seismic Analyses for the H-Canyon at the Savannah River Site, December 1996.

WSRCa. Westinghouse Savannah River Company Inter-Office Memorandum, ECS-MSM-96-0017, Summation of Results of the Structural Evaluation of H-Canyon Building 221 (U), August 29, 1996.

WSRCb. Westinghouse Savannah River Company Inter-Office Memorandum, PEC-SMS-96-0019, Conservatism in the 221-F and H-Canyon Structural Analyses (U), October 2, 1996.