APPENDIX I
REPORT ON THE STATUS AND IMPLICATIONS OF SEISMIC HAZARD STUDIES AT LANL

United States Government **Department of Energy**

memorandum

Albuquerque Operations Office

DATE: JAN 08 1999

REPLY TO: NPD

SUBJECT: Status and Implications of Seismic Hazard Studies at LANL

TO: W. Scott Gibbs, Program Director, MMP, LANL, MS A102

We have reviewed the subject LANL report (dated December 17, 1998), and concur with the conclusions reached regarding the implications of this series of seismic studies. The information summarized in this report and discussed in more detail in the five seismic studies that have been completed, to date, are and will continue to be considered in the execution of mission work at LANL. A specific example of this is the recently approved Interim Technical Safety Requirements for operations at the Chemistry and Metallurgy Research (CMR) Building, which includes reductions in material at risk in that facility and plans for containerization of material in glovebox lines which is not actively being used; these actions are taken to reduce the potential consequences of seismically-initiated accidents in the CMR Building. DOE will continue to examine the mission work at LANL in consideration of seismic and other risks to ensure that such work can be accomplished within acceptable levels of risk.

Should you have any questions on this matter, please contact me (845-6038) or Mr. Corey Cruz (845-6736) of my staff.

A. E. Whiteman
Assistant Manager for
Technology and Site Programs

cc:
E. Ives, DP-20, FORS, HQ
J. Ordaz, DP-13, GTN, HQ
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Date: December 22, 1998
Refer to: NW/M&M:98-20

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Dear Mr. Ives and Mr. Whiteman:

Subject: Transmittal of Los Alamos Report, "Status and Implications of Seismic Hazard Studies at LANL"

Attached for your use is the report "Status and Implications of Seismic Hazard Studies at LANL," December 17, 1998, prepared by Larry Goen, ESA-EA, Los Alamos National Laboratory. The report summarizes the results of five recent seismic studies for various areas at Los Alamos National Laboratory, and makes note of two additional studies that are still in progress. It has been reviewed by staff at both DOE Headquarters and the DOE Albuquerque Operations Office. This final version incorporates comments made by Jeffrey Kimball, seismologist, DOE/HQ DP-45.

The stratigraphic survey for Technical Area (TA) 55 indicates that the area is not susceptible to surface rupture from earthquakes. The stratigraphic survey for TA-3 is in progress and a full report is not expected until March 1999. It appears that surface rupture from earthquakes is not a concern for those facilities at TA-3 that are not nuclear facilities. However, the discovery of a fault under the Chemistry and Metallurgy Research (CMR) Building, which is a nuclear facility, may have implications for decisions concerning the future use of CMR. The seismic studies also address ground motion from earthquakes, and indicate that this hazard is within the parameters assumed in the 1995 probabilistic seismic hazard analysis. The studies conclude that Laboratory structural standards remain valid in regards to ground motion.

Mr. Edwin E. Ives, DOE/HDQS -2- December 22, 1998
Mr. A. Earl Whiteman, DOE/AL
NW/M&M:98-20

I appreciate your interest in this subject. Your office has copies of the completed studies, and we will transmit the remaining studies as soon as they are completed.

Sincerely,

W. Scott Gibbs
Program Director
Materials and Manufacturing Programs

WSG:MDW:bjc

Att: a/s

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Status and Implications of Seismic Hazard Studies at LANL

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December 17, 1998

Status & Implications of Seismic Hazard Studies at LANL

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Status & Implications of Seismic Hazard Studies at LANL

1.0 Summary

A number of studies (Table 1) have been initiated in the last two years to address seismic issues at LANL. These studies have focused on the potential for surface rupture at TA-55 and TA-3 and the seismic hazard in general. For surface rupture, studies have centered around the mapping of faults in and around specific technical areas. In addition, a probabilistic surface rupture assessment has been completed for TA-3. For the seismic hazard, studies have focused on the earthquake history on the Pajarito fault.

Table 1 – Seismic Hazard Studies

Task	Status	Ref.
1) Stratigraphic Survey for TA-55	Complete	1
2) FY97 Pajarito Trench Study	Complete	3
3) Probabilistic Surface Rupture Assessment for TA-3	Complete	6
4a) Core Hole Study at SCC/NISC Site	Complete	5
4b) Core Hole Study at CMR Site	Complete	4
5) Stratigraphic Survey for TA-3	In Progress	N/A
6) FY98 Pajarito Trench Study	In Progress	N/A

Surface Rupture

The stratigraphic survey (Ref. 1) for TA-55 is complete and found no evidence for existing faults. Thus the area is not susceptible to surface rupture from earthquakes.

The stratigraphic survey for TA-3 is in progress and a full report is not expected until the end of March 1999. However, it is evident that TA-3 does have faults with vertical displacements in the range of 1-10 feet in 1.2 million year old Bandelier tuff. The heaviest concentration of these faults is in the southeast corner of TA-3. This concentration is believed to be defining the southern end of the Rendija Canyon fault. The faults found include one under the CMR Building (Ref. 4) with a vertical offset of approximately 8 feet.

While surface rupture can cause significant structural damage, surface rupturing earthquakes are low probability events. From the probabilistic assessment of surface rupture (Ref. 6), earthquakes that might result in permanent ground displacements of about four inches are estimated to be 10,000 to 20,000 year events. Four inches was taken as the threshold for a displacement causing severe cracking in a concrete or masonry structure. Earthquakes with would result in permanent ground displacements capable of causing structures to collapse are estimated to be 33,000 to 100,000 year events. The displacement threshold for collapse was taken as about 20 inches.

Based on the probabilistic study (Ref. 6), for non-nuclear structures, surface rupture is not a concern. The performance goal (annual probability of seismic induced damage) for such facilities

per DOE guidance is 5 x 10^{-4} (2000 year recurrence interval). Designing to resist the ground motion caused by an earthquake is the primary concern when considering the seismic hazard. While surface rupture not a concern for non-nuclear structures, siting new facilities over known faults should not be done.

For the CMR Building, a nuclear facility, the probability of damaging ground displacement is at or beyond the performance goal for the facility, 1×10^{-4} (10,000 year recurrence interval). In its current condition, the probability of damaging ground motion is at least 20 times greater than the probability of damage caused by surface rupture. Therefore, the discovery of the fault under the building does not increase the seismic risk at CMR.

The discovery of a fault under the CMR Building has an impact on decisions concerning upgrades and future uses for the facility. From the seismic perspective, the question which needs to be assessed is whether or not it is prudent to upgrade the structure to resist ground motion loads when the probability of damaging surface rupture is near the performance goal level for the facility. While it is possible to upgrade to resist the forces/displacements caused by permanent ground deformation, the upgrade costs would increase substantially. It should be noted that this site would not be considered adequate for a new nuclear facility.

Ground Motion

In the last two years, a number of trenches have been excavated to study the earthquake history on the Pajarito fault. The purpose of the studies has been to determine when the most recent ground rupturing event occurred on the fault, to get a better understanding of recurrence intervals for earthquakes (slip rate), and to help determine if the three main faults in the Los Alamos area are connected.

For the seven trenches excavated in June 1998, data analysis is in progress and preliminary results are not available. For the seven trenches excavated in July 1997, the results (Ref. 3) show that the most recent event occurred 1500-2000 years ago with no other events in the last 10,000 years. The slip rates determined from this study indicate that they are within the parameters assumed in a 1995 probabilistic seismic hazard analysis. The 1995 study is the basis for the LANL design basis ground motion.

The significance of this information is that there is no direct evidence that the three local faults (Pajarito, Rendija Canyon and Guaje Mountain faults) are connected and the assumptions made in the probabilistic seismic hazard assessment completed in 1995 are still valid. Therefore, the design basis ground motion defined in the LANL structural standards is still valid.

Status & Implications of Seismic Hazard Studies at LANL

2.0 Introduction

In FY 1997, the first two tasks shown in Table 1 were undertaken to better understand the seismic hazard at the Los Alamos National Laboratory (LANL) site. One study was to investigate the possibility of the Rendija Canyon fault extending through Technical Area 55 (TA-55). The other was to investigate seismic history on the Pajarito fault, the main contributor to the seismic hazard for return periods of greater than 1,000 years. From preliminary results of these two studies, questions were raised concerning the possible connection of the Pajarito, Rendija Canyon and Guaje Mountain faults, shown in Figure 1, and surface rupture at TA-3. Both of the studies were finalized in FY98.

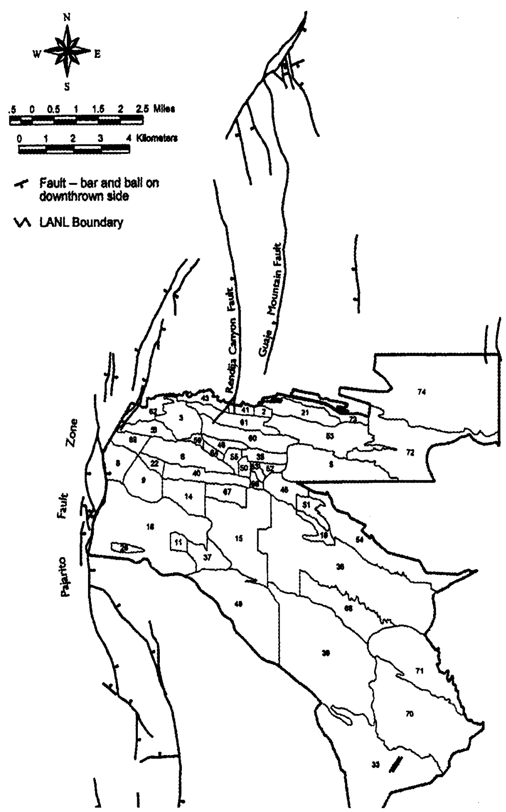

Figure 1 – Major Surface Faults at LANL

At TA-55, the study (Ref. 1) found that the Rendija Canyon fault does not project through TA-55 and that the site is free of any observable faulting. The study did find evidence for faulting further to the west, in the vicinity of TA-3. Data collection for the mapping of the faulting in the TA-3 area, the sixth task shown in Table 1, began in October, 1997 and continued through September 1998. Although the data have only been partially analyzed, it is evident that faulting is present in TA-3.

On the Pajarito fault, trench studies were conducted to try to estimate the last event on the fault, to try to estimate recurrence intervals on events, and to estimate slip rates. All of these factors were assumed in the seismic hazard evaluation (Ref. 2) completed in 1995 and physical data is needed to confirm that the assumptions made were conservative. The investigation (Ref. 3) initiated in FY97 has resulted in finding the most recent event on the Pajarito approximately 1500 - 2000 years ago and that slip rates were consistent with those assumed in Reference 2. In addition, a similar study, the sixth task in Table 1, began in FY98. For the FY98 study, the fieldwork is complete and data analysis is in progress.

In this report, the results of these studies plus those either completed or in progress are discussed as well as what the implications are for new and existing construction in TA-3. Findings for individual studies are first presented followed by a summary of DOE seismic requirements. Finally, the impacts on the understanding of the seismic hazard on facilities at LANL, in particular those in TA-3 such as CMR are presented.

Status & Implications of Seismic Hazard Studies at LANL

3.0 Findings to Date

The emphasis for work over the last two fiscal years falls in two categories: the potential for surface rupture at TA-55 and TA-3, and, investigation of the seismic history on the Pajarito fault.

3.1 Surface Rupture Investigations

Work in this area can be divided into three areas, fault mapping at TA-55 (1st task in Table 1), fault mapping at TA-3 (4th and 5th tasks in Table 1), and probabilistic surface rupture assessment of TA-3 (3rd task in Table 1).

3.1.1 Fault Mapping and Surface Rupture Investigation at TA-55

In Reference 1, results are presented of high-precision geologic mapping in the vicinity of TA-55 that has been done to identify parts of the southern portion of the Rendija Canyon fault, or any other faults, with the potential for seismic surface rupture. To assess the potential for surface rupture at TA-55, an area of approximately 3 square miles that includes the Los Alamos County Landfill and Twomile, Mortandad, and Sandia Canyons has been mapped in detail.

This mapping indicates that there is no faulting in the near surface directly below TA-55, and that the closest fault is about 1500 feet west of the Plutonium Facility. Faulting is more abundant on the western edge of the map area, west of TA-48, near TA-3, in uppermost Mortandad Canyon, upper Sandia Canyon, and at the County Landfill. With the exception of the County Landfill, measured vertical offsets ranged from 1 to 8 feet. At the County Landfill, faulting exposed has a distributed zone of faulting over 1000 feet wide with a net down to the west vertical displacement of 15 feet. Individual faults within this zone have vertical offsets ranging from 1 to greater than 15 feet. The area mapped is shown in Figure 2 (Ref. 1).

3.1.2 Fault Mapping and Surface Rupture Investigation at TA-3

The surface rupture investigation at TA-3 includes locating and mapping of existing faults using two different methods. One of methods used is high precision location of stratigraphic contacts using total station surveying techniques in the canyons to the north and south of TA-3. The other method is the drilling of core holes to locate stratigraphic contacts at specific sites, namely the CMR site (Ref. 4) and the proposed site for the Strategic Computing Center (SCC) and Nonproliferation and International Security Center (NISC) projects (Ref. 5), within TA-3.

High Precision Mapping at TA-3:

High precision mapping at TA-3, similar to that accomplished in the TA-55 area, is an in-progress study. Data collection for this study was completed in September, 1998. Data analysis and report writing is ongoing. The final report is expected to be completed in March, 1999.

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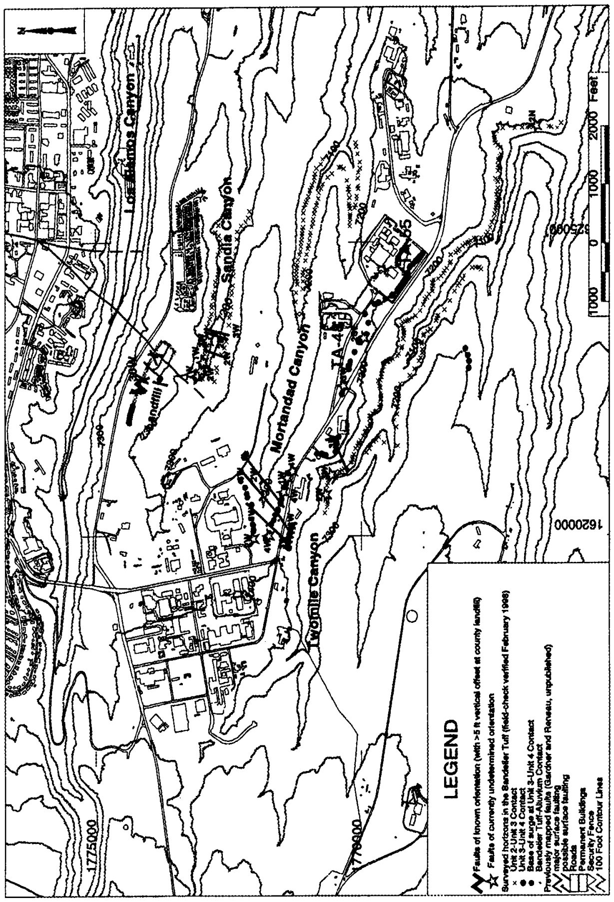

Figure 2 – Map of Faulting in TA-55 Area (Ref. 1)
Numbers and leeters adjacent ot faults indicate the amount of displacement (in feet) and sense of displacement (e.g., 4W = 4 feet of displacement down to the west).

The areas surveyed in the data collection portion of this study are indicated in Figure 3. Along with the survey locations, Figure 3 also depicts the location of linear features found in the examination of air photos dating to the 1940's. The linear features could indicate the location of faults, but could also indicate other linear features such as fences trails and roads. These linear features are being used as guides in the data analysis currently underway. As the data analysis progresses, it is expected that some of the air photo lineaments will be designated faults while others will be removed from the map.

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Although data analysis is in progress, preliminary findings indicate faulting is present in the TA-3 area. The majority of the faults is in the southeastern area of TA-3. These faults have vertical offsets in the range of 1 to 10 feet.

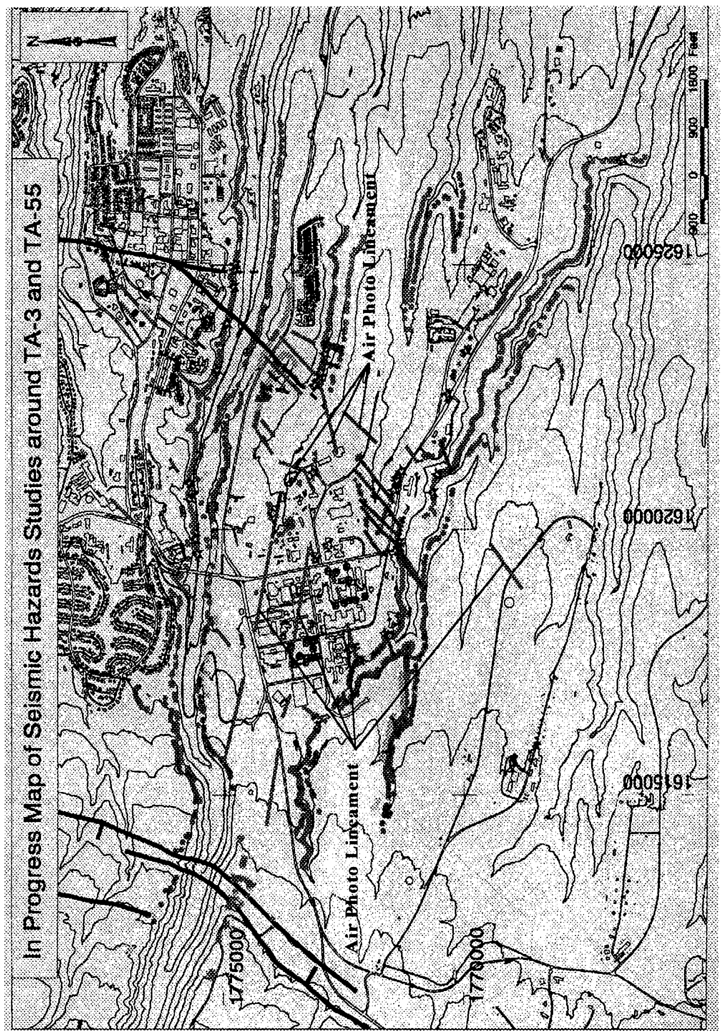

Figure 3 – In Progress Map of Fault Location in TA-3
Unless indicated as "Air Photo Lineament" (purple lines), lines indicate faults of known orientation. Stars represent faults of unknown orientation. Dots indicate surveyed points of stratigraphic contacts.

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CMR Core Hole Investigation:

At the site of the existing Chemistry and Metallurgical Research (CMR) Building, nine closely spaced, shallow holes were drilled. The purpose of the holes was to obtain the cores and to establish the elevation at which contacts between particular layers of the Bandelier Tuff are located. These elevations were then used to develop a contour map at a particular contact. Abrupt changes in the contours would indicate the presence of faulting. The goal of the investigation was to identify faults that may have the potential for earthquake-induced surface ruptures at the site.

Analysis (Ref. 4) of the data obtained indicates that a fault is present at the CMR Building. Its location and inferred orientation are shown in Figure 4. The fault is contained within the core obtained from the CMR-6 and can be inferred to occur between the CMR-2 and CMR-3 locations. This orientation is consistent with one of the air photo lineaments shown in Figure 3. The total displacement of Unit 3 in the CMR-6 core is approximately 8 feet.

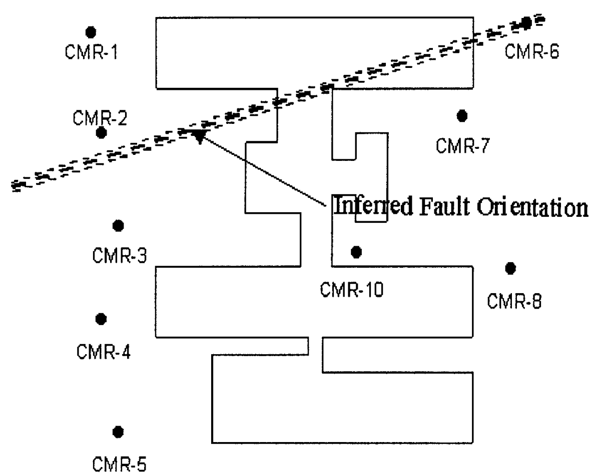

Figure 4 – Plan View of CMR Building With Inferred Location of Fault

Based on this investigation, it can be concluded that the CMR Building site has, in the past, been impacted by fault rupture. However, as discussed later in this report, the probability of an earthquake causing significant surface displacement at this site in the future is small.

SCC/NISC Core Hole Investigation:

At the site proposed for the new Strategic Computing Center (SCC) and the new Nonproliferation and International Security Center (NISC) projects, ten closely spaced, shallow holes were drilled. The purpose of the holes is the same as the holes drilled at the CMR Building.

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From analysis (Ref. 5) of the data gathered, there is no evidence for faults under the building sites. Because no significant or cumulative faulting events have disturbed the site in the last 1.22 million years, the age of the Bandelier Tuff, it is unlikely that surface rupture will occur at the site in future large earthquakes.

3.1.3 Probabilistic Surface Rupture Analysis

A probabilistic seismic hazard analysis for potential surface fault displacement at TA-3 has been performed and is described and summarized in Reference 6. The objective of the analysis was to estimate the potential surface rupture hazard posed by the Pajarito fault system, in particular, a possible splay of the Rendija Canyon fault that may transect TA-3. The principal products of this study are probabilistic surface rupture hazard curves for the CMR and SCC/NISC sites. The study focused on these two sites at TA-3 and provides bounding case assessments of the surface rupture potential at each site.

Three different cases were considered in the hazard analysis: (1) distributed faulting only; (2) principal faulting at the CMR site; and, (3) principal faulting at the SCC/NISC site. Principal faulting is faulting occurring along the main plane(s) of crustal weakness responsible for the release of seismic energy during an earthquake. Distributed faulting is defined as rupture that occurs on other faults, shears, or fractures in the vicinity of the principal rupture in response to the principal displacement. The three cases correspond to three different possible scenarios for the southern end of the Rendija Canyon fault. For Case 1, three different hypothetical conditions were assumed: (a) a distributed fault with 9m of cumulative displacement in the Bandelier Tuff, (b) a distributed fault with 1m of cumulative displacement, and (c) a fracture with no observable displacement in the tuff. A total of 15m of cumulative displacement is assumed in cases 2 and 3.

The results, summarized in Table 2, show that for annual frequencies of 10^{-4} or larger, surface rupture is minimal or nonexistent. The hazard curves developed for the two sites are shown in Figures 5 and 6. Hazard curves that investigate the sensitivity of the three main faults being connected or not are shown in Figure 7.

Table 2 – Probabilistic Surface Rupture Results

Annual Frequency	Case 1a	Case 1b	Case 1c	Case 2&3
10^{-4}	<1 mm	<1 mm	<1 mm	2 cm
10^{-5}	50 cm	20 cm	10 cm	70cm

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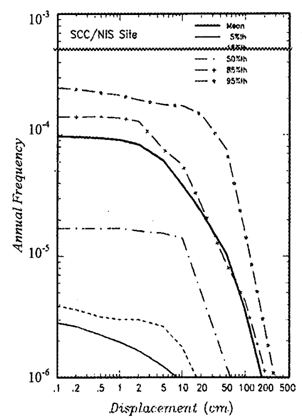

Figure 5a – Case 1a:
Distributed Faulting w/ 9m
Cumulative Displacement

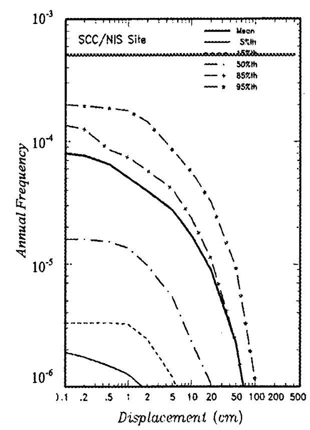

Figure 5b – Case 1b:
Distributed Faulting w/ 1m
Cumulative Displacement

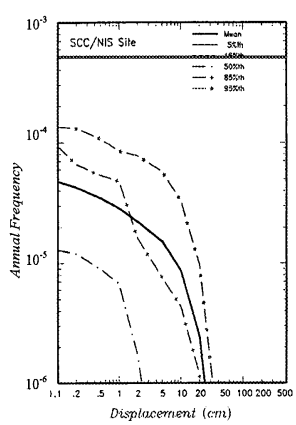

Figure 5c – Case 1c:
Distributed Faulting w/ no
Cumulative Displacement

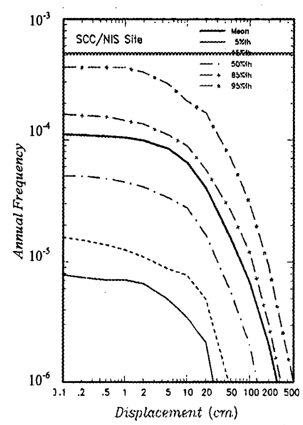

Figure 5d – Case 2:
Principal Faulting w/ 15m
Cumulative Displacement

Figure 5 – Surface Rupture Hazard Curves for the SCC/NISC Site (Performance Goal for PC 2 Facilities is $5x10^{-4}$)

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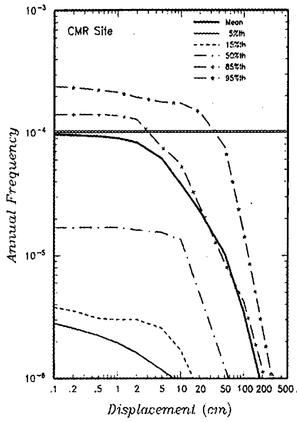

Figure 6a - Case 1a:
Distributed Faulting
9m Cum. Displacement

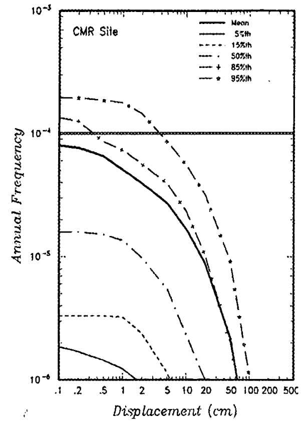

Figure 6b - Case 1b:
Distributed Faulting
1m Cum. Displacement

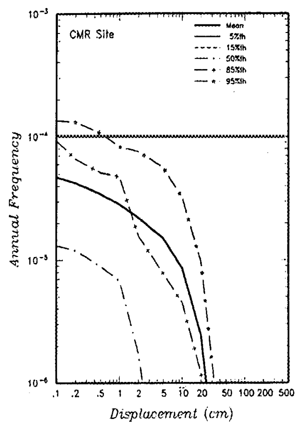

Figure 6c - Case 1c:
Distributed Faulting
No Observable Displacement

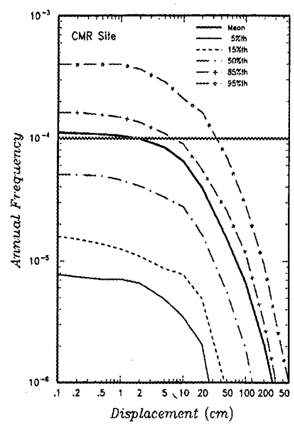

Figure 6d - Case 3:
Principal Faulting
15m Cum. Displacement

Figure 6 – Surface Rupture Hazard Curves for the CMR Building Site (Performance Goal for PC 3 Facilities is $1x10^{-4}$)

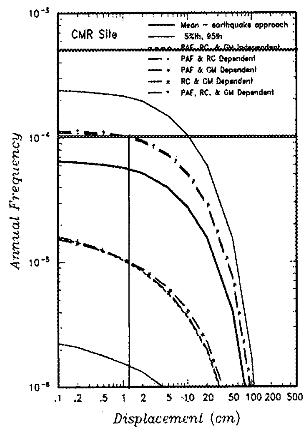

Figure 7a – Case 1b
Distributed Faulting w/ 1m
Cumulative Displacement

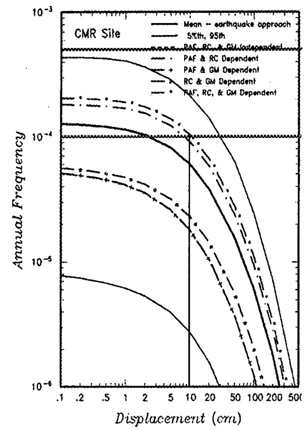

Figure 7b – Case 3:
Principal Faulting w/ 15m
Cumulative Displacement

Figure 7 – Surface Rupture Hazard Curve Sensitivity Results (Illustrates the effects of assuming fault dependency on hazard curves.)

3.2 Paleoseismic Investigations

Recent paleoseismic investigations have focussed on the Pajarito Fault. Two separate but related studies were initiated in Fiscal Year 1997 and Fiscal Year 1998. Locations of the studies are shown in Figure 8. Fieldwork for the paleoseismic studies is completed in a fairly short time frame but the analysis of samples required to develop date constraints is a time consuming process. Thus, work initiated in one fiscal year typically carries over to the following fiscal year to obtain dating information.

3.2.1 FY97 Paleoseismic Investigation on the Pajarito Fault

In July 1997, seven trenches were excavated across strands of the Pajarito fault zone to characterize the most recent faulting event (MRE), and to refine characterization of previous faulting events. The strategy for capturing the MRE was to excavate a series of seven trenches along an east-west transect across the fault zone south of Los Alamos Canyon, where parallel faults span a zone nearly 2 km wide. Two of the seven trenches were located on the main 50 m high scarp of the Pajarito fault, with the remainder on smaller east- and west-facing scarps. This study is presented in Reference 3.

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The best paleoseismic records were preserved on scarps that faced west, or upslope. Each of these trenches displayed evidence of mid- to late-Holocene MRE. The MRE appears to fall in a relatively narrow age range between about 1300 to 2300 years ago with a likely age of about 1500 years.

The MRE dated at about 1500 years does not appear to be contemporaneous with the MRE on the Guaje Mountain fault, dated at 4000-6000 years or the MRE on the Rendija Canyon fault, dated at either 8 or 23 thousand years. The trenches on the Pajarito do not show evidence for either a second (or third) earthquake at either 4000-6000 years or 8000 years. Thus, it appears that the MREs on each of the three faults in the Pajarito fault system are separate earthquakes.

3.2.2 FY98 Paleoseismic Investigation on the Pajarito Fault

In June, 1998, seven additional trenches were excavated across the Pajarito fault zone further south than the FY97 study. Again, the purpose of the excavations was to characterize the most recent faulting event (MRE), and to refine characterization of previous faulting events. While the fieldwork is complete, analysis of the data obtained is ongoing. The final report is to be complete in March, 1999.

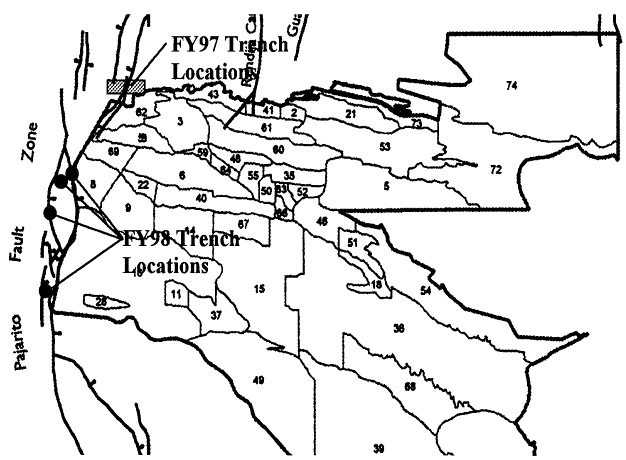

Figure 8 – Locations of Paleoseismic Studies

Status & Implications of Seismic Hazard Studies at LANL

4.0 DOE Requirements

The DOE, through orders and standards, provides guidance for facility siting and design with respect to earthquakes. The guidance is probabilistically based.

The Implementation Guide to DOE Order 420.1 "Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities" (Ref. 7) requires that structures systems and components be designed and constructed to withstand the effects of natural phenomena hazards (NPH) using a graded approach. The target safety levels for structures systems and components (SSCs) subject to NPH are given in the guide in terms of performance goals. These performance goals are defined as the acceptable annual probability of failure. The performance goals are shown in Table 3 and are a function of performance categorization. Performance categorization is determined in accordance with DOE STD 1021 (Ref. 8). The guide also states that siting of structures over active geologic faults should be avoided.

Table 3 - Performance Goals and Categories for SSCs

Performance Category	Description of Performance Required	Seismic Performance Goal
PC0	No consideration.	N/A
PC1	Prevent major structural damage or collapse which would endanger personnel (life-safety).	$1x10^{-3}$
PC2	Maintain operation of essential facilities allowing relatively minor structural damage.	$5x10^{-4}$
PC3	Confinement of hazardous materials.	$1x10^{-4}$
PC4	Confinement of hazardous materials	$1x10^{-5}$

DOE STD 1020 (Ref. 9) specifies seismic loading in probabilistic terms. The annual exceedance probability for the ground motion associated with the various performance categories is shown in Table 4. The peak ground accelerations for LANL are based on the information in Reference 2.

Table 4
Peak Ground Accelerations at LANL

Performance Category	Annual Probability of Exceedance (Return Period)	Horizontal Peak Ground Acceleration (g)	Vertical Peak Ground Acceleration (g)
PC1	$2x10^{-3}$ (500 yr.)	0.15	0.11
PC2	$1x10^{-3}$ (1,000 yr.)	0.22	0.19
PC3	$5x10^{-4}$ (2,000 yr)	0.31	0.27
PC4	$1x10^{-4}$ (10,000 yr)	0.57	0.58

For seismic design, the standard recommends using deterministic design rules that are familiar to design engineers and which have a controlled level of conservatism. This level of conservatism combined with the specification of probabilistic seismic loading leads to performance goal achievement.

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DOE STD 1022 (Ref. 10) provides guidance for NPH Characterization Criteria including the necessity for establishing the potential for surface rupture and points to EPA guidance for offsetting hazardous waste facilities from active faults. Active faults are characterized "by the presence of surface or near surface deformation of geologic deposits of a recurring nature within the last approximately 500,000 years or at least one in the last approximately 50,000 years."

DOE STD 1023 (Ref. 11) provides criteria for NPH assessment. In this document, some guidance is provided for ground failure (surface rupture). If surface rupture may occur near a facility, a probabilistic evaluation may be necessary. If the annual probability of ground failure is greater than the necessary performance goal either the site should be avoided, mitigation measures taken, or an evaluation performed of the effects of fault offset.

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5.0 Implications of Findings

This section discusses the implication of the findings on projects at TA-3 and for the Laboratory in general. These studies have implications for LANL in two areas: (1) surface rupture potential at TA-3 with respect to both non-nuclear facilities and the CMR Building, and (2) design ground motion for all facilities.

5.1 Surface Rupture at TA-3

The studies to date indicate that there are faults in some locations at TA-3 including under the CMR Building. These faults will be addressed in a manner consistent with DOE guidance. For new facilities, building sites will be selected such that "active" faults are avoided. For existing facilities that are located over faults, assume they meet "active" criteria and a probabilistic approach will be followed.

<u>Non-Nuclear Facilities (PC 1 and PC 2):</u>

For the SCC and NISC projects, a site specific study (Ref. 5) was performed to determine if faulting was present at the proposed site. The results of this study indicate the site is clear of faulting and is therefore acceptable for new construction.

For existing facilities, hazard curves developed in the probabilistic surface rupture study (Ref. 6) for TA-3 are used. At the performance goals for PC 1 and PC 2, $1x10^{-3}$ and $5x10^{-4}$, respectively, the estimated displacement for any of the cases as shown in Figures 4 and 5 and summarized in Table 2 is less than 1 millimeter. This is true even for the case where all faults are assumed to be connected. This small amount of displacement has a negligible effect on structures. Therefore, for existing PC 1 and PC 2 facilities, surface rupture is not a credible hazard and the only aspect of the seismic hazard at TA-3 that should be considered is ground motion.

<u>The CMR Building (PC 3)</u>

As previously indicated, it has been determined that there is an existing fault under the CMR. The vertical offset in this fault is approximately 8 feet. The identification, location and orientation of the fault under the CMR shown in Figure 4 is based on air photo interpretation, high precision mapping of faults in canyons to the south of TA-3, and examination of cores taken from the nine holes drilled around the CMR Building. The air photos indicate a linear feature running through the CMR site from the northeast corner of the facility and through the site to the west-southwest. The high precision mapping effort located a fault with about 5 feet of vertical offset in Twomile Canyon to the southwest which coincides with the southwest end of the air photo feature running through the CMR site. The examination of the cores showed that the core taken at the northeast corner (CMR-6) of the facility cut through a fault with a total vertical offset of about 8 feet and that it is likely that the same fault lies between cores CMR-2 and CMR-3. This information also coincides with the air photo feature. The location and orientation of the fault shown in Figure 4 are consistent with the information known to date.

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If this site were to be considered for a new nuclear facility, it would not be used and an alternate site, clear of faulting concerns, would be chosen. However, since this is an existing facility, the impact on the safe operation of the facility must be assessed. For this assessment a probabilistic approach is used.

The CMR Building is a PC 3 facility that contains special nuclear materials. The performance goal for design basis earthquakes is $1x10^{-4}$. The vertical offset of the fault under the facility lies between the existing conditions evaluated in cases 1a (9m offset) and 1b (1m offset) in Reference 6. As shown in Table 2, the probable offset for these cases at the performance goal is less than 1 mm. This small amount of displacement has a negligible effect on structures and it could be concluded that the discovery of this fault is not a credible hazard for the design basis event.

However, if the worse case assumption is made that this is a principal fault and that all three faults are connected, the estimated offset from Figure 6 for the PC 3 performance goal is approximately 10 centimeters (4 inches). A displacement of this magnitude can cause significant cracking in a concrete shear wall structure such as those used in the construction of the CMR Building. This cracking could result in a loss of confinement.

It can be shown (Ref. 12) that the annual probability of seismic induced failure, based on ground motion associated with an earthquake, is about $2x10^{-3}$ for most areas of the CMR Building. The exceptions to this is the vault that has an annual probability of seismic induced failure, again, based on ground motion, of about $7x10^{-5}$, and the floor wells which have yet a lower probability of failure. The significance of this information is that ground motion could cause a loss of confinement for most areas of the CMR Building at frequency that is at least 20 times greater than surface rupture.

In the safety analysis for the CMR Building, the consequences of the seismic accident are assessed assuming that the CMR building, with the exception of the vault and floor wells, collapses at the frequency indicated above. With the vault and floor wells located such that they would not be directly effected by a surface displacement, the assumptions used in the safety analysis for the seismic accident are still valid even with new knowledge of a fault beneath the facility.

Based on current available information, the fault under the CMR site is a subsidiary fault. As a result, any movement on the fault is likely to be small and would be a result of a large (Magnitude 6 to 7) earthquake on the Rendija Canyon or the Pajarito fault. Such earthquakes are low probability events. In Figure 9 the estimated annual frequency of damage caused by ground motion is compared to the annual frequency of damage caused by surface rupture. This figure illustrates that damaging surface rupture is far less likely to occur than damaging ground motion.

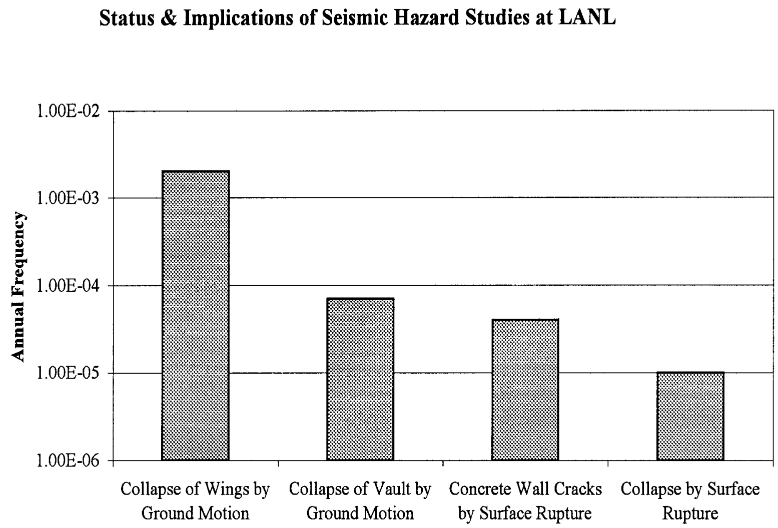

Figure 9 – Frequency of Seismic Induced Damage at CMR Building

5.2 Design Ground Motion

Of the current seismic hazard studies, only the paleoseismic investigations could influence the design ground motion at LANL. At this time only the information from the FY97 study can be assessed for its impact.

The design ground motion at LANL is based on the results of the probabilistic seismic hazard analysis (PSHA) presented in Reference 2. According to this reference, the net slip rate of the Pajarito fault is the most important input parameter in the PSHA. For this fault the PSHA assumed the slip rates shown in Table 5. One of the objectives of the paleoseismic investigations is to get a more accurate assessment of the slip rate on the Pajarito fault.

Table 5 – Net Slip Rates for Pajarito Fault Used In PSHA

Net Slip Rate (mm/yr)	Probability[1]	Percentile[2]
0.01	0.1	5th
0.05	0.2	20th
0.09	0.4	50th
0.20	0.2	80th
0.95	0.1	95th

[1]Probability used in PSHA Logic Tree
[2]Cumulative percentile

Based on the results of the FY97 paleoseismic investigation (Ref. 3) on the Pajarito fault, the net slip rate is 0.06-0.21 mm/yr. The lower of the two values is less than the median slip rate value of 0.09 mm/yr assumed in the PSHA. The higher of the two values is approximately equal to 80th

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percentile motion assumed in PSHA. Therefore, the slip rates calculated in the 1997 study are already covered in the PSHA documented in Reference 2.

Questions concerning the dependency of the three major faults are based on the physical location and style of deformation of the three faults. Their relative proximity to one another and style of deformation could lead to the conclusion that they must be connected at depth below the earth's surface. However, based on the paleoseismic studies to date, there is no evidence that supports this conclusion. The MRE on the Pajarito fault, dated at 1500-2000 years, is not coincident with either the MRE on the Guaje Mountain fault, dated at 4000-6000 years or the MRE on the Rendija Canyon fault, dated at either 8 or 23 thousand years. The trenches on the Pajarito do not show evidence for either a second (or third) earthquake at either 4000-6000 years or 8000 years.

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