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Seismic Assessment of Technical Area V (TA-V)

Assessors:

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Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Seismic Assessment of Technical Area V (TA-V)

[redacted]

Sandia National Laboratories, Albuquerque
P.O. Box 5800
Albuquerque, New Mexico 87185

January 13, 2010

ABSTRACT

The Technical Area V (TA-V) Seismic Assessment Report was commissioned as part of Sandia National Laboratories (SNL) Self Assessment Requirement per DOE O 414.1, *Quality Assurance*, for seismic impact on existing facilities at Technical Area-V (TA-V). SNL TA-V facilities are located on an existing Uniform Building Code (UBC) Seismic Zone IIB Site within the physical boundary of the Kirtland Air Force Base (KAFB). The document delineates a summary of the existing facilities with their safety-significant structure, system and components, identifies DOE Guidance, conceptual framework, past assessments and the present Geological and Seismic conditions. Building upon the past information and the evolution of the new seismic design criteria, the document discusses the potential impact of the new standards and provides recommendations based upon the current International Building Code (IBC) per DOE O 420.1B, *Facility Safety* and DOE G 420.1-2, *Guide for the Mitigation* of *Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities*.

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Executive Summary

This report was commissioned as part of Sandia National Laboratories (SNL) Self Assessment Requirement per DOE O 414.1, *Quality Assurance,* for seismic impact on existing facilities at Technical Area-V (TA-V).

The objective of this report is to document the Seismic Assessment that must be conducted at least every 10 years and include recommendations to DOE for updating the existing assessments based on significant changes found in methods or data for existing sites/facilities at SNL following significant changes in Natural Phenomena Hazards (NPH) assessment methodology or site-specific information. The Seismic Assessment uses a graded approach commensurate with the potential hazard of the facility (DOE O 420.1B, *Facility Safety*, Chapter IV "Natural Phenomena Hazards Mitigation").

Based on this assessment, it is concluded that the TA-V nuclear facilities are in compliance with DOE O 420.1B, based on the number and depth of facility reviews and analyses conducted over the last 10 years. Sandia National Laboratory, NM, has specifically followed DOE guidance which requires national laboratories to evaluate all building inventories for potential seismic risks and estimate the costs of mitigation.

In 1998, Executive Order 12941 (under the guidance provided by the Department of Energy [DOE]) *Management Plan for the Implementation of Executive Order 12941* (*Management Plan*) and *Interagency Commission on Seismic Safety in Construction* (ICSS C TR-17) required national laboratories to evaluate all building inventories for potential seismic risks and estimate the costs of mitigation. [redacted] These buildings and classification are tabulated in Section 7.1. [redacted]

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[redacted] Thus, TA-V facilities are deemed compliant with DOE O 420.1B.

However, DOE STD-1189 and ANSI/ANS 2.26 have been recently identified to specify the Seismic Design for new DOE facilities or major modification to existing facilities, SNL will review the gap identified in the seismic assessment and recommend a path forward based on a graded approach.

SNL TA-V facilities are located within the physical boundary of the Kirtland Air Force Base (KAFB). TA-V is composed of Buildings (also called Facilities), Structures, and Land. The Hazard Category (HC) of the facilities in the TA-V area range from Industrial to Nuclear Facilities HC-2. The nuclear facilities are the Annular Core Research Reactor (ACRR), the Sandia Pulsed Reactor Facility (SPRF), a Gamma Irradiation Facility (GIF), and the Auxiliary Hot Cell Facility (AHCF). . The other buildings can be categorized as radiological or industrial facilities. The Performance Category (PC) of the nuclear facilities, based on the respective UBC Zone IIB pedigree, are either PC-2 or PC-1, while the radiological and industrial facilities are categorized as PC-1 or PC-2. The nuclear facilities are used in advanced nuclear technologies, radiation effects, and radioisotope production research.

All buildings and structures, including nuclear and radiological buildings (facilities), were designed to the UBC-1994 or previous codes (Tables 3-1 and 3-2) [redacted]

For an existing site, if there are significant changes to the Assessment state-of-the-art or site-specific information, the NPH Assessment(s) must be updated. If SSCs of PC-3 and PC-4 are constructed or installed at an existing site that previously had only PC-1 and PC-2 SSCs and/or that did not have a site-specific NPH Assessment, then a site-specific NPH Assessment must be performed. A review of the state-of the-art of NPH Assessment methodology and of site-specific information must be conducted at least once every 10 years. The review should include recommendations to the Cognizant Secretarial Officers (CSOs) on the possible need for updating the existing NPH Assessments based on identification of any significant changes in methods or data. If no change is warranted from earlier assessment, then the review only needs to be documented as having taken place.

New standards to specify Seismic Design Criteria have been identified as follows: ANSI 2.26, ASCE 43-05 and ASCE 7-05. There is an adoption of national standards to specify SDC and Limit States (LS) aside from STD-1020 Performance Criteria (PC). It should be pointed out that reliance on DOE-STD-1020 series is no longer required for seismic events since the emergence of the new standards, but it is still applicable to other natural phenomena events.

The combination of new seismic contour maps and SDC assignment in 2000-IBC results in a decidedly more sophisticated approach to earthquake design than that in 1997-UBC. The primary facilities at TA-V were designed to the UBC (1954-1994) codes. The 2000-IBC has simply refined the design process to make it more accurate and reflective of the latest scientific information.

The TA-V Seismic Assessment specifically identifies the following recommendations:

- An IBC Seismic Site Class map should be prepared for TA-V to assist site planners in comparing the UBC based design of existing building(s), selecting a location for new facilities, and to help reduce cost of facilities modification renovation project in the Class “C” areas. This will result in significant long-term project savings.
- Establish a new Performance Category using the independently determined Seismic Design Category (SDC) and Limit State (LS) matrix discussed in this report.
- Evaluate Structure, System, and Components (SSC) to ensure that the IBC criteria are met.
- A prioritized schedule should be prepared based on the outcome of the reevaluation and the need for upgrade.
- A need for a Seismic Detection System for SSCs with PC equal to or greater than 2 should be evaluated.
- Post-Natural Phenomena Procedures should be prepared, as needed.

Seismic Assessment of Technical Area V (TA-V)

1.0 Objective

This report was commissioned as part of Sandia National Laboratories Self Assessment Requirement per DOE O 414.1, *Quality Assurance*, for seismic impact on existing facilities at TA-V. The objective of this report is to document the Seismic Assessment that must be conducted at least every 10 years and include recommendations to DOE for updating the existing assessments based on significant changes found in methods or data for existing sites/facilities at SNL following significant changes in NPH (Seismic) assessment methodology or site-specific information. The Seismic Assessment uses a graded approach commensurate with the potential hazard of the facility (DOE O 420.1B, *Facility Safety*, Chapter IV "Natural Phenomena Hazards Mitigation"). NPH and Seismic Terminology are used synonymously in this document).

2.0 Introduction

SNL TA-V Facilities are located on an existing Site within the physical boundary of Kirtland Air Force Base (KAFB). For an existing site, if there are significant changes in NPH assessment state-of-the-art or site-specific information, the NPH assessments must be updated. If SSCs of PC-3 and/or PC-4 are constructed or installed at an existing site that previously had only PC-1 and/or PC-2 SSCs, and/or that did not have a site-specific NPH Assessment, then a site-specific NPH Assessment must be performed. A review of the state-of the-art of NPH assessment methodology and of site-specific information must be conducted at least every 10 years. The review should include recommendations to the Cognizant Secretarial Officers (CSOs) on the need for updating the existing NPH assessments based on identification of any significant changes in methods or data. If no change is warranted from earlier assessment, then it must be documented as such.

SNL TA-V facilities are located on an existing UBC Seismic Zone IIB Site. TA-V is composed of buildings (also called facilities), structures, and land. The Hazard Category (HC) of the facilities range from HC-2 to Below Radiological facilities. The primary facilities HC-2 and HC-3 are the Annular Core Research Reactor Facility (ACRRF) and the Sandia Pulsed Reactor Facility (SPRF) (which is in two reactor facilities), the Gamma Irradiation Facility (GIF), and the Auxiliary Hot Cell Facility (AHCF). Other facilities are classified as radiological or Industrial Facilities. The performance categories for each facility are PC-2 or PC-1. These nuclear facilities are used in advanced Nuclear Technologies, Radiation Effects, and Radioisotope production research.

In 1998, Executive Order 12941 (under the guidance provided by the Department of Energy [DOE]) *Management Plan for the Implementation of Executive Order 12941* (*Management Plan*) and *Interagency Commission on Seismic Safety in Construction* (ICSSC TR-17) required national laboratories to evaluate all building inventories for potential seismic risks and estimate the costs of mitigation. [redacted]

Except for the one storage facility and one storage structure that was designed to the IBC-2000 code, all other buildings and structures were deigned to the UBC-1997 and previous codes. The primary nuclear facilities were designed to the UBC -1994 and/or the prior UBC versions of the code.

A new set of requirements for development of the seismic design basis is provided by DOE-STD-1189-2008, Appendix A, *Safety Systems Design Criteria*. These standards require the use of Seismic Design Category (SDC) and Limit States (LS) rather than the Performance Category (PC) and a five (SDC) by four (LS) array to characterize the SSCs.

2.1 Earthquake Design Philosophy – IBC vs. UBC

Understanding the difference between the earthquake design philosophies of the UBC versus those of the IBC is the key to appreciating the increase in safety made possible across the U.S. by the newer code. The UBC intended that structures be designed for "life-safety" in the event of an earthquake, with a 10-percent probability of being exceeded in 50 years (commonly referred to as the 475-year earthquake). The problem with this design earthquake, as was recognized during the development of the new spectral response acceleration maps, was that it did not provide adequate protection for the infrequent but very large seismic events. The IBC intends design for "collapse prevention" in a much larger earthquake, with a 2-percent probability of being exceeded in 50 years (commonly referred to as the 2,500-year earthquake).

One of the most significant improvements in the 2000 IBC over the 1997 UBC is the ground motion parameters used for seismic design. The maps in the UBC have always been based on seismic zones. The 1997 UBC maps were upgraded through the implementation of near-source factors to reflect increased ground motion for areas in close proximity to major known faults. However, their fundamental shortcoming remains: Not all areas within a Zone will have the same peak ground acceleration.

The maps provided in the IBC are more sophisticated in that they are not Zone maps at all, but rather contour maps giving spectral response quantities. The mapped quantities are the Maximum Considered Earthquake (MCE) spectral response acceleration, S_S (at short periods) and S_1 (at a 1-second period), for Site Class "B" soil (soft rock).

Two primary areas of potential impact are: 1) Seismic design, and; 2) Seismic Hazard Analysis. There is an adoption of national standards to specify Seismic Design Criteria (SDC) and Limit States (LS) rather than STD 1020 Performance Criteria (PC). It should be pointed out that under DOE-STD-1189, the provisions of ASCE/SEI 43-05/7-05 replace the seismic design requirements and performance criteria of DOE-STD-1020-2002. The seismic-related performance categorization guidelines of DOE-STD-1021-93 are replaced by the provisions of American National Standards Institute (ANSI)/ American Nuclear Society (ANS) 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A.

2.2 Hierarchy of Documents

There is an established hierarchy in the set of documents that specify NPH requirements. In this hierarchy, 10 CFR Part 830 (for Nuclear Facilities only) has the highest authority followed by DOE O 420.1 and the associated Guides DOE G 420.1-1 and DOE G 420.1-2. The four NPH standards (DOE-STDS-1020, 1021, 1022, and 1023) are the last set of documents in this hierarchy. In the event of conflicts in the information provided, the document of higher authority is to be utilized (i.e. the definitions provided in the Guides should be utilized even though corresponding definitions are provided in the NPH standards).

3.0 Site Description of Current Facilities at TA-V

[redacted] TA-V is located on DOE land situated within KAFB, which inhabits approximately 210 square kilometers (km^2) (81.25 mi^2 or 51,000 acres) and is under the direct control of the United States Air Force (USAF). By Memorandum of Understanding, the USAF will assist DOE in base occupancy control, including evacuation in the event of an accident or other emergency involving DOE facilities on KAFB.

[redacted]

[redacted]

All nuclear and radiological facilities, along with other supporting buildings (facilities), infrastructures, and land are identified on Tables 3-1 and 3-2. All nuclear facilities have been assigned a Hazard Category (HC) per DOE-STD-1027 and a Performance Category (PC) per DOE-STD-1020. Industrial facilities have been assigned a PC based on occupancy category. The buildings (facilities), infrastructures, and land are assigned a Hazard Category or an Occupancy Category to correlate with the assigned performance category.

[redacted]

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*[redacted]

3.1 Nuclear and Radiological Facilities

TA-V is a remote research area where experimental and engineering nuclear reactors, hot cells, [redacted] and gamma irradiation facilities are located. It contains the Annular Core Research Reactor (ACRR) and the SPR (in two reactor facilities), an intense Gamma Irradiation Facility (GIF), and the Auxiliary Hot Cell Facility (AHCF).

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4.0 TA-V Geology and Seismic Information

4.1 Geology

TA-V is situated on a mesa composed of alluvial deposits eroded from the adjacent mountains. The mesa is bounded on the east by the Manzano Mountains, on the west by the Rio Grande, on the north by Tijeras Arroyo and Arroyo del Coyote, and on the south by Hell's Canyon Wash. The slope of the mesa is characterized by a consistently gradual decline toward the river. [redacted] The terrain is characterized by numerous small canyons that have been cut through the mesa by drainage from the mountains.

4.2 Site Geology

TA-V is underlain by formations of the Santa Fe Group of Quaternary and Tertiary age. The Santa Fe Group is in turn underlain by formations of Permian, Pennsylvanian, and Precambrian age. These older rocks crop out in the horst approximately 800 m (0.5 mi) east of the site and in the mountains farther east. Thin deposits of recent alluvium occur in the arroyos in the area. Table 4-1 summarizes the stratigraphy of TA-V.

Table 4-1. Stratigraphy of TA-V

AGE	FORMATION/ GROUP	THICKNESS (m)	CHARACTER	WATER-BEARING CHARACTERISTICS
Recent	Alluvium	4-6	Sand & Gravel	Unsaturated but generally highly porous & permeable.
Quaternary & Tertiary	Santa Fe Group	0-3000	Sand, Gravel & Silt; Generally unconsolidated	Permeable & porous. The only important aquifer in the area.
Permian	San Anders, Yeso & Abo Formations, Glorieta Sandstone	850	Sand, Silt, & Lime stones	Low permeability & porosity, but some water occurs in Glorieta sandstone. Most water in these formations occurs in cracks & joints.
Pennsylvania	Magdalena Group	240-270	Sand, Silt, & Lime stones	Low permeability & porosity. Most, if not all, water occurs in cracks & joints.
Precambrian	Sevilett Formation, Upper & Lower Metaclastic Series, Greenstone Complex Intrusives	≥ 5500	Metamorphosed sedimentary & pyroclastic rock & intrusives & granites & pegmatites.	Low permeability, low porosity. All water in these formations occurs in cracks & joints.

4.3 Soil Characteristics

TA-V falls within the Upper Llano de Manzano geomorphic sub-province, and Arroyo del Coyote, at least the part that drains TA-V, falls within the Tijeras Arroyo geomorphic sub-province. Soils associated with the Arroyo del Coyote valley floor and embankments and the northeast section of TA-V are of the Embudo and Tijeras series. These soils are generally well drained, have moderate permeability, and have high potential for surface erosion. Water percolates rapidly through the fine sandy loam associated with the Arroyo del Coyote valley floor (DOE/EIS-0281). In addition to the Embudo and Tijeras Series, TA-V has soils of the Madurez Series (SAND99-1775). Water percolates very rapidly through Madurez loamy fine sand and Madurez Wink association soils. The moderate-to-rapid percolation in these soils reduces excess runoff that might cause flooding. Major soil classifications for TA-V are described in Table 4-2.

Table 4-2. Major Soil Classification and Arroyo del Coyote Drainage Area (USDA, 1977)

SERIES	TYPE	SUB-PROVINCE*	SLOPE (%)	RUNOFF	SOIL & WATER EROSION HAZARD
Embudo	Embudo gravely fine sandy loam	1,3	0 to 5	Medium	Water erosion moderate
	Embudo Tijeras Complex	1	0 to9	Medium	Water erosion moderate
Tijeras	Tijeras gravely fine sandy loam	1,3	1 to 5	Moderate	Water erosion moderate
Madurez	Madures loamy fine sand	1,3	1 to 5	Slow	Soil blowing severe
	Madurez-Wink association	1,3	1 to 5	Slow	Soil blowing moderate-to-severe

*Sub-province: 1 = Tijeras Arroyo; 3 = Upper Llano de Manzano

4.4 Seismicity

Ten absolute-gravity stations in the vicinity of SNL/KAFB are maintained by the National Geodetic Survey and the Defense Mapping Agency. Based on available information, most earthquakes recorded in New Mexico have occurred along the Rio Grande trough, with the region between Albuquerque and Socorro (100 km [62 mi] apart) exhibiting the highest concentration and accounting for approximately 90% of the recorded earthquakes between 1890 and 1960. Instrumented seismic records for New Mexico beginning in 1960 indicate that the pattern of seismic activity for earthquakes of Richter magnitude 2.7 or greater has shifted such that the center of activity is in the northeast quadrant of the state. So far as can be determined from geologic data, there have been no intensive earthquakes in the Albuquerque area within recent geologic history.

Three zones of faulting on the western slopes of the Sandia and Manzano Mountains have been identified in the vicinity of Manzano Area and the SNL Technical Areas: The Tijeras Fault, the Sandia Fault, and the Hubbell Springs Fault. The Tijeras and Sandia Faults converge near the south end of TA-III into the Hubbell Springs Fault (Figure 4-1). The Hubbell Springs Fault is particularly important to the ACRRF and other facilities in TA-V/TA-III because it has been active as recently as the period from 1932 to 1935, when earth movement along the fault shut off the water flow from nearby springs.

4.5 Surface Faulting

Faults that extend from depth to the surface do exist on the KAFB (Figure 4-1). Recent spectral mapping has revealed tributaries close to the TA-V area. End points of the tributaries are limited by the information available beyond the plotted information.

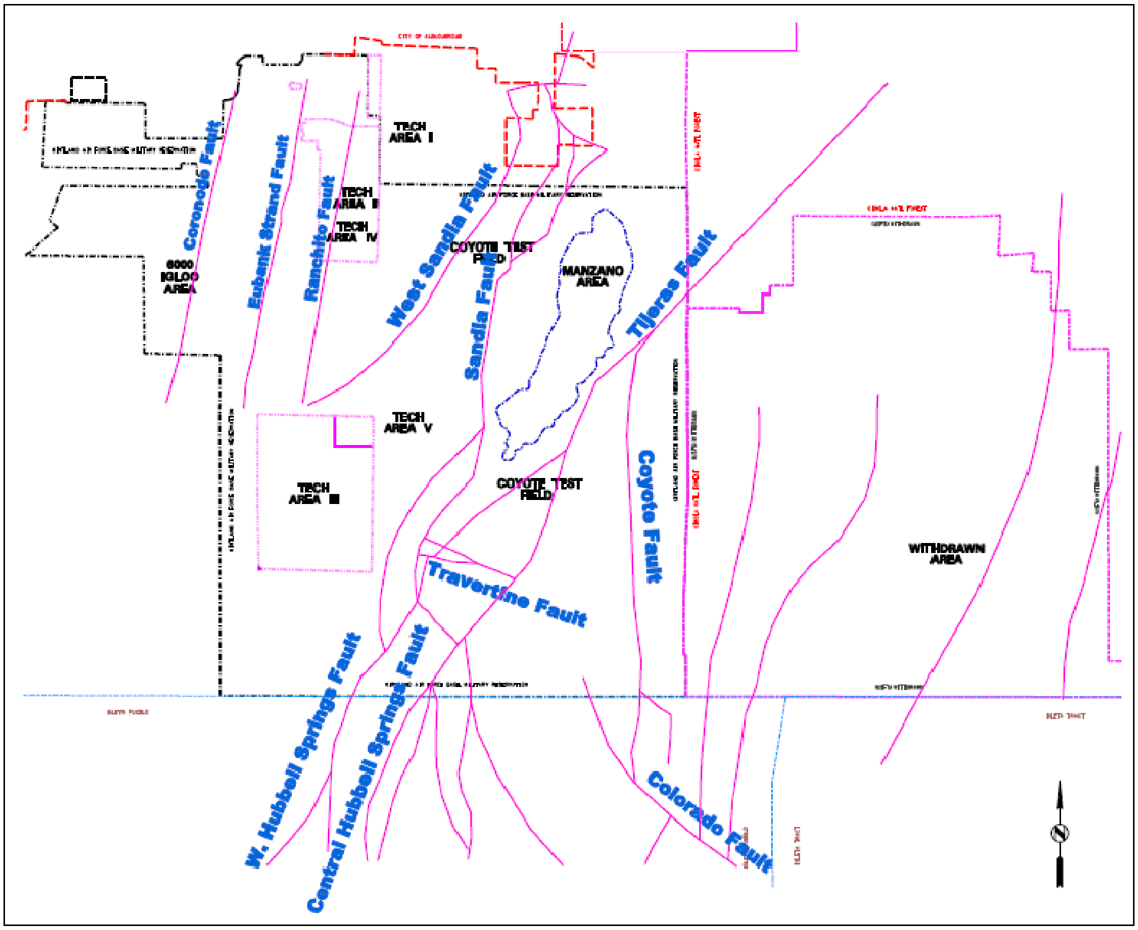

Figure 4-1. Fault Zones Near SNL

4.6 Maximum Earthquake Potential

An examination of the records available for the Albuquerque-Belen Basin shows that the frequency of earthquakes is relatively high but that the normal magnitudes are low. Between 1960 and 1986, 46 earthquakes of approximate Richter Magnitude 2.7 or greater were recorded. Some current seismic events are identified below. More recent recorded earthquakes were reviewed and chronologically identified below. The largest recorded earthquake in New Mexico was in 1971 with a Richter Magnitude of 4.7. Two other earthquakes (SNL, 2006a) with magnitudes of approximately 4.7 on the Richter scale occurred on November 28, 1970, and January 4, 1990, near the town of Bernardo, New Mexico, 104 kilometers (65 miles) south of Albuquerque. Damage was reported only to the Bernardo area. Present seismic activity, which shows little correlation with the Albuquerque area fault zones, is concentrated more in the vicinity of the mountains west of Socorro, 120 kilometers (75 miles) south of KAFB.

Earthquake records prior to 1960 are based on the Modified-Mercalli Intensity Scale, which is highly subjective in evaluation and, as such, is of minimal value in seismic design evaluation. Within the Albuquerque-Belen Basin, most seismic activity is centered in the Socorro area, approximately 90 km (56 mi) south of the TA-V site. Seismic activity in the Basin is characterized by “swarms;” that is, earthquakes that occur in rapid succession and are of small magnitude. Larger earthquakes (magnitude 2.7 or greater) have occurred with an average frequency of 1.8 per year since 1960.

The largest shock predicted in New Mexico in a 100-year time period is of magnitude 6.0 on the Richter scale (SAND95-2126). The equation for the Expected Number predicts approximately 1.5 for a 100-year period.

Presented chronologically below is seismic activity from the New Mexico Tech Seismological Observatory:

Date: 12/31/97, 11:00 a.m. MST

This morning's earthquakes were centered approximately 10 km NE of Mountainair, NM (the appears to be centered near 34 deg, 35.791 min N, 106 deg, 10.267 min W). The largest earthquake occurred at 6:28:27 a.m. MST and had an NM Tech duration magnitude of approximately 3.0. Note that these earthquakes were rather distant from the NMT network, and these locations should be taken as preliminary.

Date: 1/04/98, 1:00 p.m. MST

The strongest earthquake to date in the ongoing Willard Swarm occurred this morning at 01:05:32 a.m. and measured 3.8 on the NMT duration magnitude scale. The epicenter of the event (34 deg 32.13 N 106 7.71 W) was within a few km of previous event epicenters observed in this area since 12/23/97 (approximately 100 to date), including the strong triple event at 6:28:27 a.m. MST which had an NM Tech duration magnitude of approximately 3.0. Earthquakes of this size are not especially rare in New Mexico, occurring at irregular intervals of several years. Comparably-sized or larger earthquakes remain possible in this swarm.

Date: 1997-1998 Willard Swarm Information

The Willard Swarm earthquakes of 1997-1998 (maximum magnitude 3.8), while widely felt, were not especially large by New Mexico standards. On January 4, 1998, the Albuquerque Seismological Laboratory seismic station ANMO recorded an earthquake with a duration magnitude of 3.8. This earthquake occurred southeast of Albuquerque, just south of Willard, New Mexico. This earthquake is only a few miles from the seismic activity which occurred on New Year's Eve. The earthquake plotted above (in black) is the largest of the recent earthquakes to have occurred in the area. A micro-earthquake aftershock with a duration magnitude of less than 1.0 occurred in the same vicinity, approximately 200 seconds after the arrival of the P-wave of the main event (Earthquake seismograms from the Willard Swarm).

Date: 3/23/98, 2:00 p.m. MST

Several residents of San Acacia, NM felt a local earthquake around 10:05 p.m. Sunday evening, March 22. The NMT Seismological Observatory has recorded a small swarm of approximately 10 earthquakes with epicenters near San Lorenzo Arroyo since then, with the first (10:03:46.8 p.m. MST) and largest having a magnitude of 2.1. This first earthquake was felt because it was fairly large and because its source was shallow (only approximately 2.5 km or 1.6 miles deep). All of the other events in this swarm so far have been much smaller (less than about magnitude 1).

Date: 3/24/98, 9:00 p.m. MST

A series of minor earthquakes measuring between magnitudes 2.1 and less than 1 occurred Sunday night, March 22, through Monday, March 23, near the northern Socorro County communities of San Acacia and Alamillo, NM, which are located about 11 miles north of Socorro.

Seismologists at New Mexico Tech in Socorro recorded the earthquake activity on the university's network of seismic stations and fielded felt reports from the largest tremor from San Acacia area residents. Preliminary analyses of the quakes show the epicenter to be about three and a half miles west of San Acacia, near San Lorenzo Arroyo.

The first earthquake, which registered at magnitude 2.1, occurred at 10:03:46.8 p.m. This temblor was the strongest. It was then followed by a swarm of at least 10 smaller earthquakes, all measuring less than magnitude 1 and were too small to be felt. "The first earthquake was felt because it was fairly large and because its source was shallow--only approximately 2.5 kilometers or 1.6 miles deep," says Richard C. Aster, Associate Professor of Geophysics and Research Geophysics at New Mexico Tech.

Historical and recent records of New Mexico earthquakes show that, although the area along the Rio Grande from Socorro north to Bernardo occupies only two percent of the total area of the state, it accounts for about 45 percent of all of New Mexico's earthquake activity. Seismic records also show that the earthquake activity in the area is often dominated by swarms of temblors lasting days or weeks, some strong enough to be felt.

Aster explains that the relatively high earthquake activity in the Socorro area, an area that seismologists refer to as the "Socorro seismic anomaly," is probably attributable to the ongoing inflation of a mostly thin, yet extensive, horizontal layer of molten rock, the "Socorro magma body," residing about 12 miles below the middle Rio Grande valley, between Socorro and Bernardo.

Date: 4/7/98, 11:00 a.m. MST

Several residents of Lemitar and Escondida, NM felt an earthquake around 06:21 p.m. Monday evening, April 6th. The NMT Seismological Observatory recordings placed the epicenter near Lemitar with a magnitude of 1.9. Numerous earthquakes have been recorded in the same area before April 6th, including a slightly stronger earthquake with a magnitude of 2.0 at 11:25 p.m. on March 24. No felt reports were received for this earthquake.

A series of minor earthquakes measuring between magnitudes 2.1 and less than 1 occurred Sunday night, March 22, through Monday, March 23, near the northern Socorro County communities of San Acacia and Alamillo, located about 11 miles north of Socorro.
Seismologists at New Mexico Tech in Socorro recorded the earthquake activity on the university's network of seismic stations and fielded felt reports from the largest tremor from San Acacia area residents. Preliminary analyses of the quakes show the epicenter to be about three and a half miles west of San Acacia, near San Lorenzo Arroyo.

The first earthquake, which registered at magnitude 2.1, occurred at 10:03:46.8 p.m. This strongest temblor was then followed by a swarm of at least 10 smaller earthquakes, all measuring less than magnitude 1 and too small to be felt. "The first earthquake was felt because it was fairly large and because its source was shallow--only approximately 2.5 kilometers or 1.6 miles deep," says Richard C. Aster, associate professor of geophysics and research geophysics at New Mexico Tech.

Date: 8/19/00, 05:26:28 a.m. MDT

The WIPP Seismograph Network recorded signals from the pipeline explosion at all seven of its stations. However, all signals recorded were sonic rather than seismic, that is, they traveled through the air rather than the ground. The best recording of this event was at Station CL2B, located about 23 km NNE. The first signal received at this station was a weak short duration pulse followed by a 24 second period of very weak oscillations. At the end of the 24 second period the largest of the sonic pulses occurred followed by strong continuous noise that persisted until the pipeline was shut down a little less than one hour later. A sonic pulse about twice the strength of the continuous noise was recorded about 17 seconds after the largest signal. Using a velocity of 335 m/sec and a distance of 23 km, we obtained the following origin times for the three sonic pulses based on arrival times at station CL2B:

- First 05:26:28 MDT Weak;
- Second 05:26:52 MDT Strong;
- Third 05:27:10 MDT Moderate

We speculate that the first sonic pulse is the initial rupture of the gas pipeline. The second is the ignition of the gas and possibly further rupture of the pipeline. The third might also be further rupture.

Historical and recent records of New Mexico earthquakes show that, although the area along the Rio Grande from Socorro north to Bernardo occupies only two percent of the total area of the state, it accounts for about 45 percent of all of New Mexico's earthquake activity. Seismic records also show that the earthquake activity in the area is often dominated by swarms of temblors lasting days or weeks, some strong enough to be felt.

Aster explains that the relatively high earthquake activity in the Socorro area, an area that seismologists refer to as the "Socorro seismic anomaly," is probably attributable to the ongoing inflation of a mostly thin, yet extensive, horizontal layer of molten rock, the "Socorro magma body," residing about 12 miles below the middle Rio Grande valley, between Socorro and Bernardo.

Date: 3/02/04, 10:00 a.m. MST

Beginning on February 27th, the NMT Seismological Observatory recorded a sequence of small earthquakes in Northern Socorro County and has fielded reports that several of these have been felt in the La Joya area. The largest of these events had a magnitude of 1.9 and occurred at approximately 12:17:30 p.m. MST on February 29th. As of 10:00 a.m. on March 2nd, there have been approximately 15 events up to this size associated with an epicentral area approximately 2.5 miles north of the Walking Sands rest stop on Interstate 25, and approximately 1 mile east of the Interstate. Such swarms have been observed many times in the region during the past several decades, and there is no reason to believe that they presage larger shocks. Swarms of earthquakes in the Socorro region are related to the presence of a deep (12 miles) slowly inflating (approximately 1 tenth of an inch per year) magma body that underlies the Rio Grande Rift in this part of New Mexico.

Vibratory Ground Motion

In 1970 and 1971, earthquakes of Richter Magnitude 3.5 and 3.8, respectively, occurred with epicenters in the area west of Albuquerque known as the west mesa. A time-history accelerogram compiled for the November 28, 1970, earthquake, with an epicenter approximately 21 km (13 mi) west of the TA-V facility, shows that the frequency of ground motion during the most active part was 13 to 20 Hertz (Hz); it shows also that there was a build-up period of approximately 10 seconds followed by approximately 20 seconds of sustained maximum motion. Ground motion then gradually decayed over the next several minutes. This accelerogram was made at the Black Butte Station, located approximately 64 km (39.8 mi) south of Albuquerque and situated on the basin plane. Therefore, because the entire basin region is the same general unified alluvial fill structure, the ground motion recorded at Black Butte would be representative of ground motion at TA-V. The 3.5 magnitude of this earthquake has an associated maximum acceleration of approximately 0.007 g.

The Albuquerque area is located in Seismic Zone “2B” on the Seismic Risk Map of the United States (ICBO, 1994), which is defined as a region that can be expected to receive moderate damage from earthquakes. This is approximately equivalent to a Richter Magnitude of 5.0 to 6.0, with maximum acceleration of 0.22 g.

4.7 Liquefaction Potential

Liquefaction is a phenomenon in which loose and water-saturated sediments become liquefied by strong ground motion due to a seismic event. The most susceptible soils are generally along rivers, streams, lake, and ocean shorelines where saturated sediments lay between 0 and 30 feet of the surface. Given the arid nature of the Albuquerque basin and surrounding highlands; the 420 feet to 520 feet deep water table under TA-V; the lack of rivers, streams, and lake or ocean shorelines near TA-V; and the fact that TA-V is built outside the 100-year and 500-year floodplains of nearby arroyos (normally dry drainages common to the arid Southwest US) such that the facilities are not threatened by flooding (SAND93-0681), the conclusion that liquefaction of the TA-V soils is highly unlikely.

4.8 Seismic Detection Requirement (DOE 0 420.1B)

Facilities or sites with hazardous materials must have instrumentation or other means to detect and record the occurrence and severity of seismic events.

Earthquake Early Warning Systems (EEWS), based on real-time prediction of ground motion or structural response measures, may play a role in reducing vulnerability and/or exposition of buildings and lifelines. Seismologists recently developed efficient methods for rapid estimation of event features by means of limited information of the P-waves[1]. When an event is occurring, probabilistic distributions of magnitude and source-to-site distance are available and the prediction of the ground motion at the site, conditioned to the seismic network measures, may be performed in analogy with the Probabilistic Seismic Hazard Analysis (PSHA). Consequently, the structural performance may be obtained by the Probabilistic Seismic Demand Analysis (PSDA), and used for real-time risk management purposes. However, such prediction is performed in very uncertain conditions which have to be taken into proper account to limit false and/or missed alarms.

There are ten absolute-gravity stations in the vicinity of SNL/KAFB. These stations are maintained by the National Geodetic Survey and the Defense Mapping Agency. SNL maintains the National Seismic Station (F.A.C.T site), which is located southeast of TA-V. The current UBC based facilities and PC-2 SSC’s do not have instrumentation to identify the occurrence of a seismic event.

4.9 Post-Natural Phenomena Procedures (DOE 0 420.1B - Only for Seismic)

Facilities or sites that have SSCs in PC-2, PC-3, or PC-4 are required to have procedures to inspect the facility for damage due to a severe NPH in order to be able to place the facility into a safe configuration when damage occurs, and to document and report such damage.

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[1] Seismic waves are the waves of energy (recorded on seismographs) that travel through the earth. There are several different kinds of seismic waves, which all move in different ways. The two main types of waves are body waves and surface waves. Body waves can travel through the earth's inner layers, but surface waves can only move along the surface of the planet like ripples on water. Earthquakes radiate seismic energy in the form of both body and surface waves. Traveling through the interior of the earth, body waves arrive before the surface waves emitted by an earthquake. These waves are of a higher frequency than surface waves. The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave, and, consequently, the first to “arrive” at a seismic station. The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. P waves are also known as compression waves, because of the pushing and pulling they do. Subjected to a P wave, particles move in the same direction that the wave is moving in (which is the direction that the energy is traveling in) and are sometimes called the “direction of wave propagation.” The second type of body wave is the S wave or secondary wave, which is the second wave felt in an earthquake. An S wave is slower than a P wave and can only move through solid rock, not through any liquid medium. It is this property of S waves that led seismologists to conclude that the Earth's outer core is liquid. S waves move rock particles up and down, or side-to-side – perpendicular to the direction that the wave is traveling (the direction of wave propagation).

SNL has assembled a team of multi-discipline engineers (structural, mechanical, electrical, and fire protection) having post-disaster Safety Inspection Training to assess, document, and report the damage incurred and to determine the what mitigative actions are required to place the facility into safe configuration of non-nuclear facilities. [redacted]

5.0 Applicable DOE Guidance for Seismic Assessment

5.1 DOE Guidance (DOE G 420.1-2)

The current requirements for natural phenomena hazard design are contained in DOE O 420.1B, *Facility Safety,* (Attachment *2,* Chapter IV, “Natural Phenomena Hazards Mitigation,” Section 3, ‘Requirements’). The requirements state that:

> *U.S. Department of Energy facilities and operations must be analyzed to ensure that Structures, Systems, and Components (SSCs) and personnel will be able to perform their intended safety functions effectively under the effects of NPH, where no specific requirements are identified. Model building codes or national consensus industry standards must be used consistent with intended SSC functions.*

New set of requirements for development of the seismic design basis is provided by DOE-STD-1189-2008, Appendix A, *Safety Systems Design Criteria*. Under DOE-STD-1189, the provisions of ASCE/SEI 43-05/7-05 replace the seismic design requirements and performance criteria of DOE-STD-1020-2002. The seismic-related performance categorization guidelines of DOE-STD-1021-93 are replaced by the provisions of American National Standards Institute (ANSI)/American Nuclear Society (ANS) 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A.

The National Earthquake Hazard Reduction Program (NEHRP), Executive Order 12699 (1/5/90), and Executive Order 12941 (12/1/94) were created in response to the Earthquake Hazards Reduction Act (Public Law 95-124). The Act was written to reduce the risk to life and property in federally owned, leased, or regulated buildings. Executive Order 12699 chartered the Interagency Committee on Seismic Safety and Construction (ICSSC) to recommend cost-effective seismic design and construction standards and practices that would reduce the seismic risk to life and property for new Federal buildings. The ICSSC recommendations for seismic design criteria are provided in *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* (FEMA, 302). The corresponding implementation guidelines for new buildings are provided in ICSSC RP-2.1-A. The ICSSC also periodically reviews the seismic provisions of current model building codes. Three model building codes (UBC, BOCA, and SBCCI), combined in the year 2000 as the International Building Code (IBC 2000) were found to be substantially equivalent to, or to exceed, NEHRP-recommended provisions. The IBC is revised every three years; therefore the most recent applicable IBC code should be applied. The DOE requirements for seismic engineering follow the UBC (including references to support materials), unless the importance of achieving a high level of protection warranted the use of more demanding methods and criteria. The DOE requirements are, therefore, essentially in compliance with NEHRP provisions. Executive Order 12941 (issued December 1, 1994) extended seismic requirements to existing Federally owned or leased buildings.

Executive Order 12941 requires an assessment of compliance with minimum performance criteria, identification of the need for seismic upgrades, and the development of a cost estimate for seismic upgrades within 4 years. The guidance provided herein is consistent with the requirements of Executive Order 12941, the provisions of ICSSCRP-4, the guidance provided in ICSSC RP-5 and the *Handbook for the Seismic Evaluation of Existing Buildings* (FEMA-178).

It is important to note that Executive Orders 12699 and 12941 apply to all Federal buildings (including nuclear facilities), however, they do not address the confinement of hazardous materials nor do they address non-seismic natural phenomena. DOE O 420.1B and the associated Guides address these issues.

5.2 DOE NPH (Seismic) Design Guidance (DOE-STD-1020)

The overall approach for NPH mitigation is consistent with the graded approach embodied in the facility SAR, DSA and the BIO. The application of NPH design requirements to Structures, Systems, and Components (SSCs) is based on the life-safety or the safety classifications for the SSCs as established by safety analysis. The application of the most rigorous design requirements should be limited to those SSCs classified by safety analysis as Safety-Class or Safety-Significant consistent with DOE-STD-3009-94. .

Mission importance and economic considerations should also be used to categorize SSCs which require NPH design. Once the SSCs have been classified, DOE O 420.1B and the associated Guides specify the NPH requirements to ensure that the SSCs are adequately designed to resist NPH. The NPH requirements utilize a graded approach in order to provide a reasonable level of NPH protection for the wide variety of DOE facilities. A graded approach is one in which various levels of NPH design, evaluation, and construction requirements of varying conservatism and rigor are established, ranging from common practice for conventional facilities to practices used for more hazardous critical facilities.

Four DOE Standards (DOE-STDS-1020, 1021, 1022, and 1023) have been developed to provide specific acceptance criteria for various aspects of NPH to meet the requirements of DOE O 420.1 and the associated Guides. These NPH standards should be used in conjunction with other pertinent documents which provide more detailed methods on specific NPH design and evaluation subjects such as DOE guidance documents, consensus national standards, model building codes, and industry accepted codes and specifications. Figure 5-1 (DOE-STD-1020) presents a conceptual NPH design frame work which identifies how the DOE standards are used to assess NPH design requirements.

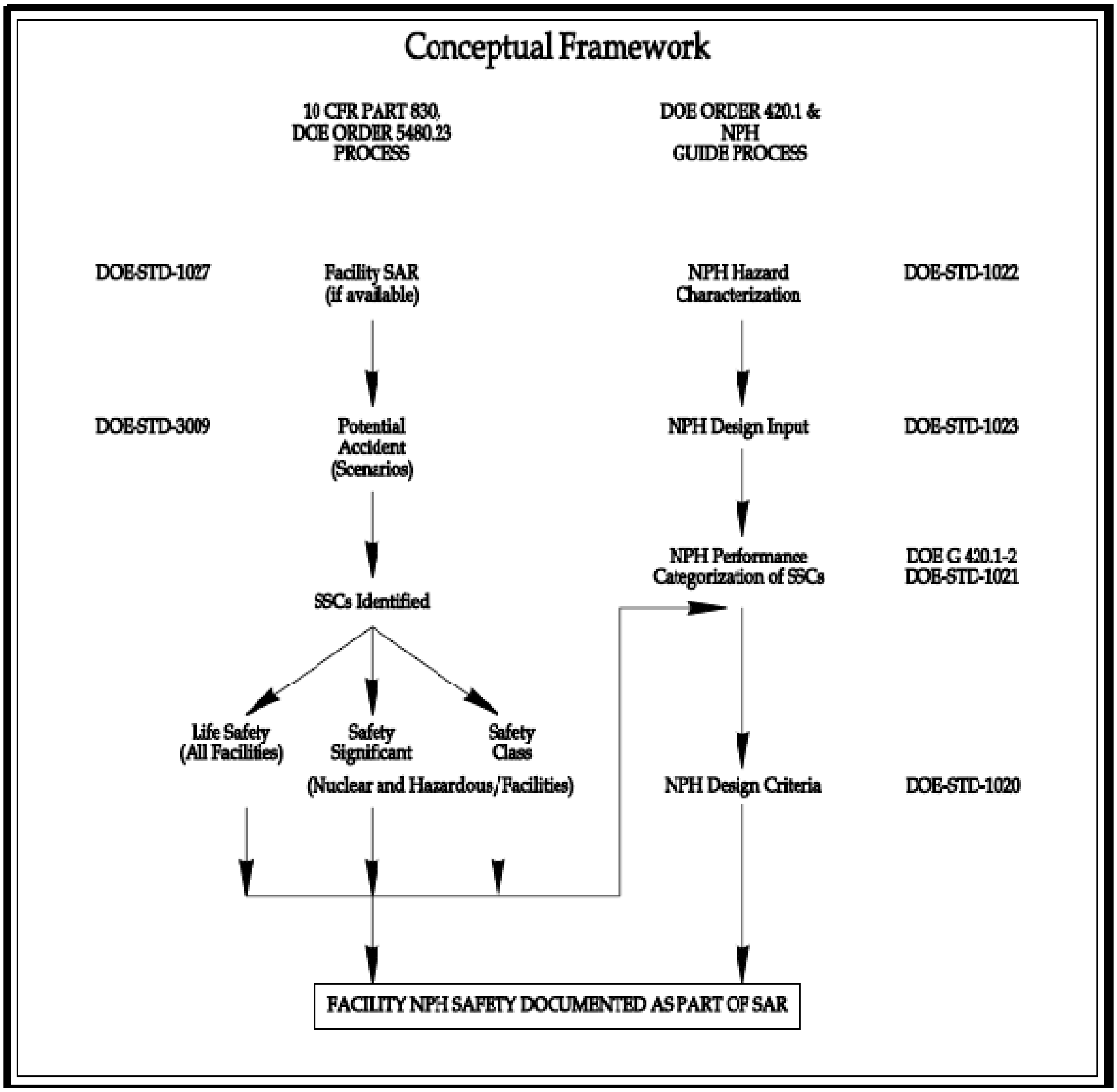

Figure 5-1. Natural Phenomenon Design Input[2]

5.2.1 Historical DOE Guidance per DOE-STD-1020, Evaluation of Existing Facilities

These criteria are applicable to evaluations of existing facilities. General guidelines for the seismic evaluation of existing facilities are presented in National Institute of Standards and Technology documents (Refs. ICSSC RP-3 & ICSSC RP-6). In addition, guidelines for upgrading and strengthening equipment are presented in Ref. FEMA 356. Also, guidance for evaluation of existing equipment by experience data is provided in References DOE-EH-0545 and Seismic Qualification Utility Group SQUG. These documents should be referred to for the overall procedure of evaluating seismic adequacy of existing facilities, as well as for specific guidelines on upgrading and retrofitting.

[2] This figure is dated since DOE O5480.23 is probably no longer applicable and DOE O 420.1B has replaced DOE O 420.1.

Once the “as-is” condition of a facility has been verified, and deficiencies or weak links have been identified, detailed seismic evaluation and/or upgrading of the facility, as necessary, can be undertaken. Obvious deficiencies that can be readily improved should be remedied as soon as possible. Seismic evaluation for existing facilities would be similar to evaluations performed for new designs except that a single as-is configuration is evaluated instead of several configurations in an iterative manner (as is often required in the design process). Evaluations should be conducted in order of priority. Highest priority should be given to those areas identified as weak links by the preliminary investigation and to areas that are most important to personnel safety and operations with hazardous materials. Input from safety personnel and/or accident analyses should be used as an aid in determining safety priorities.

The evaluation of existing facilities for natural phenomena hazards can result in a number of options based on the evaluation results. If the existing facility can be shown to meet the design and evaluation criteria presented in Sections 2.3.1 or 2.3.2 and good seismic design practice had been employed, then the facility would be judged to be adequate for potential seismic hazards to which it might be subjected. If the facility does not meet the seismic evaluation criteria of this chapter, a back-fit analysis should be conducted. Several alternatives can be considered:

1) If an existing SSC is close to meeting the criteria, a slight increase in the annual risk to natural phenomena hazards can be allowed within the tolerance of meeting the target performance goals (Section 1.3). Note that reduced criteria for seismic evaluation of existing SSCs are supported in Reference ICSSC RP-3. As a result, some relief in the criteria can be allowed by performing the evaluation using hazard exceedance probability of twice the value recommended in DOE Standard for the Performance Category of the SSC being considered.
2) The SSC may be strengthened such that its seismic resistance capacity is sufficiently increased to meet these seismic criteria. When upgrading is required it should be designed for the current design criteria.
3) The usage of the facility may be changed such that it falls within a less hazardous Performance Category and consequently less stringent seismic requirements.
4) It may be possible to conduct the aspects of the seismic evaluation in a more rigorous manner that removes conservatism such that the SSC may be shown to be adequate. Alternatively, a probabilistic assessment might be undertaken in order to demonstrate that the performance goals can be met.

Requirements of Executive Order 12941 are to be implemented. The requirements of ICSSC RP6 are minimum requirements to be met for existing buildings, especially the mitigation requirements triggered by Section 2 of this Standard. The line organization may define “Exceptionally High Risk buildings” to meet their safety and mission needs. Provisions in FEMA 310 and FEMA 356 should be taken into account while evaluating and upgrading existing buildings. Specific provisions may have to be modified to meet criteria for PC-3 and PC-4 in this standard. DOE O 420.1 requires that the sites should prepare upgrade plans for buildings that are deemed deficient to meet NPH requirements. Some of these deficiencies may have been discovered during the facility safety reviews and or during implementation of Executive Order 12941. One of the prioritization schemes to upgrade such deficient building is given in DOE Standard although sites may choose their own schemes.

5.3 DOE Guidance (DOE-STD-1189-2008), New Facilities and Major Modifications of Existing Facilities

The seismic design classification and collocated worker safety significant criteria of this Appendix should not be applied in a backfit sense to existing facilities that are not undergoing modifications. For major modifications of existing facilities, these criteria should be used with the following caveats. Backfit analyses should examine:

1) The need to upgrade interfacing Structures, Systems, and Components in accordance with these criteria, and;
2) Whether there should be relief for the modification from the design requirements that application of these criteria in design would imply.

TA-V safety basis documents have been developed and approved in accordance with current DOE requirements. Hazard and accident analyses (as applicable) evaluate off-site and worker impacts and identify safety SSCs. There are no facility installed safety class SSCs at any TA-V facility.

6.0 Quality Assurance (QA) and Peer Review

All DOE Structures, Systems, and Components must be designed or evaluated utilizing a formal Quality Assurance (QA) plan as required by 10 CFR Part 830 and DOE O 414.1C. The QA and peer review should be conducted within the framework of a graded approach with increasing level of rigor employed from Performance Category 1 to 4. The major features of a thorough QA plan for design or evaluation for natural phenomena hazards is described as follows:

In general, it is good practice for a formal QA plan to include the following requirements:

On the design drawings or evaluation calculations, the engineer must describe the NPH design basis including: 1) Description of the system resisting NPH effects, and; 2) Definition of the NPH loading used for the design or evaluation. Design or evaluation calculations should be checked for numerical accuracy and for theory and assumptions.

For new construction, the engineer should specify a program to test materials and inspect construction. In addition, the engineer should review all testing and inspection reports and visit the site periodically to observe compliance with plans and specifications.

For Performance Categories 2, 3, and 4, NPH design or evaluation must include independent peer review. The peer review is to be performed by independent, qualified personnel. The peer reviewer must not have been involved in the original design or evaluation. If the peer reviewer is from the same company/organization as the designer/evaluator, the peer reviewer must not be part of the same program where (s)he could be influenced by cost and schedule consideration. Individuals performing peer reviews must be degreed civil/mechanical engineers or qualified professionals in the field of review with 5 or more years of experience in NPH evaluation.

Since the TA-V Nuclear facilities have been categorized as PC-1 or PC-2, Quality Assurance Program is required within a graded approach, with increasing rigor ranging from the IBC requirements from PC-1 to nuclear power plant requirements for PC-4). Per the DSA, SAR or the BIO the QA program is implemented at the facility.

Similarly, since the TA-V Nuclear facilities have been categorized as PC-2 Peer Review for PC-1 category is not required although in a nuclear facility it is recommended. For Performance Categories 2, 3 and 4 peer review is required within a graded approach, with the increasing ranging from IBC requirements from PC-2 to nuclear power plant requirements for PC-4. The NPH design and evaluations during the 1998 assessment and 2007 Scoping study were performed by independent, qualified personnel.

7.0 Past and Current Seismic Assessments of TA-V

The following sections document the past seismic assessment conducted in 1998 per Executive Order 12941 under the guidance of DOE and the current seismic assessment per DOE O 420.1B, *Facility Safety*.

7.1 Past Seismic Assessments of TA-V and Other Facilities at SNL (Ref: 12941)

In 1998, Executive Order 12941 under the guidance provided by the DOE, *Management Plan for the Implementation of Executive Order 12941* (Management Plan) and the *Interagency Commission on Seismic Safety in Construction* document (ICSSC TR-17) required national laboratories to evaluate their building inventory for potential seismic risks and estimate the costs of mitigation. SNL downloaded data from the DOE's Facilities Information Management System (FIMS) database on August 29, 1998. The inventory comprises of four separate sites Albuquerque, New Mexico; Livermore, California; Tonopah, Nevada; and Kauai, Hawaii.

[redacted]

[redacted]

[redacted]

As inferred by Executive Order 12941, buildings requiring evaluation were evaluated for compliance with the requirements of FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA 178). In lieu of performing FEMA 178 evaluation, Section 3.3 of ICSSC RP-4 allows

[3] *Note: EHR scores greater than 42 were considered extremely high risk.*

"alternative analysis techniques" to evaluate the seismic safety of federally owned buildings. [redacted]

The assessment of TA-V was based on FEMA methodology and computational analysis to verify the adequacy of the facilities structural integrity was not done to verify the changes identified by the 1997 UBC code. All buildings, except for the storage facilities, were designed prior to 1994. The biggest change in the UBC code occurred in 1997 to incorporate near fault analysis. Thus, visual inspection of the buildings and drawings were merely subjective conclusions.

Requirements of Executive Order 12941, as discussed in the DOE Guide 420.1-2, are to be implemented. The requirements of ICSSC RP6 are minimum requirements to be met for existing buildings, especially the mitigation requirements triggered by Section 2 of the DOE STD-1020. The line organization may define "Exceptionally High Risk" buildings to meet their safety and mission needs. Provisions in FEMA 310 and FEMA 356 should be taken into account while evaluating and upgrading existing buildings. Specific provisions may have to be modified to meet criteria for PC-3 and PC-4 in this standard. DOE O 420.1 requires that the sites should prepare upgrade plans for buildings that are deemed deficient to meet NPH requirements. Some of these deficiencies may have been discovered during the facility safety reviews and or during implementation of Executive Order 12941. One of the prioritization schemes to upgrade such deficient building is given in the standard although sites may choose their own schemes (DOE STD-1020).

7.2 Seismic Scoping Study for the ACRR

ARES report (No. G70771601-002 Rev. 0, dated September 30, 2007**)** details the documentation review, seismic walkthrough activities and the results and findings of these two activities that together comprise the Seismic Scoping Study for the ACRR.

The Seismic Scoping Study was directed by the enquiry of the SSO regarding the ability of the safety SSCs meet current seismic qualifications requirements and, if not, what would be required to upgrade the SSCs. As a result, SNL identified a commitment in the DSA for the ACRRF (§15.3.2.5.2, *Planned Design and Operational Safety Improvements*,) to perform an ACRRF Seismic Scoping Study that "will evaluate the seismic qualification of selected SSCs in the ACRRF… This evaluation would result in a plan for the eventual seismic evaluation of the ACRRF that is compliant with DOE seismic criteria."

[redacted]

U.S. DOE Order 420.1B, *Facility Safety* (Ref. 1) requires that all DOE facilities be designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of Natural Phenomena Hazards (NPHs), including earthquakes and strong winds. The DSA for the ACRRF identifies safety-related SSCs, which must comply with seismic and wind evaluation requirements in accordance with DOE orders and standards.

The DSA for the ACRRF, prepared by SNL, makes a commitment in **§** 15.3.2.5.2, "Planned Design and Operational Safety Improvements," to perform an ACRRF Seismic Scoping Study of selected SSCs, and states:

> *"This study will evaluate the seismic qualification of selected SSCs in the ACRRF. This evaluation will result in a plan for the eventual seismic evaluation of the ACRRF that is compliant with DOE seismic criteria."*

In fulfillment of this commitment, ARES Corporation (ARES) was retained by SNL to perform the Seismic Scoping Study for the ACRR during the period of August through September, 2007. ARES concluded:

> *"A seismic walkthrough screening evaluation of the essential SSCs required to remain functional through a Design Basis Earthquake (DBE) was performed. The screening walkthrough found the essential SSCs to be seismically rugged."*

7.3 Structural Report for Building 6590-KIVA and Building 6593-Adjacent Structure

The scope of work included analysis of Building 6590, the KIVA structure, for earthquake loading that could cause structural damage such that the structure was not safe for its intended use as a reactor containment facility.

The calculations indicate that the maximum earthquake acceleration, based on equivalent static coefficient method of the IBC, is nominally .67g for anticipated soil restraints. Albuquerque is UBC Zone 2. Considering the properties of the dome, soil profile, and importance of the structure, a typical design earthquake for the area and this structure is .10g to .15g. Hence, the structure can withstand earthquakes nominally 4 to 6 times that anticipated for the area without any loss of containment capability. The analysis neglects the increase in soil capacity because of the dynamic nature of the load. This assumption is conservative. For comparison purposes, the maximum recorded earthquake in the Albuquerque area from the USGS Seismic Station on Kirtland Air Force Base, the location of the KIVA, is a magnitude 4 which occurred in 1971 on the west side of the city. Maximum documented earthquakes in the Rio Grande rift of New Mexico are approximately magnitude 5 to 6 and occurred in the Socorro area about 50 to 70 miles south of Albuquerque. These magnitude earthquakes are not structurally significant relative to the KIVA structure capacity.

This analysis predates UBC 1997 and pre-IBC 2000 codes. Thus, the analysis does not incorporate the changes reflected in these codes.

7.4 Analysis of "Densepack" Storage Hole Bearing Capacity

A structural analysis of a typical "Dense Pack" storage hole was conducted to study four conditions of possible structural weakness (SNL Memo, May 14, 1990 J.D. Miller to C.W. Tucker):

- Crushing of the concrete due to inadequate bearing strength;
- Punching shear failure through the slab adjacent to the hole;
- Shear failure of the horizontal steel tie bars, and;
- Foundation failure due to inadequate soil support.

The structural analysis reviewed the placement a loaded cask (32,000 lbs.) on the raised steel surface of the 10 in. nominal diameter hole. Based on Ireland's equation, a bearing capacity of 184,600 lbs. added to skin resistance of 72,800 lbs. results in a total pile capacity, *P*, of 257,400 lbs. This is 7.2 times greater than the total load of placement load of 32,000 lbs. The analysis concluded that a large margin of safety existed for the proposed loading, based on an extremely conservative analysis of the structure. This analysis dates UBC 1997 and pre-IBC-2000 codes. Thus, the changes in the current codes are not reflected in the design at this stage.

7.5 Current Seismic Assessment of TA-V per DOE 0 420.1B, Facility Safety

The current requirements for NPH design are contained in DOE O 420.1B, *Facility Safety,* (Attachment *2*, Chapter IV, "Natural Phenomena Hazards Mitigation," Section 3, 'Requirements'), which state:

> *"U.S. DOE facilities and operations must be analyzed to ensure that SSCs and personnel will be able to perform their intended safety functions effectively under the effects of NPH where no specific requirements are identified, model building codes or national consensus industry standards must be used consistent with intended SSC functions."*

The primary goals of NPH mitigation and specific seismic design of SSCs, as stated by DOE O 420.1B, are:

- Confinement of hazardous materials;
- Protection of occupants of the facility, as well as members of the public;
- Continued operation of essential facilities;
- Protection of government property.

A footnote to this section invokes DOE G 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-nuclear Facilities.* This guidance document (as stated) is not intended to establish or invoke any new requirements, but simply to provide guidance in implementing the NPH mitigation requirements of DOE O 420.1B. The language with which DOE G 420.1-2 invokes the series of technical standards on NPH mitigation is as follows:

> *"The fundamental statement of policy covers the basic objectives of NPH protection. Occupants of buildings need to be protected from building collapse or other failures that could endanger their lives or prevent safe exit. This objective is referred to as 'life safety.'"*

Secondly, it may be cost-effective to engineer additional provisions to protect capital investments in structures or to reduce the risk of property damage from NPH-induced accidents and effects.

A third, more stringent objective is "continued operation." Some structures perform an essential function that is important to preserve during and/or after an earthquake or other natural disturbance. Hospitals and emergency response centers are good examples.

The fourth objective is the confinement of hazardous materials. Some facilities are capable of giving rise to severe accidents involving hazardous materials or processes. These facilities may warrant hardening of confinement features to reduce the likelihood of that NPH, such as seismic, wind, floods, and lightning, might precipitate such accidents by damaging the installed safety features. The only NPH being considered in this document is seismic.

Cost-effectiveness is inevitably a consideration. The cost of hardening facilities and their SSCs against the effects of a NPH may be large. The protection afforded is not absolute and the value of protection is uncertain due, in part, to the uncertainty in the hazard itself. Furthermore, the value of NPH risk reduction is a function of the remaining service-life of a facility and the magnitude and duration of any residual hazards that may be present. The location, timing, and magnitude of future events cannot be foretold, nor can the potential effects of these uncertain events be bounded without a degree of conservatism in design that would be impractical to accommodate on the scale of the DOE complex.

DOE policy for NPH mitigation does not prescribe the balance to be struck among the four mitigation goals and the cost-effectiveness consideration, but these issues are addressed in the requirements and guidance. The appropriate balance requires judgment and cannot be captured by a simple formula.

For facilities with a remaining service life of less than 5 years, it may not be necessary to upgrade the facility for NPH mitigation unless the presence of hazardous materials or other special conditions present an ESH to occupants or the public at large.

DOE in the process, has prepared, or has updated the following five supporting standards to implement the NPH requirements of DOE O 420.1B. Compliance with the most current version of these standards is required in order to provide desired safety at DOE facilities.

- DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.*
- DOE-STD-1021, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components.*
- DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria.*
- DOE-STD-1023, *Natural Phenomena Hazards Assessment Criteria.*
- DOE-STD-1024, *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites.*

A new set of requirements for development of the seismic design basis is provided by DOE-STD-1189-2008, Appendix A, *Safety Systems Design Criteria*. These requirements are based on recently published national standards for seismic design:

- ASCE/SEI 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities.*
- ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 2005.*
- ANSI/ANS 2.26-2004, *Categorization of Nuclear Facility Structures, Systems and Components for Seismic Design.*

Under DOE-STD-1189, the provisions of ASCE/SEI 43-05 and ASCE/SEI 7-05 replace the seismic design requirements and performance criteria of DOE-STD-1020-2002. The seismic-related performance categorization guidelines of DOE-STD-1021-93 are replaced by the provisions of American National Standards Institute (ANSI)/American Nuclear Society (ANS) 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A. Both ASCE/SEI 43-05, and ASCE/SEI 7-05, and ANSI/ANS 2.26-2004 indicate that they are intended to be used in conjunction with ANSI 2.27, Site Characterization Requirements for Natural Phenomena Hazards and Nuclear Materials Facilities Sites, and ANSI 2.29, Probabilistic Analysis of Natural Phenomena Hazards for Nuclear Materials Facilities.

7.6 Review of State-of-the-Art Seismic Assessment Methodology

The NPH mitigation requirements of DOE 0 420.1B indicate that design requirements may be satisfied through implementation of the specific requirements identified in the corresponding guidance document (DOE G 420.1-2) or through the use of model building codes or national consensus industry standards applied in a manner consistent with intended SSC functions. The implementation of DOE-STD-1189-2008 currently requires the use of some existing DOE technical standards, the partial implementation of

ANS/ANS 2.26-2004, and the implementation of the new ASCE/SEI 43-05/7-05. The mapping between the existing and proposed requirements is shown in Table 7-2.

Table 7-2. Mapping of Existing and Current Seismic Design Requirements

Subject	Requirements	
	Existing*	Current
Seismic Design & Evaluation Criteria	DOE-STD-1020-2002	ASCE/SEI 43-05/ ASCE/SEI 7-05
Seismic Performance Characterization for Structures, Systems & Components	DOE-STD-1021-93	ANSI/ANS 2.26-2004 as modified by DOE-STD-1189
Seismic Site Characterization Criteria	DOE-STD-1022-2002	DOE-STD-1022-2002
Seismic Assessment Criteria	DOE-STD-1023-95	DOE-STD-1023-95
Probabilistic Seismic Hazards Assessment	DOE-STD-1024-92	DOE-STD-1024-92

New design guidance is considered only for seismic phenomena.
* Based on the vintage of the buildings and structures, these standards were probably *not* applied.

7.6.1 Comparison of Existing and Current Requirements

In general, the new guidance established via DOE-STD-1189, Appendix A, provides a systematic process that is consistent with the existing requirements via reference to the seismic ASCE/SEI and ANSI/ANS standards as identified in Table 7-3. The analysis provided below summarizes the differences between the new and existing requirements as related to categorization of SSCs, performance and seismic design categories, seismic response spectra, seismic evaluation and design criteria, and seismic interaction.

7.6.1.1 Categorization of Structures, Systems, and Components, (SSCs)

The existing process for NPH PC is provided by DOE-STD-1021-93. In this process, the PC for a nuclear facility and associated SSCs is based upon:

- The facility Hazard Category, established in accordance with DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.*
- Safety classification of SSCs, determined in accordance with DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Non-Reactor Nuclear Facility Analysis.*
- Identification of SSCs whose failure may adversely affect the general life safety of facility occupants.

The specific criteria provided by DOE-STD-3009-94 and DOE-STD-1021-93 for NPH PC are as follows:

- SSCs are designated PC-3 if the failure of the SSC has adverse release consequences to the public in excess of 25 rem. The value of 25 rem Total Effective Dose Equivalent (TEDE) per DOE-STD-3009 is not to be used as a definitive pass/fail equation. Unmitigated releases should be compared against the EG to determine whether they challenge the EG, rather than exceed it. The evaluation guideline for radiation dose to be used in identifying safety-class SSCs is 25 rem TEDE to the whole body at the 1350 m exclusion-area boundary of TA-V. There are not facility-installed safety class SSCs at TA-V.
- SSCs are designated PC-2 if the SSC has been classified as safety significant for protection of the collocated worker.
- SSCs are designated PC-2 if the failure of the SSC may result in loss of function for any emergency handling, hazard recovery, fire suppression, emergency preparedness, communication, or power system that may be necessary for the health and safety of the facility worker.
- SSCs are designated PC-2 if they are part of a building primarily used for the assembly of more than 300 persons in one room, and if the failure of the SSC could adversely affect the life safety of the occupants.
- SSCs are designated PC-1 in buildings with the potential for human occupancy if the SSC failure may cause fatality or serious injuries to the facility worker, or if failure can be cost-effectively prevented.

The radiological dose-based alternate criteria identified by DOE-STD-1189-2008 are shown in Table 7-3. These criteria modify the radiological dose-based criteria provided in ANSI/ANS-2.26-2004. The radiological dose-based criteria specified by DOE-STD-1189-2008, Appendix A, replace the more conservative criteria provided by ANSI/ANS-2.26-2004 (Table 8-2). This only applies to new or major modifications of existing facilities. [redacted]

Table 7-3. Seismic Design Category Comparison of DOE-STD-1189 and ANSI/ANS-2.26-2004-2008

	DOE-STD-1189-2008		ANSI/ANS 2.26-2004	
	Requirements for Categorization of Structures, Systems, & Component		Guidance for Seismic Design Category on Unmitigated Radiological Consequences of Structure, System or Component Failure	
SEISMIC DESIGN CATEGORY	Collocated Worker (100 m)	Public (1350 m)	Worker	Public
SDC-1	Dose < 5 rem	N/A	Failure of SSC may place facility worker at physical injury.	N/A
SDC-2	5 rem < Dose < 100 rem	5 rem < Dose < 25 rem	Consequences less than SDC-3; No permanent health effects.	Essentially no off-site consequences.
SDC-3	100 rem < Dose	25 rem < Dose	25 rem < Dose < 100 rem	5 rem < Dose < 25 rem
SDC-4			100 rem < Dose < 500 rem	25 rem < Dose < 100 rem
SDC-5			Radiological effects may be likely to result in worker fatality.	100 rem < Dose

DOE-STD-1189-2008 also modifies the prescribed methodology provided in ANSI/ANS 2.26-2004 for calculation of unmitigated radiological dose consequence to the collocated worker (100 m). These modifications provide a more conservative methodology than that mandated by ANSI/ANS 2.26-2004 by specifying the use of conservative or bounding rather than mean values for the parameters associated with the material release, dispersal, and health consequences.

With respect to categorization of SSCs for protection of the public, the new criteria are more stringent. Requiring the categorization of SSCs as SDC-2 for unmitigated consequences between 5 rem and 25 rem Total Effective Dose Equivalent (TEDE) may result in a more robust design, although it is likely that the affected SSCs would be classified under the current requirements as safety-significant for the protection of the collocated worker and, therefore, designated as PC-2.

With respect to categorization of SSCs for protection of the collocated worker, the new criteria are significantly more conservative. Under the existing requirements, the highest Performance Category assigned to any SSC necessary for protection of the collocated worker is PC-2. Under the new requirements, SSCs may be designated as SDC-3 for unmitigated consequences in excess of 100 rem TEDE to the collocated worker.

With respect to categorization of SSCs for protection of the facility worker, the new criteria are essentially equivalent to, although less prescriptive than, the existing criteria. All of TA-V safety bases have been developed and approved in accordance with 10 CFR 830 and applicable DOE requirements. [redacted]

8.0 Evolution of Seismic Design Criteria

Building codes establish minimum requirements for building design and construction with a primary goal of assuring public safety. The secondary, and much less important goal, is minimizing property damage and maintaining function during and following an earthquake. With respect to earthquake hazards, the underlying issues to be considered in the development of code criteria are the levels of seismic risk and the establishment of appropriate design requirements commensurate with those levels of risk. Since the risk of severe seismic ground motion varies from place to place, it logically follows that seismic code provisions will vary depending on location. The variable aspect of code provisions for seismic design has been accentuated by the fact that local and regional building code jurisdictions in the U.S. have typically based their provisions on one of three model building codes:

1) The Uniform Building Code (UBC), which is predominant in the west;
2) The Standard Building Code (SBC), which is predominant in the southeast, and;
3) The BOCA National Building Code, which is predominant in the northeast.

Given the greater frequency and intensity of earthquakes in the west, it is not surprising that the UBC has traditionally placed more emphasis on seismic design provisions than the SBC and the BOCA/NBC.

Recently, however, this situation has changed. In late 1994, representatives from the three model code sponsoring organizations formed the International Code Council (ICC). In April 2000, the ICC published the first edition of the *International Building Code* (IBC), which includes significant changes in seismic design requirements, particularly in how the level of detailing requirements for a specific structure is determined. The IBC will replace the three previous model codes.

The following section briefly introduces the seismic zones/ performance categories.

8.1 Seismic Zones

Seismic zones are regions in which earthquake ground motion, corresponding to a certain probability of occurrence, is within certain ranges. In recent editions of the UBC-1997, the U.S. has been divided into Seismic Zones 0 through 4, with 0 indicating the weakest earthquake ground motion and 4 indicating the strongest. In the Uniform Building Code (UBC), the seismic zone in which a structure is located determines permissible structural systems, including the level of detailing required for structural members and joints that are part of the lateral force-resisting system as well as for the structural components that are not permissible systems. The Seismic Zone also determines applicable limitations on the height of a structure, the permissible structural irregularities, the type of lateral analysis that must be performed as the basis of design for seismic forces, and the nonstructural component requirements for seismic forces.

The 1997 UBC is a refinement of a UBC specification issued in 1994. The UBC-1994 version was relatively general in scope, and broadly divided the U.S. into four geographical zones, of which Zone 4 - comprising most of central and coastal California - was rated the most prone to earthquake activity. The subject is discussed further in a later section.

8.2 Seismic Performance Categories (SPC)

Given that public safety is a primary code objective and that not all buildings in a seismic zone are equally crucial to public safety, a new system of classification called the Seismic Performance Category (SPC) was developed. The SPC classification depends not only on the seismicity at the site, but also on the occupancy and use of the structure. The 1994 (and prior) editions of the National Earthquake Hazards

Reduction Program (NEHRP) Provisions (starting with the predecessor document, ATC 3), use the SPC rather than the Seismic Zone alone as the determinant of seismic design and detailing requirements. This also means that the three latest editions of the BOCA/ National Building Code (BOCA/NBC) and the SBC also use the SPC since these model codes are based upon the 1991 NEHRP provisions.

On the basis of the SPC, a hospital in an area of moderate seismic risk must be detailed in a similar manner and be subjected to the same restrictions as an office building in an area of high seismic risk. The detailing requirements under SPC A and B are roughly equivalent to those for Seismic Zone 2 and the detailing requirements for SPC D and E are roughly equivalent to those for Seismic Zones 3 and 4. The detailing requirements under Seismic Performance Categories A & B, C, and D & E were roughly equivalent to those for Seismic Zones 0 & 1, 2, and 3 & 4, respectively.

8.3 Seismic Design Categories

The most recent development in structural classification has been the establishment of Seismic Design Categories as the determinant of seismic detailing requirements. Recognizing that building performance during a seismic event depends not only on the severity of subsurface rock motion, but also on the type of soil upon which a structure is founded, the SDC is a function of location, building occupancy, and soil type. The 1997 NEHRP Provisions, the 2000 IBC and later revisions, and ASCE 7-05 have replaced the SPC with the SDC.

Table 8-1 summarizes how the building codes (ACI 530/ASCE 5/TMS 402), have addressed seismic design over the past decade. Dates list the last edition in which a given classification system was used by a model code or standard. As indicated, IBC 2000 is the first model code to use Seismic Design Categories.

Table 8-1. Basis for Seismic Design Criteria in Model Codes and Standards

DESCRIPTION	SEISMIC		
	ZONES	CATEGORIES	
		PERFORMANCE (SPC)	DESIGN (SDC)
Classification	0,1,2,3,4	A, B, C, D, E	A, B, C, D, E, F
Criteria for Classification			
Location/ Site	Yes	Yes	Yes
Seismic Use Group*, Building Use/ Occupancy Category**	No	Yes	Yes (*IBC-2003, **IBC-2006)
Soil Type	No	No	Yes
Used by Model Codes and Standards			
IBC			2000
UBC	1997		
SBC	1991	1999	
BOCA/ NBC	1990	1999	
MSJC	1992	1999	

8.3.1 Impact of Changes

Clearly, the procedure for establishing the seismic classification of a structure has become more complex. Determining the Seismic Zone simply required establishing the location of the structure on Seismic Zone maps that were contained in model codes. Determining the Seismic Performance Category of a structure required: 1) The interpolation of a ground motion parameter on a contour map, based on the location of the structure; 2) Determining the use classification of the structure, and; 3) Consulting a Table. The process leading to the classification of the Seismic Design Category involves several steps and is identified in Table 13-2 pertaining to the section dealing with Seismic Design Category later on.

- Site-specific soil data must be gathered to establish the site class (otherwise, the default site class is “D”);
- The classification procedure requires evaluation of SDC for a short-period and a long-period ground motion parameter;
- After working through the calculations, the most severe SDC determined from the two conditions is selected.

SDC ratings, depending on the site, can be more stringent or less stringent than the previous UBC code ratings depending on the site. The soil condition at the site is the additional variable that must now be dealt with. While this adds another element to an already complicated procedure, it does incorporate established knowledge about the effect of soil properties during an earthquake into SDC. There is an associated economic impact to these changes. When a structure is assigned to a higher SDC under the IBC than what its Seismic Performance Category would have been under the BOCA/NBC or the SBC, more restrictive code provisions increase the cost of design, materials, and construction.

[redacted].

9.0 Definition of Limiting States (LS): A, B, C, D

- Limit State A: Structural components retain some margin against collapse so that egress is not impaired, although major repair may be required for continued occupancy. Containment structures may fail if secondary containment is provided, the release has no immediate impact to the worker, and spill recovery can be completed with little risk. Mechanical or electrical SSCs may undergo large permanent distortion if they remain capable of performing their safety functions. Design to Limit State A is not allowed for confinement systems.
- Limit State B: Structural components retain substantial margin against collapse, although repair may be required for continued occupancy and restart of operations. Containment structures may experience damage sufficient to result in a slow release of contents. Secondary containment is provided, or the release has no adverse consequence and cleanup/repair may be accomplished expediently. Confinement structures remain operable with the assistance of active exhaust; mechanical or electrical SSCs may experience moderate permanent distortion if they remain capable of performing their safety functions and are repairable for restoration of normal functional capability.
- Limit State C: Structural and passive SSCs are capable of performing both their normal and safety functions during and after the seismic event. Structural components retain full strength and nearly full stiffness. Containment structures may sustain minor damage; confinement structures

remain operable with the assistance of active exhaust. Mechanical or electrical SSCs may experience limited permanent distortion but remain capable of performing both their normal and safety functions during and after the seismic event.

- Limit State D: Damage resulting from the seismic event is negligible. Building structures retain full strength and stiffness capacities and are safe for occupancy. Containment structures remain leak-tight and remain operable without assistance of active exhaust. Mechanical and electrical SSCs remain essentially elastic and are capable of performing both their normal and safety functions during and after the seismic event.

Table 9-1 provides a comparison of the ASCE/SEI 43-05 and DOE-STD-1020-2002.

Table 9-1. ASCE 43-05 vs. DOE-STD-1020-2002

Acceptable	Large Permanent Distortions	Moderate Permanent Distortions	Limited Permanent Distortions	Essentially Elastic Behavior
P_f	**A**	**B**	**C**	**D**
< $1x10^{-3}$	ASCE 7-05 (SG-I) DOE PC_1	ASCE 7-05 (SG-II)	ASCE 7-05 (SG-III)	Not Addressed
< $1x10^{-4}$	ASCE 7-05 (SG-II)	ASCE 7-05 (SG-II) DOE PC_2	Not Addressed	Not Addressed
~ $1x10^{-4}$			DOE PC 3 Many DOE SSCs	
~ $4x10^{-4}$				
~$1x10^{-5}$			DOE PC 4 Near NRC NPP	Similar to Modern NRC NPP

Since the 2006 IBC now references the seismic requirements specified in ASCE/SEI 7-05, the use and understanding of the requirements ASCE/SEI 7-05 becomes paramount to engineer to meet the IBC requirements. The degree of required performance for SSCs associated with each limit state is provided in ANSI/ANS-2.26-2004, Appendix B, and is summarized below. Table 9-2 presents seismic design factors for a range Seismic Design Categories and Limiting State.

Evaluation conducted by Brookhaven National Laboratory concludes that the requirements of ASCE/SEI 43-05 are conservative with respect to customary building code requirements for critical facilities, and provide acceptable levels of protection against severe low-probability seismic events. The methodology provided by ASCE/SEI 43-05 is concluded to be comparable to the seismic design approach presented by DOE-STD-1020-2002 for critical facilities identified as SDC-4 or SDC-5.

Table 9-2. Seismic Design Factors for Range of SDC & LS

SDC	LS-A	LS-B	LS-C	LS-D
	Short of Collapse structurally stable	Moderate Permanent Deformation	Limited Permanent Deformation	Essentially Elastic
I ASCE 7-05	OC I OR II (I=1.0) $R_a = R$ (**Equivalent to PC-1**)	OC I OR II (I=1.0) Ra =0.80R but Ra ≥ 1.0	OC I OR II (I=1.0) Ra = R but Ra ≥ 1.0	OC I OR II (I=1.0) USE Ra = 1.0
II ASCE 7-05	OC III or IV* $R_a = R$	OC III or IV* Ra =0.80R but Ra ≥ 1.0 **(Equivalent to PC-2)**	OC III or IV* $R_a = 0.67R$ but Ra ≥ 1.0	OC III or IV* USE $R_a = 1.0$
III ASCE 43-05	DF = (0.8 - 1.0) $F_{GM} = 1$ Fμ =1 (Table 5-1*)	DF = (0.8 - 1.0) $F_{GM} = 1$ Fμ =1 (Table 5-1*)	DF = 0.9 $F_{GM} = 1$ Fμ =1 (Table 5-1*) **(Equivalent to PC-3)**	DF = (0.8 - 1.0) $F_{GM} = 1$ Fμ =1

SDC = Seismic Design Category, LS = Limit State, OC = Occupational Category (Table 1-1. ASCE 7-05)

I - Importance Factor (Table 11.5-1, ASCE-7-05): R = Response Modification Coefficient (Table 12.2-1 & 15.4-2, ASCE 7-05)

R_a = Actual (reduced) design Response Modification Coefficient, DF = Design Factor (Table 2-1, ASCE 43-05*): Fμ =Inelastic Energy Absorption Factor

[redacted]

With respect to performance and design categorization, the new criteria mandate a more stringent initial categorization; Limit State D requires design that survives the event with essentially elastic behavior. The performance of additional analysis to determine and justify the level of functionality actually required for an SSC to meet its designated safety function has the potential to result in the design of selected SSCs to less stringent criteria than mandated under the existing system.

10.0 Seismic Response Spectra

The existing process requires the development of a site-specific seismic hazard curve and design response spectra in accordance with DOE-STD-1022-94 for SSCs designated as PC-3 or PC-4. For developed areas of existing DOE sites, seismic hazard curves and design response spectra should be defined in approved documentation. Under the existing set of requirements, seismic design spectra developed for PC-3 SSCs are based on a return period of 2,000 years or an annual probability of exceedance of 5E-04.

The new requirements for seismic evaluation and design are provided by ASCE/SEI 43-05/ASCE/SEI 7-05.. As defined by the standard, the process of seismic design or evaluation begins with the definition of appropriate design response spectra and development of seismic hazard curves for the site of interest. The following industry standards are referenced:

- ANSI/ANS 2.26-2004, *Categorization of Nuclear Facility Structures, Systems and Components for Seismic Design.*
- ANSI 2.27, *Site Characterization Requirements for Natural Phenomena Hazards and Nuclear Materials Facilities Sites*

- ANSI 2.29, *Probabilistic Analysis of Natural Phenomena Hazards for Nuclear Materials Facilities.*

These standards will replace the guidance currently provided in DOE-STD-1022-94, DOE-STD-1023-95, and DOE-STD-1024-92. Under DOE-STD-1189, the provisions of ASCE/SEI 43-05 replace the seismic design requirements and performance criteria of DOE-STD-1020-2002. The seismic-related performance categorization guidelines of DOE-STD-1021-93 are replaced by the provisions of American National Standards Institute (ANSI)/American Nuclear Society (ANS) 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A. However, the requirements of ASCE/SEI 43-05/ASCE/SEI 7-05 for development of seismic design spectra for SDC-3 SSCs are based on a return period of 2,500 years or an annual probability of exceedance of 4E-04. For SSCs designated as SDC-1 or SDC-2, both the new requirements (ASCE/SEI 43-05/ASCE/SEI 7-05) and the existing requirements (DOE-STD-1020-2002) require design to be based on the IBC.

10.1 Seismic Interaction

The existing requirements of DOE-STD-1021-93 specifically address the potential for interaction of SSCs in a seismic event, in which the failure of one SSC impacts the functionality of another. In general, failure of an SSC (the source) is not allowed to result in failure of an SSC (the target) with a higher performance category. The standard provides detailed criteria for revision of performance category for source SSCs based on the performance category of the target SSC and the potential for interaction.

According to the new requirements of ANSI/ANS 2.26-2004, system interaction is to be addressed by upgrading the source SSC to the extent necessary to preclude its adverse interaction with the target SSC, via a change in seismic design category, limit state, or both. Unlike the existing requirements, an assessment of the potential for interaction is not included in this methodology.

Although the interaction-related requirements of ANSI/ANS 2.26-2004 are less prescriptive than those provided by DOE-STD-1021-93, they are judged to provide an equivalent level of protection. Although the level of SSC upgrade required under ANSI/ANS 2.26-2004 may not equal that required under DOE-STD-1021-93 analysis will be required to justify the adequacy of the upgrade to prevent adverse interaction.

[redacted]

11.0 Impact of Seismic Design Provisions of 2000 IBC

The intent of this section is to offer some simplified guidance to understanding the above codes. Significantly more detailed information is provided in the codes.

Understanding the difference between the earthquake design philosophies of the UBC versus those of the IBC is key to appreciating the increase in safety made possible across the U.S. by the newer code. The

UBC intended that structures be designed for "life-safety" in the event of an earthquake with a 10-percent probability of being exceeded in 50 years (commonly referred to as the 475-year earthquake). The issue with this design earthquake, as was recognized during the development of the new spectral response acceleration maps, was that it did not provide adequate protection for the infrequent but very large seismic events. The IBC intends design for "collapse prevention" in a much larger earthquake, with a 2-percent probability of being exceeded in 50 years (commonly referred to as the 2,500-year earthquake). For the purpose of this document, "collapse prevention" and "life-safety" are defined as follows:

> *Collapse prevention* – The building remains standing, but only barely; any other damage or loss is acceptable.
>
> *Life-safety* – The structure remains stable and has significant reserve capacity; hazardous nonstructural damage is controlled.

One of the most significant improvements in the 2000 IBC over the 1997 UBC is the ground motion parameters used for seismic design. To begin with, the maps in the UBC have always been based on seismic zones. The 1997 UBC maps were upgraded through the implementation of near-source factors to reflect increased ground motion for areas in close proximity to major known faults, but their fundamental shortcoming remains: not all areas within a zone will have the same peak ground acceleration. The maps provided in the IBC are more sophisticated in that they are not zone maps at all, but rather contour maps giving spectral response quantities. The mapped quantities are the maximum considered earthquake (MCE) spectral response acceleration, S_s (at short periods) and S_1 (at 1-second period), for Site Class B soil (soft rock).

It is important to note that the 2,500-year earthquake in the Eastern U.S. is on the order of 4 to 5 times as strong as the 475-year earthquake, whereas the 2,500-year earthquake in the Western U.S. is only on the order of 1.5 as strong as the 475-year earthquake. Thus, although the UBC provided uniform likelihood that the design ground motion would not be exceeded, it did not provide for a uniform margin of safety against collapse, which the IBC does.

12.0 Status of UBC Maps and the USGS Maps

Building code maps using numbered zones, 0, 1, 2, 3, 4, are practically obsolete. 1969 was the last year such a map was published. The 1997 Uniform Building Code (UBC) is the only building code that still uses such zones. Generally, over the past two decades, building codes have replaced maps having numbered zones with maps showing contours of design ground motion. These maps produced by the U.S. Geological Survey, show earthquake ground motions that have a specified probability of being exceeded in 50 years. These maps in turn have been derived from probabilistic ground motion maps. Probabilistic ground motion maps have been included in the seismic provisions of the most recent U.S. model building codes, such as the new "International Building code," and in national standards such as "Minimum Design Loads for Buildings and Other Structures," prepared by the American Society of Structural Engineers. These ground motion values are used for reference in construction design for earthquake resistance. The ground motion values can also be used to assess relative hazard between sites, when making economic and safety decisions.

12.1 Brief Explanation of UBC Seismic Zones

The guidelines for seismic ratings are derived from two sets of specifications established by independent organizations. The 1997 Uniform Building Code (UBC) is a refinement of a UBC specification issued three years earlier. The UBC-1994 version was relatively general in scope, and broadly divided the U.S. into four geographical zones, of which Zone 4 - comprising most of central and coastal California - was rated the most prone to earthquake activity.

The seismic zone factor (or Z factor) corresponds numerically to the effective horizontal peak bedrock acceleration (or equivalent velocity) that is estimated as a component of the design base shear calculation. For instance, the area within seismic Zone 1 (Z-factor of 0.075 ≈ 0.1) should expect an earthquake-related effective peak bedrock acceleration of 0.1 times the force of gravity. These values correspond to ground motion values with a 10 percent probability of being exceeded in 50 years.

Seismic Zone 2 is subdivided into two regions. Seismic Zone 2A has a Z-factor of 0.15 and is not associated with a particular fault zone. TA-V per UBC is mapped as Seismic Zone 2B which has a Z factor of 0.20 and indicates an association with known crustal faults. Z of the 1997 UBC indicates effective peak ground acceleration (more exactly, the larger of effective peak acceleration or effective peak velocity-related acceleration) expected within a seismic zone corresponding to the design earthquake of the UBC on Type S_B soil or soft rock. The mapped MCE spectral response accelerations S_S and S_1 of the 2000 IBC are also mapped on Type S_B soil.

Table 12-1 lists the five basic Seismic Zone Categories and assigns a “Z-factor” to each zone (UBC Appendix).

Table 12-1. Seismic Zone Category Assignments

ZONE	1	2A	2B	3	4
Z - Factor	0.075	0.15	0.20	0.30	0.40

12.2 Comparison of the IBC and UBC Code and Maps

The earthquake regulations of Sections 1613 through 1623 of the 2000 IBC, based on the 1997 NEHRP provisions (BSSC 1997), are substantially different from the corresponding provisions of the 1997 UBC. There are many scientific and engineering reasons behind this change. Factors such as site classification, seismic use group and seismic design category are considered in determining seismic requirements for structures.

The seismic provisions in UBC 1997 have not been found to be equivalent to the 1997 NEHRP provisions. However, this code may be used on case-by-case basis as long as the intent of the seismic provisions in this standard are met (based on IBC 2000/1997 NEHRP provisions). The seismic design maps associated with 1997 UBC are generally out of date (over 20 years old) and, at a minimum, the MCE ground motion maps in IBC 2000 should be consulted to ensure that DBE ground motion are adequate and conservative. Other model building codes may be followed provided site-specific ground motion data is incorporated into the development of the earthquake loading in a manner consistent with DOESTD-1023, and the NEHRP provisions. Differences are visually discernible. The following Figures illustrate the magnitude of the change between the UBC Zone Map (Figure 12-1) and the IBC seismic hazard maps for the coterminous United States, Map C – peak horizontal acceleration with 2% probability exceedance in 50 years (Figure 12-2).

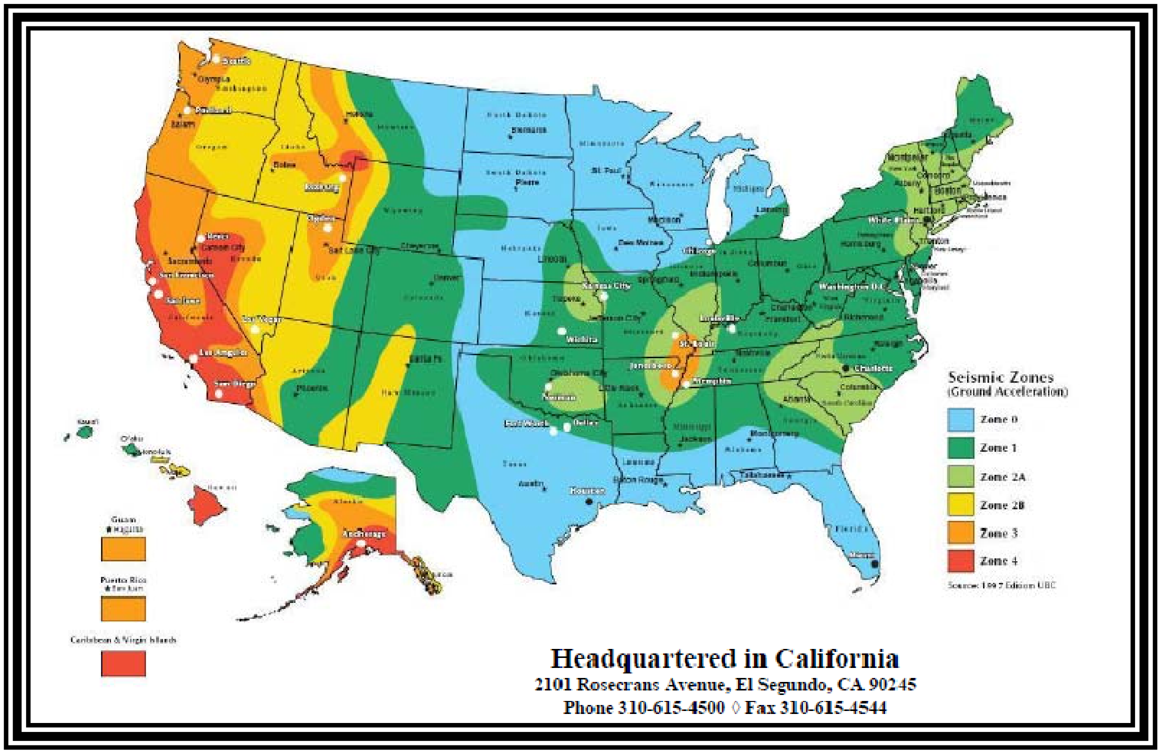

Figure 12-1. UBC Zone Maps

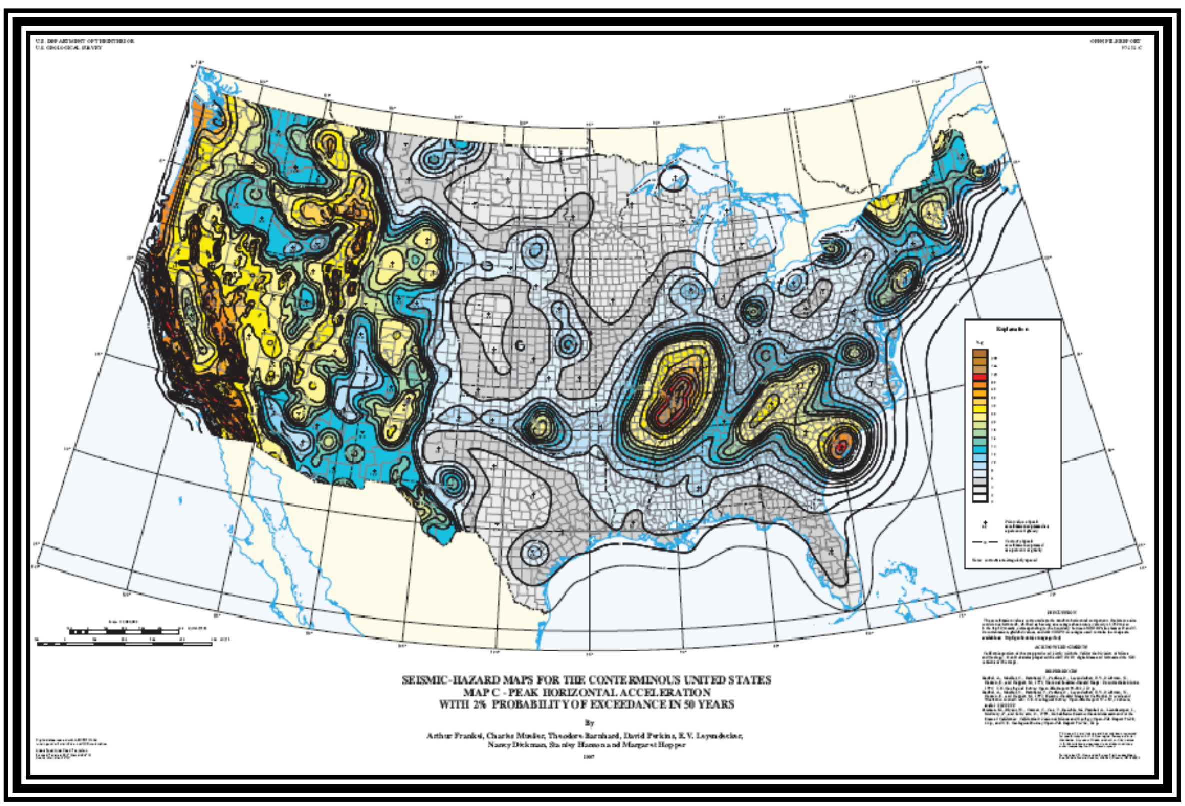

Figure 12-2. IBC Seismic Hazard Map

12.3 Development of the Maximum Considered Earthquake Ground Motion for Use in Design

The concept for developing maximum considered earthquake ground motions for use in design involved two distinct steps:
Seismic spectral IBC map peak horizontal acceleration with 2% probability of exceedence in 50 years

1) The various USGS probabilistic seismic hazard maps were combined with deterministic hazard maps by a set of rules (logic) to create the maximum considered earthquake ground motion maps that can be used to define response spectra for use in design and
2) Design procedures were developed that transform the response spectra into design values (e.g. design base shear).

The response spectra defined from the first step represent general "site-dependent" spectra similar to those that would be obtained by a geotechnical study and used for dynamic analysis except their shapes are less refined (i.e. shape defined for only a limited number of response periods). The response spectra do not represent the same hazard level across the country but do represent actual ground motion consistent with providing approximately uniform protection against the collapse of structures. The response spectra represent the maximum considered earthquake ground motions for use in design for Site Class B (rock with a shear wave velocity of 760 meters/second).

The maximum considered earthquake ground motion maps for use in design are based on a defined set of rules for combining the USGS seismic hazard maps to reflect the differences in the ability to define the fault sources and seismicity characteristics across the regions of the country as discussed in the policy decisions. Accommodating regional differences allows the maximum considered earthquake maps to represent ground motions for use in design that provide reasonably consistent margins of preventing the collapse of structures. Based on this, three regions have been defined:

1) Regions of negligible seismicity with very low probability of collapse of the structure;
2) Regions of low and moderate to high seismicity, and;
3) Regions of high seismicity near known fault sources with short return periods.

Considering the rules for the three regions discussed above, the maximum considered earthquake ground motion maps for use in design were developed by combining the regions in the following manner:

1) Where the maximum considered earthquake map ground motion values (based on the 2 percent probability of exceedance in 50 years) for Site Class B adjusted for the specific site conditions are ≤0.25g for the short-period spectral response and ≤ 0.10g for the long period spectral response, then the site will be in the region of negligible seismicity and a minimum lateral force design of 1 percent of the dead load of the structure shall be used in addition to the detailing requirements for the Seismic Design Category "A" structures.
2) Where the maximum considered earthquake ground motion values (based on the 2 percent probability of exceedance in 50 years) for Site Class B adjusted for the specific site conditions are greater than 0.25g for the short-period spectral response and 0.10g for the long-period spectral response, the maximum considered earthquake ground motion values (based on the 2 percent probability of exceedance in 50 years adjusted for the specific site conditions) will be used until the values equal the present (*Provisions*, 1994) ceiling design values increased by 50 percent (short period = 1.50g, long period = 0.60g). The present ceiling design values are increased by 50

percent to represent the maximum considered earthquake ground motion values. This will define the sites in regions of low and moderate to high seismicity.

3) To transition from regions of low and moderate to high seismicity to regions of high seismicity with short return periods, the maximum considered earthquake ground motion values based on 2 percent probability of exceedance in 50 years will be used until the values equal the present (*Provisions*, 1994) ceiling design values increased by 50 percent (short period = 1.50g, long period = 0.60g). The present ceiling design values are increased by 50 percent to represent maximum considered earthquake ground motion values. When the 1.5 times the ceiling values are reached, then they will be used until the deterministic maximum considered earthquake map values of 1.5g (long period) and 0.60g (short period) are obtained. From there, the deterministic maximum considered earthquake ground motion map values will be used.

In some cases, there are regions of high seismicity near known faults with return periods such that the probabilistic map values (2 percent probability of exceedance in 50 years) will exceed the present ceiling values of the *Provisions* (1994) increased by 50 percent and will be less than the deterministic map values. In these regions, the probabilistic map values will be used for the maximum considered earthquake ground motions.

The basis for using present ceiling design values as the transition between the two regions is because earthquake experience has shown that regularly configured, properly designed structures performed satisfactorily in past earthquakes. The most significant structural damage experienced in the Northridge and Kobe earthquakes was related to configuration, structural systems, inadequate connection detailing, incompatibility of deformations, and design or construction deficiencies – not due to deficiency in strength. The earthquake designs of the structures in the United States which have performed satisfactorily in past earthquakes were based on the criteria in the *Uniform Building Code* (UBC). Considering the site conditions of the structures and the criteria in the UBC, the ceiling design values for these structures were determined to be appropriate for use with the *Provisions* maximum considered earthquake ground motion maps for Site Class "B." Based on this, the equivalent maximum considered earthquake ground motion values for the ceiling were determined to be 1.50g for the short period and 0.60g for the long period.

As indicated above, there also are some regions of high seismicity near known fault sources with return periods such that the probabilistic map values (2 percent probability of exceedance in 50 years) will exceed the ceiling values of the *Provisions* (1994) increased by 50 percent and also be less than the deterministic map values. In these regions, the probabilistic map values are used for the maximum considered earthquake ground motions.

The near source area in the high seismicity regions is defined as the area where the maximum considered earthquake ground motion values are 0.75g on the 1.0 second map. In the near source area, *Provisions* Section 5.2.3 through 5.2.6 impose additional requirements for certain structures unless the structures are fairly regular, do not exceed 5 stories in height, and do not have a period of vibration over 0.5 seconds. For the fairly regular structures not exceeding 5 stories in height and not having a period of vibration over 0.5 seconds, the maximum considered earthquake ground motion values will not exceed the present ceiling design values increased by 50 percent. The basis for this is because of the earthquake experience discussed above.

The application of these rules resulted in the Maximum Considered Earthquake Ground Motion Maps (Maps 1 through 24), introduced in 1997 and used again in the 2000 *Provisions*.

12.4 2008 United States National Seismic Hazard Maps

The U.S. Geological Survey recently updated the National Seismic Hazard Maps by incorporating new seismic, geologic, and geodetic information on earthquake rates and associated ground shaking. These 2008 maps supersede versions released in 1996 and 2002. Updating the maps involved interactions with hundreds of scientists and engineers at regional and topical workshops. USGS also solicited advice from working groups, expert panels, State geological surveys, Federal agencies, and hazard experts from industry and academia. The Pacific Earthquake Engineering Research Center developed new crustal ground-motion models; the Working Group on California Earthquake Probabilities revised the California earthquake rate model; the Western States Seismic Policy Council submitted recommendations for the Intermountain West; and three expert panels were assembled to provide advice on best available science.

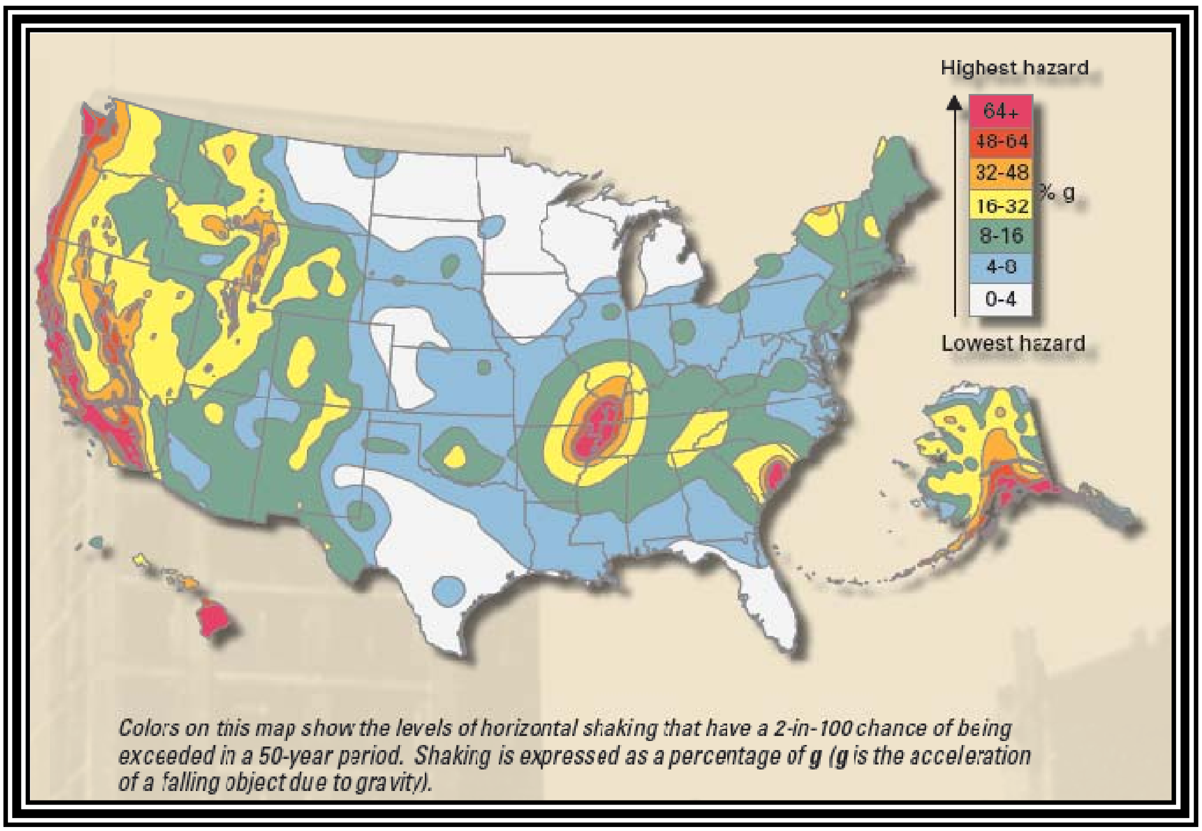

Figure 12-3. USGS (NEHRP) 2008 U.S. National Seismic Hazard

12.4.1 Significance of Results

The new National Seismic Hazard Maps show, with some exceptions, similar or lower ground motion compared with the 2002 edition. For example, ground motion in the Central and Eastern U.S. has been generally lower by about 10–25 percent due to the modifications of the ground-motion models. Ground motion in the Western U.S. is as much as 30 percent lower for shaking caused by long-period (1-second) seismic waves, which affect taller multistory buildings, and ground motion is similar (within 10–20 percent) for shaking caused by short-period (0.2-second) waves, which affect structures of one or a few stories.

The new 2008 maps represent the best available science as determined by the USGS from an extensive information-gathering and review process. Changes will be made in future versions of the maps as new information on earthquake sources and resulting ground motion is gathered and processed.

The 2000 International Building Code (IBC) is considerably more precise: in addition to viewing the entire continent as a series of potential seismic locations, the specification has also resulted in maps that measure a given location's potential for experiencing seismic activity relative to an identified fault, along with probability maps for every 100-foot section relative to that fault's location. This enables seismologists to determine the "*S factor*" for a location - the degree of likelihood that that location will experience seismic activity. The two code specifications are different in philosophical approach, but are ultimately complimentary in practice; the IBC is in essence a more focused and refined view of the UBC.

While the UBC as it was originally developed was somewhat rigid in its application, it also provided the basis for the calculations that determine a structure's rating. The IBC specification then allows the output of these calculations to be more precisely applied to physical structures taking into account but not limited to their geographical situations. Having this information, along with historical information about the severity and duration of previous seismic events, enables engineers and architects to determine the level of seismic resistance and endurance that equipment will require.

The structures, systems, and components at TA-V were designed to the UBC (pre-1997) codes (Table 3-1). Based on seismic spectral mapping faults and tributaries have been identified. The tributaries identified are limited only by the information available. Thus, a mapping of the TA-V area will determine the altercation in the seismic information and locate the TA-V region on the national seismic hazard map.

13.0 Seismic Design Ground Motion Parameters: Zone Maps to Ground Motion Spectra

The biggest change from the 1997 UBC to the 2000 IBC is in the design ground motion parameters which are now S_{DS} and S_{D1}, rather than Z. S_{DS} and S_{D1} are 5%-damped design spectral response accelerations at short periods and 1 sec. period respectively. S_{DS} determines the upper bound design base shear (the "flat-top" of the design spectrum) used in seismic design (see IBC Fig. 1615.1.41, reproduced here as Fig. 14-1, and Section 1617.4).

S_{D1} defines the descending branch or the period-dependent part of the design spectrum (Ref: IBC Fig. 1615.1.4-1 and Section 1617.4). The seismic zone map of the UBC has been replaced by contour maps giving two quantities from which S_{DS} and S_{D1} are to be derived. The mapped quantities are the Maximum Considered Earthquake spectral response accelerations S_S (at short periods) and S_1 (at 1 sec. period).

13.1 Use of the Maximum Considered Earthquake Ground Motion Maps in the Design Procedure

The *Provisions* (1994) defined the seismic base shear as a function of the outdated effective peak velocity-related acceleration A_v, and effective peak acceleration, A_a. Beginning with the 1997 *Provisions*, the base shear of the structure is defined as a function of the maximum considered earthquake ground motion maps where:

- S_S = Maximum considered earthquake spectral acceleration in the short-period range for Site Class B;
- S_1 = Maximum considered earthquake spectral acceleration at the 1.0 second period for Site Class B;

- $S_{MS} = F_a S_S$, Maximum considered earthquake spectral acceleration in the short-period range adjusted for Site Class effects where F_a is the site coefficient defined in the *Provisions*;
- $S_{M1} = F_v S_1$, Maximum considered earthquake spectral acceleration at 1.0 second period adjusted for Site Class effects where Fv is the site coefficient defined in the *Provisions*;
- S_{DS} = (2/3) S_{MS}, Spectral acceleration in the short-period range for the design ground motions, and;
- S_{D1} = (2/3) S_{M1}, Spectral acceleration at 1.0 second period for the design ground motions.

As noted above, the design ground motions S_{DS} and S_{D1} are defined as 2/3 times the maximum considered earthquake ground motions. The 2/3 factor is based on the estimated seismic margins in the design process of the *Provisions* as previously discussed (i.e. the design level of ground motion is 1/1.5 or 2/3 times the maximum considered earthquake ground motion).

Based on the above defined ground motions, the base shear is:

$$V = C_s W..where..C_s = \frac{S_{DS}}{\left(\frac{R}{I}\right)}$$

and

S_{DS} = the design spectral response acceleration in the short period range
R = the response modification factor and
I = the occupancy importance factor

The value of Cs need not exceed

$$C_S = \frac{S_{D1}}{T\left(\frac{R}{I}\right)}$$

(but shall not be taken less than $C_S = 0.1 S_{D1}$ or, for buildings and structures in Seismic Design Categories E and F,

$$C_S = \frac{0.5 S_1}{\left(\frac{R}{I}\right)}$$

where I and R are as defined above and

S_{D1} = the design spectral response acceleration at a period of 1.0 second,
T = the fundamental period of the structure (sec) and;
S_1 = the mapped maximum considered earthquake spectral response acceleration

Where a design response spectrum is required by these provisions and site-specific procedures are not used, the design response spectrum curve shall be developed as indicated in Figure 13-1 and as follows:

1) For periods less than or equal to T_0, the design spectral response acceleration, S_a, shall be taken as given by

$$S_a = 0.6\frac{S_{DS}}{T_0}T + 0.4S_{DS}$$

2) For periods greater than or equal to T_0 and less than or equal to T_S, the design spectral response

3) For periods greater than *TS*, the design spectral response acceleration, *Sa*, shall be taken as given by

$$S_a = \frac{S_{D1}}{T}$$

S_{DS} = the design spectral response acceleration at short periods;

S_{D1} = the design spectral response acceleration at 1second period;

T = the fundamental period of the *structure* (sec);

$$T_0 = 0.2\left(S_{D1} / S_{DS} \right);$$

and

$$T_S = \left(S_{D1} / S_{DS} \right)$$

Site-specific procedures for determining ground motions and response spectra are discussed in the *Provisions*.

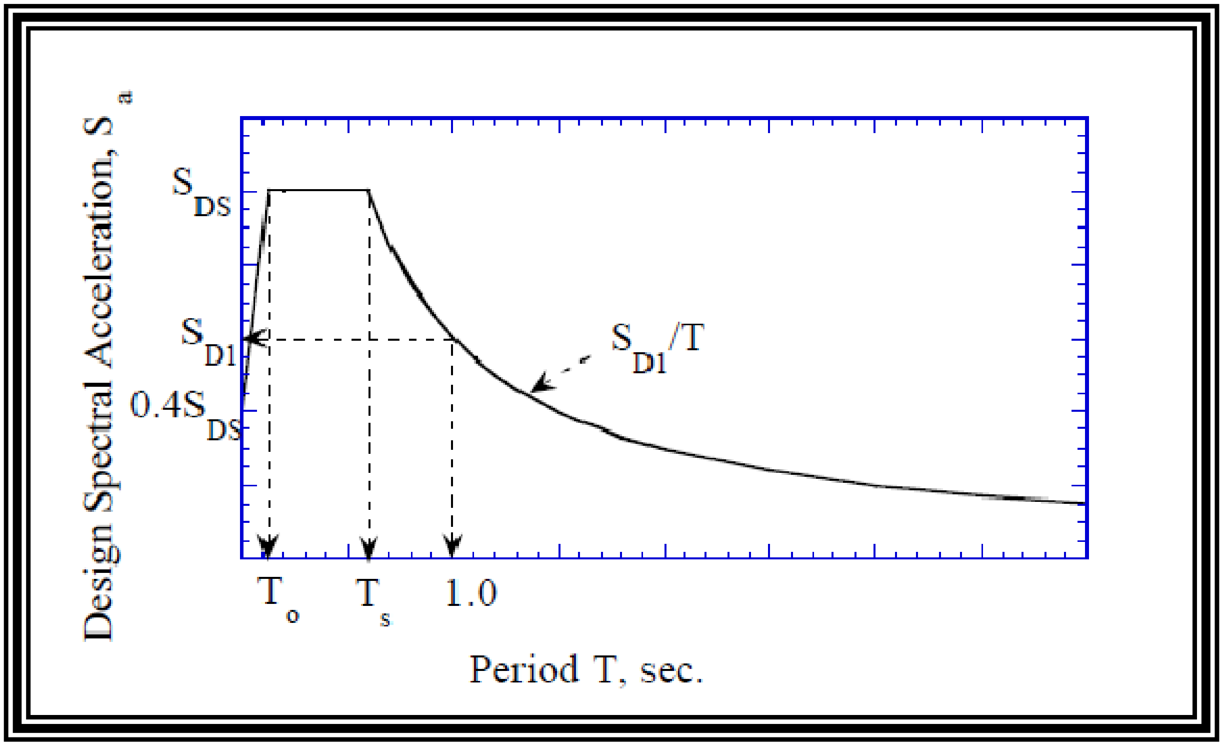

Figure 13-1. Design Spectral Acceleration Period

S_{DS} and S_{D1} are derived from the values S_{MS} and S_{M1}, Fa and Fv and S_S and S_1. S_S and $S_1$are map of values of 2,500 year event. Maps assume Type B (rock) soil conditions.

Since DOE-STD-1020-94 adopted the UBC for the seismic design and evaluation of PC-1 and PC-2 structures, it was necessary to accommodate the use of the IBC 2000 instead of the UBC for DOE facilities. The seismic hazard in the IBC 2000 is provided by maps that define the seismic hazard in terms of the Maximum Considered Earthquake (MCE) ground motions. Except for locations on or near very active known faults, the maps contain accelerations that are associated with a 2500-year return period earthquake. The ground motions associated with MCE ground motions as modified by the site conditions are used for the design and evaluation of PC-1 and PC-2 structures in this revised DOE standard. The graded approach is maintained by applying a 2/3 factor for PC-1 facilities, and a factor of unity for PC-2 facilities. At the same time PC-3 design ground motions have been adjusted from a 2,000 year return period to a 2,500 year return period.

This differs from DOE-STD-1020-94 where different return periods of 500, 1000, 2000 (1000*), and 10,000 (5000*) years were used for PC-1, PC-2, PC-3, and PC-4, respectively. (*in parenthesis are for locations near tectonic plate boundaries). Also, specific performance goals were established for each performance category (PC-1 thru PC-4). These performance goals (in terms of a mean annual probability of failure) were based on a combination of the seismic hazard exceedance levels and accounting for the level of conservatism used in the design/evaluation. In this revised standard the performance goals for PC-1 and PC-2 facilities are not explicitly calculated but are consistent with those of the IBC 2000 for Seismic Use Group I and III, respectively[4].

[4] Refer to 1997 NEHRP Provisions for a description of the performance goals associated with Seismic Use Groups. For PC-3 SSCs there is no change to the performance goal when compared to the previous version of this Standard. This was accomplished by making a slight adjustment to the PC-3 scale factor. Thus, it is *not* the intent of this revision to alter the methodology for evaluating PC-3 facilities, nor to increase the

[redacted] is the mapped (MCE) spectral response acceleration at 1.0-second period for Site Class B. ASCE 7-05 Figs. 9.4.1.1(a) through (j)/ IBC Figs. 1615(1) through 1615(10) give contour maps for S_S and S_1.

It must be noted that the maps indicate the Maximum Spectral Response for long and short periods (S_S & S_1) and not the Design Spectral Response. The ground accelerations used for the design of Architectural and Equipment's attachment are the short period (.2 second) values only (S_S). These are multiplied by the site (soil) Classification Factor (F_a) from IBC Table 1615.1.2(1) and then multiplied by a factor of 2/3, per IBC Section 1615.1.3.

S_{MS} is obtained by multiplying the mapped MCE spectral response acceleration S_S (at short periods) by F_a, the acceleration-related soil factor. Similarly S_{M1} is obtained by multiplying the mapped MCE spectral response acceleration S_1 (at 1 sec. period) by F_v, the velocity-related soil factor.

NOTES:

1. *F_a and F_v are analogous to C_S/Z and C_v/Z of the 1997 UBC, respectively.*
2. *If S_{DS} of the 2000 IBC is equal to $2.5C_a$ and S_{D1} of the 2000 IBC is equal to C_v for a particular location, then the soil-modified seismicity for that site has not changed from the 1997 UBC to the 2000 IBC.*

13.2 Deterministic Cap (Threshold Limit on S_s, S_1)

Faults are fractures or fracture zones in the Earth's crust along which one side moves with respect to the other. A fault scarp is a cliff or steep slope that sometimes forms along the fault at the surface. There are many types of faults, for example, strike-slip, normal, reverse, and thrust faults, ranging in size from a few tens of meters to hundreds of kilometers in dimension.

Near the fault zones, purely probabilistic acceleration contours become close and S_S, S_1 for 2,500 year event (2 percent probability of exceedance in 50 years) could become very large. S_S, S_1 values invisibly transition from a 2,500-year "probabilistic" event to a "deterministic" event defined as "150% of the median accelerations of the characteristic event." A Magnitude of Characteristic event is defined as "*equal to the maximum magnitude capable of occurring on the fault, but not less than the largest magnitude that has historically occurred on the fault.*"

The design earthquake of the IBC is two-thirds of the Maximum Considered Earthquake (MCE), whereas the design earthquake of the 1997 UBC has a return period of 475 years (10 percent probability of exceedance in 50 years). The two-thirds is the reciprocal of 1.5, which is agreed to be the "seismic margin" built into structures designed by the UBC or older editions of the NEHRP Provisions. In other words, a structure designed by the UBC or older editions of the NEHRP *Provisions* is believed to have a low likelihood of collapse under an earthquake that is one and one-half times as large as the design earthquake of those documents. The redefinition of the design earthquake in the IBC is intended to provide a uniform level of safety across the country against collapse in the Maximum Considered Earthquake.

performance goal of PC-3 facilities by increasing the return period for the PC-3 DBE from a 2000-year earthquake to a 2500-year earthquake. Rather, the intention is more for convenience to provide a linkage from the NEHRP maps and DOE Standards. All PC-3 SSCs which have been evaluated for compliance with the previous version of this Standard do not require any reevaluation considering that the PC-3 level of performance has not changed.

13.3 Code Description Factor

Since the code requirements are generic, they are also generally conservative. The Code includes provisions for use of a site-specific seismic study to derive structural parameters. The decision to perform this study can be driven by the following factors:

- Site Classification: If the surface condition indicate Site Class "F," the Code requires that a site specific study be performed.
- Cost Optimization: If the owner wants to reduce construction and analysis costs, a site specific study can be performed to reduce dynamic loads and the SDC. The study adds a few thousand dollars to the project budget, which is minimal compared to the potential cost savings.
- Analysis Methods: The importance or the site conditions of the structure may require input parameters for the seismic analysis.

13.4 Site Classification

Sites are classified from "A" to "F" in the Code, with "A" being the hardest rock and "F" being the weakest soil. Sites classified as "F" require a site-specific study. Examples of Class "F" sites are those containing potentially liquefiable soils, thick clay layers, peat or highly organic or plastic clays, etc. For other classes, a site-specific study is permitted, however, design acceleration values obtained from the study cannot be less than 89 percent of the code values for the particular site condition.

Site Class "D" must be used when the soil properties are not known in sufficient detail, unless the building official determines that Site Class "E" or "F" is likely to be present at the site.

The Site Factors for various soil types and mapped Acceleration Factors (S_S & S_1) are listed in Table 13-1.

Table 13-1. Values of Site Soil Coefficient*

$F_a{}^a$: IBC -Table 9.4.1.2.4a/1615.1.2(1)							$F_v{}^a$: IBC- Table 9.4.1.2.4b/1615.1.2(2)				
Site Class	**Soil Type**	**Mapped Spectral Response ACC at Short Periods**					**Mapped Spectral response ACC at 1 Second Period**				
		≤0.25	=0.5	=0.75	=1.00	≥ 1.25	≤0.1	=0.2	=0.30	=0.40	≥ 0.50
A	HARD ROCK	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
B	MODERATE ROCK	1	1	1	1	1	1	1	1	1	1
C	DENSE SOFT SOIL, SOFT ROCK	1.2	1.2	1.1	1	1	1.7	1.6	1.5	1.4	1.5
D**	STIFF SOIL	1.6	1.4	1.2	1.1	1	2.4	2	1.8	1.6	1.5
E	SOFT SOIL, CLAY	2.5	1.7	1.2	0.9	0.9	3.5	3.2	2.8	2.4	2.4
F	FILL & OTHER	***	***	***	***	***	***	***	***	***	***
*	Straight line interpolation can be used for mapped spectral acceleration										
**	In lieu of geotechnical data and in cases where site class E or are not expected, Site Class D shall be assumed.										
***	Site specific geotechnical investigation and dynamic site response analyses shall be performed to determine values. Also applicable to type E $S_S \geq 1.25$ & $S_1 \geq 0.5$										

13.5 Seismic Design Category

Code requires that every new structure and portion thereof be assigned a SDC, and designed and constructed to resist effects of earthquake motions. SDC is based on the occupancy Category and the severity of the design earthquake motion as expressed by S_{DS} and S_{D1}.

SDC defines the required level of structural analysis and construction detailing (Section 1613.5.6 of 2006 IBC). SDC determines permissible structural systems, limitations on height and irregularity, requirements for design of components for seismic resistance, and types of lateral force that should be performed. Figure 13-2 identifies the steps for the derivation of the SDC and seismic analysis. The Occupancy category is defined by the owner and ranges from I to IV, depending upon the consequences of a potential failure and the need for operational accessibility following a seismic event.

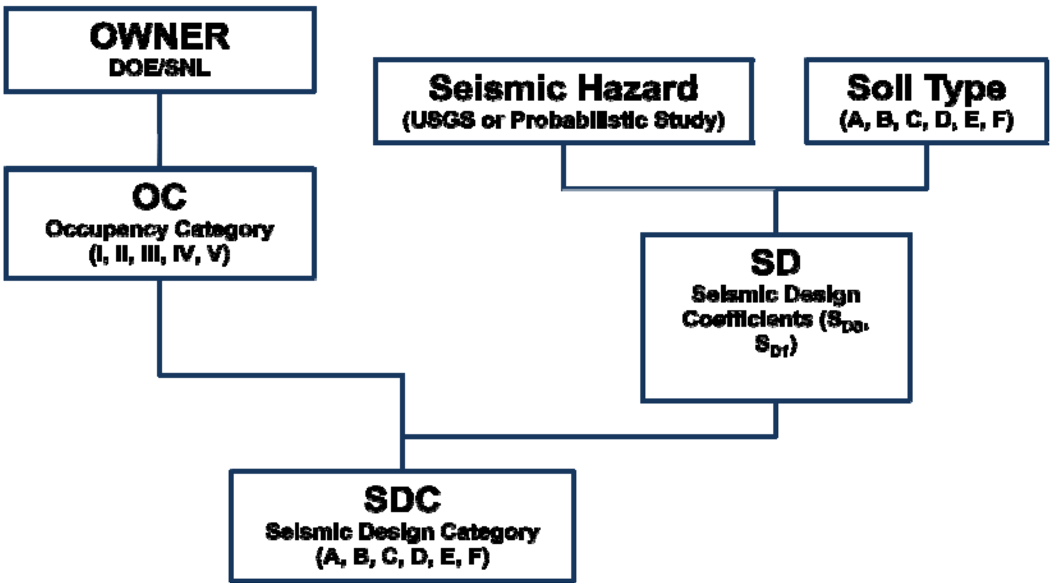

Figure 13-2. Identification of Steps to Derive Seismic Design Category (SDC) per IBC-2006[5]

According to current IBC requirements, the Seismic Design Category for a structure needs to be determined twice – first as a function of S_{DS}, the design spectral response acceleration at short periods, and a second time as a function of S_{D1}, the design spectral response acceleration at 1 sec. period. The more severe category governs and the determination process is reflected in the flowchart Figure 13-3.

[5] In IBC-2003, Seismic Use Group (SUG) Range I to III is used instead of OC.

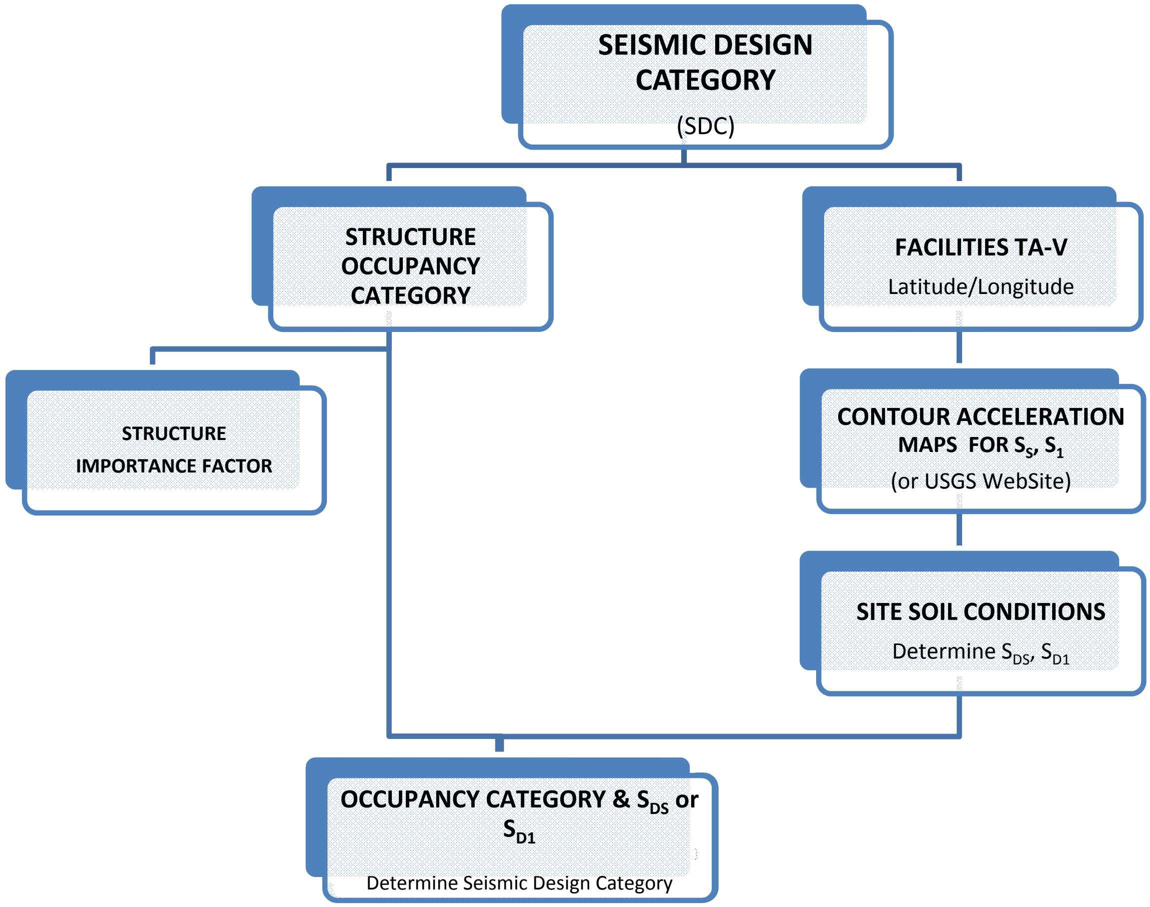

Figure 13-3. Seismic Design Category (SDC)

The process leading to the classification of the SDC involves several steps (Table 13-2): 1) Site-specific soil data must be gathered to establish the site class (otherwise, the default Site Class is "D"); 2) The classification procedure requires evaluation of SDC for a short-period and a long-period ground motion parameter; 3) After working through the calculations, the most severe SDC determined from the two conditions is selected.

Table 13-2. Determining the Seismic Category

Step	Column	
1	**2**	**3**
	Consider Ground Motion	
	Short Period	**Long Period**
Determine Spectral Response Acceleration From Contour Maps	S_S - Site Class B	S_1-Site Class B
Determine Site Class		
If Site Class (IBC Criteria) is	Perform Site-Specific Design	
If data available for Shear Velocity, Standard Penetration resistance, and undrained shear strength	Choose from site class A, B, C, D, E	
If NO data available:	**Use Site Class D**	
Determine soil site coefficient for acceleration or velocity	F_a *Table 1615.1.2(1)	F_v *Table 1615.1.2(2)
Determine soil-modified spectral response acceleration	$S_{MS}=F_aS_S$	$S_{M1}=F_vS_1$
Compute the design spectral response acceleration	$S_{DS}=2/3S_{MS}$	$S_{D1}=2/3S_{M1}$
Determine the Seismic Use Group (SUG) of structure		
SUGI	Standard Occupancy Building	
SUGII	Assembly Buildings	
SUGIII	Essential Functions	
Determine Seismic Design Category	As a function of SUG & SDC from	
Seismic Vulnerability	*Table 1616.3(1)	*Table 1616.3(2)
Very small	A	A
Low to Moderate	B	B
Moderate	C	C
High	D	D
Very High (near a Fault)	E	E
Very High (near a Fault)	F	F
Choose Most Severe SDC	Compare Column 2 with Column 3 from line	

***IBC**

As shown in Figure 13-1, S_{DS} and S_{D1} define the design response spectrum of the IBC-2000. SDS defines the "flat top" or acceleration-governed part of the spectrum, while S_{D1} defines the period-dependent descending branch or the velocity-governed part. The design spectral acceleration, Sa, on the vertical axis of Figure 13-1 is directly related to the design base shear, V.

V is equal to S_a multiplied by mass (or S_a/g multiplied by weight), except that for design purposes it is reduced by (R/IE) where R is the response modification factor (dependent upon the structural system used to resist seismic forces) and IE is the seismic load importance factor (dependent upon the use or occupancy of the structure.

13.5.1 Adverse Impact of Current Requirement

The current IBC requirement means that many structures designed for forces corresponding to the flat portion of the design spectrum (T equal to or less than Ts in Figure 13-1) have their Seismic Design Category determined from the value of S_{D1} rather than S_{DS}. It should be clear that many short-period buildings are unnecessarily penalized under the IBC because the Seismic Design Category based on the long-period spectral response acceleration (S_{D1}) makes it necessary to provide a higher level of detailing for these structures than would have been required if the SDC were allowed to be determined by S_{DS} only.

Following the precedent set by the *International Residential Code*, the *International Building Code* should allow the Seismic Design Category of short-period buildings to be determined solely on the basis of the short-period ground motion parameters, S_{DS}, subject to certain safeguards. Per current requirements, the SDC of many short-period buildings is determined by the long-period ground motion parameter, S_{D1}, imposing an unnecessary penalty on these buildings of more stringent detailing requirements which cost time, effort, and money. It is not clear at this stage whether this suggestion was accepted or not. It needs to be verified prior to its application.

13.5.2 Occupancy Category

Levels of Seismic Concern are identified in the new code as “Seismic Design Category”. These are a function of the structure’s end use and the ground acceleration coefficient. A rough definition of the 3 possible Occupancy Use Groups (I, II and III) is as follows (Table 13-3):

- Group III is an Emergency Treatment or Response Center (Hospitals, Fire Stations), an Essential Service structure (Emergency Phone, Backup Electric), or a structure containing potentially Hazardous Material.

- Group II is a high occupancy structure (Buildings where 300+ people can congregate, Schools, College Structures, Buildings with a total occupancy of 5000 or more) or non-Essential Utilities.

- Group I is what is left. Below are reprints of Tables 1616.3(1) and 1616.3(2) from the code indicating the Seismic Design Categories for various conditions. The Seismic Design Category appropriate for a project is the highest letter value obtained from Tables 13-3 and 13-4).

Table 13-3. Determining Occupancy Category (Partial) List (IBC Table 1604.5)

Occupancy Category	Nature of Occupancy
I	Minor Storage, Agricultural & Temporary Facilities
II	Normal Buildings
III	Schools
	Public Assembly > 300 Occupants
	Jails & detention Facilities
	Some Types of Healthcare > 50 Occupants
	Power Generation, Water Treatment Facilities
	Any Building > 5000 Occupants
	Hazardous Occupancies
IV	Hospitals, Fire, Rescue, & Police Stations
	Emergency Preparedness Centers & More

Table 13-4. Seismic Design Category Based on 0.2 Second and 1.0 Second Response Accelerations

Seismic Use Group			S_{DS} (g)	S_{D1} (g)
I	**II**	**III**		
A	A	A	$S_{DS} < 0.167$	$S_{D1} < 0.067$
B	B	C	$0.167 \leq S_{DS} \leq 0.33$	$0.067 \leq S_{D1} \leq 0.133$
C	C	D	$0.33 \leq S_{DS} \leq 0.50$	$0.133 \leq S_{D1} \leq 0.20$
D	D	D	$0.50 \leq S_{DS}$	$0.20 \leq S_{DS}$
E	E	F	$0.75 \leq S_1$*	$0.75 \leq S_1$*
*S1 is mapped Maximum Considered Spectral Response				

Both the 2000 IBC and the 1997 UBC having adopted the soil classification and the associated site coefficients first introduced in the 1994 NEHRP Provisions, a correlation of ground motion parameters between the two codes is possible.

It may be of interest to note that the 1997 edition of the *UBC* for the first time introduced two near-source factors: acceleration-related N_a and velocity-related N_v, the purpose of which is to increase the soil-modified ground motion parameters C_a and C_v when there are active faults capable of generating large-magnitude earthquakes. These factors became necessary in view of the artificial truncation of Z-values at 0.4 in UBC Seismic Zone 4. These near-source factors are not in the 2000 IBC because the artificial truncation of ground motion is not a feature of that code. Both S_S and S_1 attain high values in the vicinity of seismic sources that are judged capable of generating large earthquakes based on the seismic spectral map of the USGS. The pedigree of the TA-V facilities (except for Building 6591B and In-Ground Storage Vault (IGSV) pre-date the 1997 UBC timeline. The 1998 assessment and the 2007 scoping study addressed the seismic impact qualitatively and will need to be addressed quantitatively to address the changing paradigm of the new model.

A building's Seismic Design Category (SDC) is based on the seismicity at (S_{DS} and S_{D1}) and the occupancy category. The SDC is an important parameter that affects the building's seismic system selection and limitations, the seismic design requirements for elements within the structure, the applicability of the horizontal and vertical irregularities, and the detailing of components (discontinuous elements).

In the Uniform Building Code (ICBO 1997), the Seismic Zone in which a structure is located determines permissible structural systems including the level of detailing required for structural members and joints that are part of the lateral-force-resisting system and for the structural components that are not, limitations on height of structure and structural irregularity, the type of lateral load analysis that must be performed as the basis of design, as well as nonstructural component requirements. The 1994 and prior editions of the NEHRP Provisions (BSSC 1994) as well as the predecessor document, ATC 3 (ATC 1978), used a Seismic Performance Category (SPC) for the above purposes. The SPC was a function of occupancy (called Seismic Hazard Exposure Group in the documents being discussed) and of the seismic risk at the site of the structure in the form of the peak velocity related acceleration coefficient, A_v.

The 2000 IBC and the 1997 NEHRP Provisions have replaced the Seismic Performance Category (SPC) with a Seismic Design Category (SDC) which plays the same role as the SPC used to play. The SDC is a function of occupancy (called Seismic Use Group in the 2000 IBC and the 1997 NEHRP Provisions) and of *soil-modified* seismic risk at the site of the structure in the form of the design spectral response acceleration at short periods, S_{DS}, and the design spectral response acceleration at 1 sec. period, S_{D1}. For a structure, the SDC needs to be determined twice first as a function of S_{DS} by IBC Table1616.3-1 and a second time as a function of S_{D1} by IBC Table 1616.3-2. The more severe category will govern.

When ATC 3 in 1978 made the level of detailing (and other restrictions concerning permissible structural systems, height, irregularity and analysis procedure) a function of occupancy that was a major departure from UBC practice. The departure was continued in all the NEHRP Provisions through the 1994 edition. Now, in the 2000 IBC and the 1997 NEHRP Provisions, the level of detailing and the other restrictions have been made a function of the soil characteristics at the site of a structure. This is a further major departure from UBC practice and indeed from current practice across the country a move that is likely to have significant impact on the economic and other aspects of earthquake-resistant construction.

Table 13-5. Seismic Design Category Basic Method

				Period					
Seismic Group				**Short Response S_{DS}**			**1-Second Response S_{D1}**		
I	**II**	**III**	**IV**	**RANGE (g)**					
A	A	A	A	<0.167	S_{DS}		<0.067	S_{D1}	
B	B	C	C	0.167 ≤	S_{DS}	<0.33	0.067 ≤	S_{D1}	<0.133
C	C	D	D	0.33≤	S_{DS}	<0.5	0.133≤	S_{D1}	<0.2
D	D	D	D	0.50≤	S_{DS}		0.20≤	S_{D1}	
E	E	E	F	Mapped	S_1	≥0.75	Mapped	S_1	≥0.75
Many near-fault sites have S_1≥0.75g					S_1	≥0.75		S_1	≥0.75

Table 13-6 correlates the UBC Seismic Zone and the IBC Seismic Design Category.

Table 13-6. UBC & IBC Correlations

UBC SEISMIC ZONE	0	1	2A	2B	3	4	4
IBC SEISMIC DESIGN CATEGORY	A	B	C	C	D	E	F

13.6 Importance Factor

ATC 3, the predecessor document to NEHRP, deliberately decided to drop the importance factor that has been used in seismic design by the UBC for a long time. ATC 3 chose to institute two other requirements instead to ensure enhanced performance of structures in higher occupancy categories. Very importantly, it made drift limits tighter for structures in higher occupancy categories. Secondly, as mentioned, it made the level of detailing and other restrictions a function not only of the seismic risk at the site of a structure, but also of the occupancy of the structure. With these provisions still in place, the IBC has also chosen to bring the importance factor back. The highest value of the importance factor in the IBC is 1.5, whereas the UBC has used a maximum value of 1.25 since 1988.

The *Importance Factor* in the IBC code is now tied more closely to the use of the equipment rather than the use of the structure as was primarily the case in the past. There are 2 levels of importance (1.0 and 1.5). The Importance Factor of 1.5 is used under the following conditions:

- The component is a Life-Safety Component that must function after an Earthquake
- The component contains hazardous or flammable material in excess of exempted limits.
- Storage Racks in structures that are open to the public.
- Components needed for continued operation of Group III Occupancy Structure.

All other conditions use an Importance Factor of 1.0.

[redacted]

13.7 Soil Effects

In order to take into account soil effects at the site, the mapped MCE spectral response acceleration at short periods, *Ss*, is multiplied by the acceleration-related site coefficient, F_a, and the mapped MCE spectral response acceleration at 1-second period, S_1, is multiplied by the velocity-related site coefficient, F_v. The F_a and F_v coefficients decrease as the mapped spectral accelerations increase and increase as soil conditions go from hard rock to softer soils (i.e. from Site Class A to E), with maximum values for Site Class E soils being 2.5 and 3.5, respectively. Values for Site Class F soils must be determined from a site-specific geotechnical investigation utilizing a dynamic site response analysis. The design ground motion parameters of the 1997 UBC, C_a and C_v, are defined in terms of the Site Class (as in the 2000 IBC) and the Seismic Zone factor, *Z*.

The C_a/Z and C_v/Z of UBC are analogous, respectively, to the IBC's acceleration-dependent site coefficient, F_a, and the velocity-dependent site coefficient, F_v.

Table 13-7. UBC & IBC Importance Factor

Seismic Use Group	Occupancy Category	Importance Factor	
		IBC(I_E)	UBC(I)
I	5	1	1
	4	1	1
II	3	1.25	1
	2	1.25	1
III	1	1.5	1.25

Table 13-8. Seismic Importance Factor

Occupancy Category	I-Factor
I	1
II	1
III	1.2
IV	1.5

Based on the site-specific study, the importance factor will be incorporated into the SSC analysis.

14.0 Methodology, Potential impact, Conclusions and Recommendation

When performing the seismic assessment, there were a number of items that were considered critical in determining the extent of the seismic compliance with the requirements.

The initial four items affecting all codes are:

- Applicable effective national Code (Code document and year, UBC and IBC)
- Site and facility location and ground acceleration coefficient (Code dependent UBC/IBC)
- Type of occupancy (Essential, Hazardous or Emergency Service related).
- Any special seismic factors required that may exceed code requirements
- Geotechnical Report: The class of soil present at the site and facility (UBC 1997, IBC 2000).

14.1 Methodology

The methodology discussed above, engineering design information feeds into the hazard analysis process provided by DOE-STD-1189-2008. Hazard and accident analysis are performed in accordance with the existing site infrastructure and procedures; safety classification of candidate engineered controls is performed in accordance with DOE-STD-3009-94. The results of this process are compared with the performance criteria set forth in DOE-STD-1021-93, to determine the performance category. The resulting performance category (PC-1, -2, or -3) is translated into an equivalent SDC and Limit State combination. Figure 14-1 presents a conceptual NPH design frame work which identifies how the DOE standards are currently used to assess NPH design requirements. This figure updates Figure 6-1 found in DOE-STD-1020.

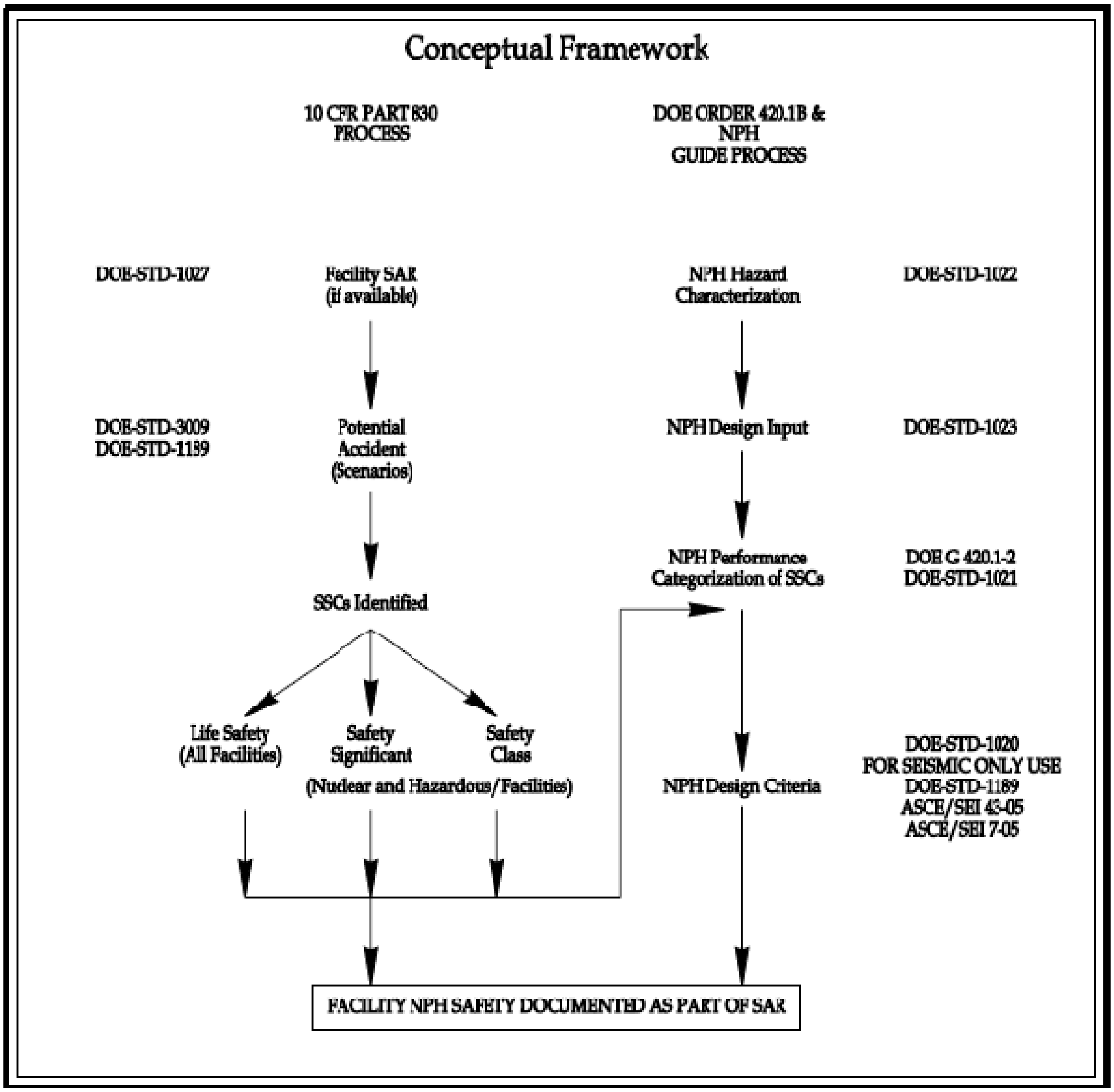

Figure 14-1. Natural Phenomenon Design Input[6]

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[6] See Figure 6-1 for comparison.

In the path split based on the new requirements, consequence calculations for the design basis seismic event are modified in accordance with the methodology provided in DOE-STD-1189-2008, Appendix A, which mandates an alternate dispersion coefficient for calculation of the dose consequence to the collocated worker. The resulting dose consequence is compared with the criteria provided by ANSI/ANS 2.26-2004, as modified by DOE-STD-1189-2008, Appendix A, to determine the appropriate SDC. Limit States are assigned based on the SSC safety function, if adequately understood, or in accordance with the default criteria of DOE-STD-1189-2008.

This methodology provides a definition of seismic performance and design requirements in terms of an SDC, regardless of the method used to derive the requirements. This allowed the engineering design team to work in accordance with ASCE/SEI 43-05/7-05 for all facility design efforts.

The process is iterative in nature; the results of engineering design feed back into the hazard analysis process, and additional hazard and accident analysis may result in the specification of additional engineered controls. An enhanced understanding of the facility design and process may result in the ability to downgrade existing controls.

The same methodology is applied in each iteration to ensure the conservatism of seismic design. While this methodology results in an additional nuclear safety burden during evaluation and/or design, it is anticipated to preclude the need for engineering design rework or justification regardless of the timeline for inclusion of new requirements.

14.2 Potential Impact, Seismic Design and Seismic Hazard Analysis

Potential impacts are in two primary areas; *Seismic design and Seismic hazard analysis*. There is an adoption of national standards to specify Seismic Design Criteria (SDC) & Limit States (LS) rather than STD 1020 Performance Criteria (PC). It should be pointed out that reliance on *DOE-STD-1020* series is no longer required for seismic, but applies for other natural phenomena. Probably the DOE Standards affecting Seismic evaluations and requirements are being updated to incorporate new national standards requirements.

New standards to specify Seismic Design Criteria have been identified: ANSI 2.26, ASCE 43-05 and ASCE 7-05. These standards requires use of Seismic Design Category (SDC) and Limit States (LS) rather the Performance Categories (PC) and five (SDC) by four (LS) array to characterize SSCs.

Except for the one storage facilities and the in-ground storage that were designed to IBC-2000, the other buildings were designed to the UBC requirements (1956-1994). The biggest code requirements transformation occurred in UBC-1997. It may be of interest to note that the 1997 edition of the *UBC* for the first time introduced two near-source factors: acceleration-related N_a and velocity-related N_v, the purpose of which is to increase the soil-modified ground motion parameters C_a and C_v when there are active faults capable of generating large-magnitude earthquakes. These near-source factors are not in the 2000 IBC because the artificial truncation of ground motion is not a feature of that code. Both S_S and S_1 attain high values in the vicinity of seismic sources that are judged capable of generating large earthquakes.

[redacted]

[redacted] The safety classification of SSCs was completed and approved in accordance with applicable DOE requirements. Existing PC categories for SSCs will be used in defining the appropriate SDC or equivalent. As input into the PC and SDC evaluation, scoping calculations may need to be completed per the DOE-STD-1189 methodology.

The combination of new seismic contour maps and SDC assignment results in a decidedly more sophisticated approach to earthquake design in the 2000 IBC over that of the 1997 UBC. The primary Facilities at TA-V were designed to the UBC (1954-1994) codes. The 2000 IBC has simply refined the design process to make it more accurate and reflective of the latest scientific information. [redacted]

14.3 Recommendations

14.3.1 Site Characterization and NPH Assessment

It is recommended that an IBC seismic Site Class map be prepared for Technical Area V. The creation of an IBC seismic Site Class map would help locate any new faults and /or identify tributaries propagating within the perimeters of Technical Area V. This effort would also provide site-specific class information to help site planners in comparing the UBC based design of existing building, selecting location for new facilities and help reduce cost of facilities modification renovation project in the class C areas and thus will results in significant long-project savings.

Per Executive Order 12941 in 1998, Sandia National Laboratories evaluated their building inventory for potential seismic risks and estimated the costs of mitigation. After the screening process, none of the buildings in Area 5 were classified as Exceptionally High Risk. The 1998 evaluation of buildings at Sandia National Laboratories was based on the 1997 Uniform Building Code (UBC) since then the UBC has been replaced with the International Building Code (IBC). With the implementation of the International building code (IBC) evaluation of subsurface profile to determine Site Class has become more important to design of structures. Standard refraction seismic gear and analytical techniques combine to provide fast, dependable evaluations of shear wave velocity profiles to depths of 30 meters (100 feet) to support the collection of parameters for Site Classification Determination.

14.3.1.1 Recommended Evaluation of Existing SSCs

Evaluations of existing SSCs must follow or, at least, be measured against the NPH criteria provided in the DOE standards. For SSCs not meeting these criteria and which cannot be easily remedied, budgets and schedule for required strengthening must be established on a prioritized basis. A back-fit analysis should be conducted. Priorities should be established on the basis of Seismic Design Category, cost of strengthening and margin between as-is SSC capacity and the capacity required by the criteria. For SSCs which are close to meeting criteria, it is probably not cost effective to strengthen the SSC in order to obtain a small reduction in risk.

As a result, some relief in the criteria is allowed for evaluation of existing SSCs. It is permissible to perform such evaluations using natural phenomena hazard exceedance probability of twice the value specified for new design. For example, if the natural phenomena hazard annual probability of exceedance for the SSC under consideration was 10^{-4}, it would be acceptable to reconsider the SSC at hazard annual probability of exceedance of 1×10^{-4}. This would have the effect of slightly reducing the seismic loads in the SSC evaluation by about 10% to 20%. This amount of relief is within the tolerance of meeting the target performance goals and is only a minor adjustment of the corresponding NPH design and evaluation criteria. In addition, it is consistent with the intent of the Federal Program developed by the Interagency Committee on Seismic Safety in Construction. When upgrading becomes necessary, the design should be based on the current design criteria in the standard for the new facility. The DOE G 420.1-2 Guide provides guidance for facilities with a remaining service life of less than 5 years.

14.3.2 Establish Seismic Design Category and New Performance Category (PC)

New standards to specify the Seismic Design Criteria have been identified. These standards require the use of Seismic Design Category (SDC) and Limit States (LS) rather than the Performance Category (PC) and a five (SDC) by four (LS) array to characterize the SSCs. Scoping calculations following DOE-STD-1189, Seismic Hazards Analysis methodology may be needed. A new PC can be established based on the matrix discussed in the document and the site seismic evaluation based on IBC.

13.3.3 Evaluate Existing Structures, Systems, and Components (SSCs)

The existing SSCs should be evaluated based upon specified annual probabilities of exceedance for NPHs to establish loadings, deterministic design methods for response evaluation, permissible response levels, load combination rules, design detailing requirements, and quality assurance and independent peer review requirements per DOE standards.

The Standard provides sufficient documentation to–

a) Communicate the process, rationale, and results of the NPH evaluation;

b) Present information that can be evaluated during peer reviews; and

c) Provide traceability and a basis for future assessments.

14.3.4 Establish a Prioritized Schedule

A prioritized schedule should be for reevaluation and upgrade of existing facilities if there is a significant degradation in the safety basis for the facility, or when Executive Order 12941 requires that this be done. A prioritization program should direct initial efforts to facilities of greatest importance in terms of safety, mission, and cost. A screening program may enable a relatively rapid initial evaluation to be conducted such that areas of greatest vulnerability to natural phenomena effects can be identified and addressed. Areas where SSCs might not be vulnerable to natural phenomena effects due to inherent ruggedness or benign site conditions can be identified and eliminated from further consideration.

14.3.5 Seismic Detection

Facilities or sites with SSCs in PC-2 (with hazardous material), PC-3, or PC-4 should have instrumentation, such as strong motion detectors or other means, to detect and record the occurrence and severity of seismic events.

Earthquake Early Warning Systems (EEWS), based on real-time prediction of ground motion or structural response measures, may play a role in reducing vulnerability and/or exposition of buildings and lifelines. In fact, recently seismologists developed efficient methods for rapid estimation of event features by means of limited information of the P-waves. Then, when an event is occurring, probabilistic distributions of magnitude and source-to-site distance are available and the prediction of the ground motion at the site, conditioned to the seismic network measures, may be performed in analogy with the Probabilistic Seismic Hazard Analysis (PSHA). Consequently the structural performance may be obtained by the Probabilistic Seismic Demand Analysis (PSDA), and used for real-time risk management purposes. However, such prediction is performed in very uncertain conditions which have to be taken into proper account to limit false and missed alarms.

There are ten absolute-gravity stations in the vicinity of SNL/KAFB are maintained by the National Geodetic Survey and the Defense Mapping Agency. [redacted]

It is recommended that the condition be assessed and evaluated after the Seismic analysis to determine if there is a need to install a Earthquake Early Warning System and instrumentation such as strong motion detectors or other means, to detect and record the occurrence and severity of seismic events to initiate mitigative actions to place the facilities in a safe-shutdown mode and for life safety.

14.3.6 Post-Natural Phenomena Procedures

Facilities or sites that have SSCs in PC-2, PC-3, or PC-4 must have procedures to inspect the facility for damage due to a severe natural phenomena event, to place the facility into a safe configuration when damage occurs, and to document and report such damage. [redacted]

It is recommended a procedure specific to TA-V be developed.

SNL has assembled a team of engineers (structural, mechanical, electrical, and fire protection professional) having post-disaster safety Inspection training to assess, document and report the damage incurred and determine the what mitigative actions are required to place the facility into safe configuration of non-nuclear facilities. [redacted]

It is recommended that a team of radiological personnel and engineers specific for TA-V having post-disaster safety Inspection training to assess, document and report the damage incurred and determine the what mitigative actions are required to place the TA-V facility into a safe configuration and a team be assembled to meet the requirements.

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