NOT MEASUREMENT SENSITIVE

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DOE STANDARD

NATURAL PHENOMENA HAZARDS ASSESSMENT CRITERIA

U.S. Department of Energy
Washington, D.C. 20585

AREA FACR

ERRATA FOR DOE-STD-1023-95

- FOREWORD RE-WRITTEN
- ADDED REFERENCE TO 10 CFR PART 830, SSHAC (1997) AND UCRL-ID-140922
- REPLACED REFERENCES FROM DOE O 5480.28 TO DOE O 420.1
- UPDATED REFERENCE DOE-STD-1020-2002
- ADDED REFERENCE TO DOE G 420.1-2
- LIMITS ON USE OF SITE SPECIFIC VALUES EXPLAINED IN SECTION 1.d, 3.1.1.e
- USE OF USGS CURVES CLARIFIED IN SECTION 3.1.2.1a
- CLARIFYING SENTENCES ADDED IN SECTION 3.1 TO CONFORM TO LATEST CODES AND INDUSTRY STANDARDS
- REFERENCE ADDED FOR NUREG/CR-6372 & USE OF SSHAC REPORT
- DOE-STD-1024-92 AND DOE O 5480.23 DELETED
- USE OF DBE VALUES FOR PC-1 & PC-2 IN SECTION 3.1.1e STREAMLINED
- USE OF DBE RESPONSE SPECTRA ACCEPTANCE CRITERIA CLARIFIED IN 3.1.3 (OUTDATED MATERIAL DELETED)
- WIND WAVES CLARIFIED IN SECTION 3.3.4
- REFERENCES UPDATED IN SECTION 4.0 (OUTDATED REFERENCES DELETED)
- APPENDIX UPDATED TO MEET CURRENT STANDARDS

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FOREWORD

The Department of Energy (DOE) has issued an DOE Order 420.1, Facility Safety, an associated NPH Guide, DOE G 420.1-2 which establishes policy and requirements for Natural Phenomena Hazard (NPH) mitigation for DOE sites and facilities. To implement the NPH mitigation requirements, several standards have been developed for compliance with DOE O 420.1. This standard, DOE-STD-1023-95, provides general and detailed criteria for establishing adequate design basis load levels.

The criteria given in this standard should be used in conjunction with other DOE Orders, Guides and Standards as listed in Section 2 (Applicable Documents) of this Standard and with other pertinent National consensus codes and standards such as the model building codes.

DOE technical standards such as this technical standard do not establish requirements. However, all or part of the provisions in a technical standard can become requirements under the following circumstances:

(1) they are explicitly stated to be requirements in a DOE requirements document; or

(2) the organization makes a commitment to meet a standard in a contract or in a plan required by a DOE requirements document (such as in an implementation plan).

Throughout this standard, the words “should” and “shall” are used to clarify which actions need to be done to meet this standard. The word “shall” is used to denote actions which must be performed if this standard is to be met. The word “should” is used to indicate recommended practice. If the provisions in this technical standard are made requirements through one of the two ways discussed above, then the “shall” statements would become requirements but the “should” statements would not.

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1. SCOPE

a. It is the policy of the Department of Energy (DOE) to design, construct, and operate DOE facilities so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards (NPHs) on DOE facilities. As discussed in 10 CFR Part 830, Nuclear Safety Management, natural external events need to be evaluated as part of Documented Safety Analysis (830.204). NPH safety policy requirements for natural phenomena hazard (NPH) mitigation are established by DOE O 420.1 which is referenced in 10 CFR Part 830, Nuclear Safety Management Rule.

b. DOE 0 420.1 and associated NPH Guide, DOE G-420.1-2 requires that structures, systems, and components (SSCs) at DOE facilities are designed and constructed to withstand the effects of natural phenomena hazards using a graded approach. The graded approach is implemented by the five (5) performance categories established for SSCs based on criteria provided by DOE-STD-1021-93. Performance Category (PC) 0 is for SSCs which require no NPH protection. The performance categories requiring NPH protection range from PC 1, which represents protection for life-safety at the level provided by model building codes, to PC 4, which represents protection from release of hazardous material similar to that provided by commercial nuclear power plants. For each performance category, NPH design, evaluation, and construction requirements of varying conservatism and rigor are provided in DOE-STD-1020-2002.

c. In applying the design/evaluation criteria of DOE-STD-1020-2002 for DOE facilities subjected to one of the natural phenomena hazards, the establishment of design basis load levels consistent with the corresponding performance category is required. Design basis load levels are established by conducting natural phenomena hazard assessments.

d. For sites containing facilities with structures, systems, and components (SSCs) in only Performance Category 1 or 2 and having no site-specific probabilistic NPH assessment, it is sufficient to utilize natural phenomena hazard maps from model building codes or national consensus standards if they have input values at the specified hazard probabilities. For sites which have site-specific probabilistic NPH assessments, the SSCs in Performance Category 1 or 2 shall be evaluated or designed for the greater of the site-specific values or the model code values, unless lower site specific values can be justified and approved by DOE. Limitations on use of site specific probabilistic NPH assessments contained in Model Building Codes shall be complied with.

e. For sites containing facilities with SSCs in Performance Category 3 or 4, a site-specific probabilistic natural phenomena hazard assessment review shall be conducted if none has been conducted within the last 10 years. This NPH assessment review shall consider site-specific information as discussed in DOE-STD-1022-94.

f. The purpose of this standard, DOE-STD-1023-95, is to provide criteria for natural phenomena hazard assessments to construct hazard curves. The mean hazard curve shall be used to determine the design basis NPH event for design and/or evaluation of DOE facilities. This Standard provides specific criteria applicable to various natural phenomena hazards including seismic, wind and tornado, and flood.

g. Specific criteria applicable to seismic hazard assessment are provided in Section 3.1 of this Standard.

h. Specific criteria applicable to wind hazard assessment are provided in Section 3.2 of this Standard.

i. Specific criteria applicable to flood hazard assessment are provided in Section 3.3 of this Standard.

j. Criteria for natural phenomena hazard assessments applicable to other natural phenomena hazards such as volcanic ash, lightning, and snow are not provided in this Standard. Therefore, the minimum criteria necessary for these and other NPH assessments of DOE facilities should be derived from relevant consensus national codes and standards, or appropriate local codes wherever available.

k. General guidelines for acceptable methods to meet the NPH assessment criteria can be found in Appendix A

2. APPLICABLE DOE DOCUMENTS

a. DOE O 5480.1B, "Environment, Safety and Health Program for DOE Operations," of 9-23-86, which establishes the Environment, Safety, and Health (ES&H) Program for DOE Operations.

b. DOE O 420.1 CHG-3, Facility Safety" of 11-22-00, which establishes policy and requirements for natural phenomena hazard (NPH) mitigation for DOE sites and facilities using a graded approach.

c. DOE O 5480.30, "Nuclear Reactor Safety," of 1-19-93, which specifies requirements for DOE nuclear reactor safety.

d. DOE O 5481.1B, "Safety Analysis and Review System," of 9-23-86, which establishes uniform requirements for the preparation and review of safety analyses of DOE operations.

e. Department of Energy 10 C Part 830, which establishes requirements (Nuclear Safety Management Rule).

f. DOE-STD-1020-2002 "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," January 2002, which defines criteria for designing or evaluating structures, systems, and components for NPH loads.

g. DOE-STD-1021-93, "Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components,"July 1993, which provides criteria for placing structures, systems, and components into performance categories.

h. DOE-STD-1022-94, "Natural Phenomena Hazards Site Characterization Criteria," March 1994, which provides requirements for obtaining the necessary site-specific information to implement DOE-STD-1023-95.

3. CRITERIA

3.1 Detailed Criteria for Seismic Hazard Assessment

3.1.1 General

a. This Standard provides criteria for determining ground motion parameters for the Design/Evaluation Basis Earthquake (DBE). It also provides criteria for determining the acceptable design response spectral shape.

b. Seismic design and evaluation criteria for Department of Energy facilities are provided by DOE-STD-1020-2002. In accordance with DOE-STD-1020-2002, DBE spectra shall be determined and used for the design/evaluation process.

c. In accordance with DOE-STD-1020-2002 the DBE spectra shall be a site-specific shape anchored to the appropriate ground motion parameters following the provisions of Sections 3.1.3 and 3.1.5. When a site-specific response spectrum shape is unavailable, a standardized spectrum shape is acceptable.

d. The seismic hazard assessment shall consider all effects of earthquakes including not only earthquake ground shaking, but also earthquake-induced ground failure modes such as fault offset (see Section 3.1.4).

e. For sites containing facilities with SSCs in only Performance Category (PC) 1 or 2, it is sufficient to utilize seismic hazard maps from the current version of model building codes or national consensus standards if no site-specific probabilistic seismic hazard assessment (PSHA) has been conducted for the sites. For sites which have site-specific probabilistic seismic hazard assessments, the SSCs in Performance Category 1 or 2 shall be evaluated or designed for the greater of the site-specific values or the model code values unless lower site-specific values are approved by DOE. Limitations on use of site specific probabilistic natural phenomena assessments contained within model building codes shall be complied with.

f. For sites containing facilities with SSCs in Performance Category 3 or 4, a site-specific PSHA shall be conducted to determine the DBE.

g. DOE O 420.1 requires that site-specific seismic hazard assessment methodology be reviewed at least every 10 years.

3.1.2 Development of Site-Specific Seismic Hazard Curves (SHC)

a. Two options are acceptable for the development of SHC. The first option is to utilize existing probabilistic seismic hazard assessment (PSHA) studies. This option is addressed in Section 3.1.2.1. The second option is to conduct a new site-specific PSHA, as described in Section 3.1.2.2.

b. Any new site-specific seismic hazard assessment to generate seismic hazard curves shall consider available site-specific geologic and seismic data in conformance with DOE-STD-1022-94.

3.1.2.1 Development of Seismic Hazard Curves Based on Existing PSHA

a. This option allows the use of existing PSHA studies similar to those conducted by the Electric Power Research Institute (EPRI, 1989a) for the commercial nuclear power industry and Lawrence Livermore National Laboratory (LLNL) (Bernreuter, et al., 1989) for the U.S. Nuclear Regulatory Commission (USNRC), which can be used at particular DOE sites in the Eastern United States. Experience has shown that application of the 1989 LLNL and EPRI methodologies can yield significantly different results. It is permissible to directly average the mean hazard curves from EPRI (1989a) and more recent hazard assessments from LLNL (Savy, et al., 1993 and Sobel, 1994). The United States Geological Survey has completed probabilistic seismic hazard estimates for the entire United States (USGS, 1996, USGS, 2001). While the USGS (1996) has stated that these curves do not consider the uncertainty in seismicity or fault parameters, the USGS (2001) seismic hazard curves should be compared to those available for the site. Differences in seismic hazard estimates should be evaluated, after adjustments have been made to ensure these comparisons apply to similar site conditions. The technical basis for the differences must be understood and documented to validate the adequacy of the site-specific seismic hazard estimates.

b. This option is particularly suitable for DOE sites in the eastern United States, with the exception of sites located near active sources for large magnitude earthquakes, e.g., near New Madrid, Missouri and Charleston, South Carolina. In these cases, it is required to either incorporate additional site-specific seismic sources or show that the regional seismic sources in the LLNL EPRI, or USGS studies adequately model the tectonics in the vicinity of the site.

3.1.2.2 Development of Seismic Hazard Curves Based on New Site-Specific PSHA

a. Acceptable methodologies for conducting new PSHA for DOE sites should be consistent with SSHAC (1997), Recommendations for Probabilistic Seismic Hazard Analysis: Guidance of Uncertainty and Use of Experts (NUREG/CR-6372). As discussed in SSHAC (1997), an acceptable methodology for the development of DOE site-specific seismic hazard curves must accommodate uncertainties in the potential earthquake occurrence and ground motion attenuation processes affecting the site.

b. The description given here applies to facilities with SSCs in PC 4, as specified in Section 3.1.1.f. For PC 3, the same methodology as for PC 4 is required, but simplifications as described in Section A3.1.2.2.5 are acceptable.

c. The following elements shall be included in the methodology to conduct a new PSHA.

    (1) Basic Hazard Model - The four steps required to determine the seismic hazard curve using the basic hazard model are shown in Fig. 3.1.

    (2) Data Used in the Hazard Modeling - The PSHA shall consider available data in conformance with DOE-STD-1022-94.

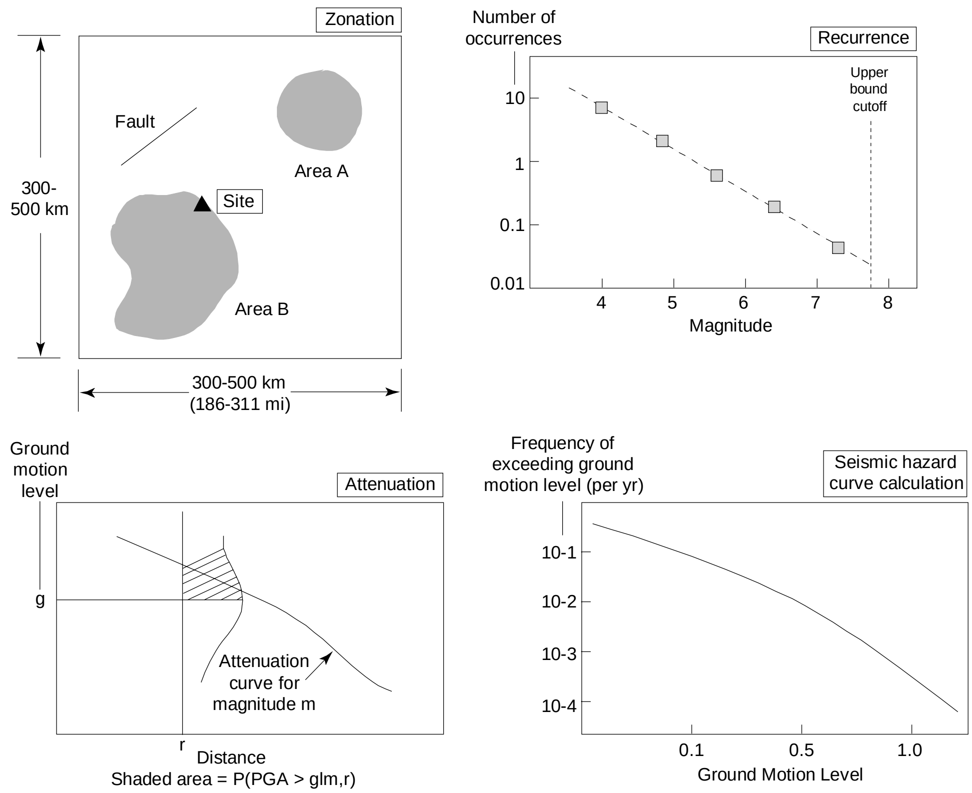

Figure 3.1 Four Steps in Probabilistic Seismic Hazard Analysis

(3) Characterization of Uncertainty in Parameters of the Hazard Model - The PSHA shall accommodate random variability in location, size, and ground motions associated with future earthquakes as well as uncertainties related to the lack of knowledge of the models and parameters that characterize the hazard.

(4) Quantifying Uncertainty - Two approaches are acceptable for characterizing and quantifying uncertainties in PSHA: elicitation of multiple experts and peer review (the approaches can be used separately or together). Proper documentation of the technical basis for all assessments is an essential element.

3.1.2.3 <u>Level of Review</u>

a. The SSHAC (1997) report provides guidance on completion of independent reviews. The credibility and defensibility of a modern PSHA depends on the quality of the input as well as the completeness of the documentation. All the information, input, and analysis should be fully documented and independently reviewed. The independent review should focus on the arguments and logic used to develop the hazard results. The review team should include personnel with expertise in the seismic hazard methodology and input parameters. The review should be documented including questions raised by reviewers and resolutions provided by the analyst.

3.1.3 <u>DBE Response Spectra Acceptance Criteria</u>

a. The target DBE response spectrum may be defined as the mean uniform hazard response spectrum (UHS) associated with the seismic hazard annual probability of exceedance over the entire frequency range of interest. The slope of the seismic hazard curve is also an important consideration when using the DBE for structural analysis (see DOE STD-1020-2002).

b. The target DBE response spectra should be reviewed to ensure its adequacy. Recommendations for spectral shapes as functions of magnitude, distance from the seismic source and site conditions are presented in McGuire, et. al. (2001) and should be considered in this evaluation.

c. Earthquake vibratory ground motions to be used as input excitation for design and evaluation of DOE facilities, according to DOE-STD-1020-2002, is defined using an approach similar to that developed by the United States Nuclear Regulatory Commission (see Regulatory Guide 1.165, 1997). When site-specific response spectra are unavailable, a median standardized spectral shape may be used so long as such a spectrum shape is either reasonably consistent with or conservative for the site conditions. In these cases the median spectral shape should be scaled to the mean ground motion parameters based on the Uniform Hazard Spectrum to produce an appropriate DBE spectra.

d. The final DBE ground motion at the site shall be specified in terms of smooth and broad frequency content horizontal and vertical response spectra defined at a specific control point. The control point is typically defined at the bedrock outcrop, at the top of ground or at some intermediate surface. The selection of the appropriate control point depends upon the details of the seismic response analysis to be performed for the facility. The method to transfer the DBE spectra from one depth of the site to another must adequately account for the effects of the primary contributors to the seismic hazard on all aspects of site response.

e. Acceptable methods for the development of site-specific response spectra are described in Section 3.1.3.1 of this Standard. Alternatively, methods commonly used for the development of standardized response spectra based on general site conditions instead of a site-specific geotechnical study are described in Section 3.1.3.2 of this Standard.

3.1.3.1 <u>Site-Specific DBE Response Spectra</u>

a. The procedure described in this Section for developing a median site-specific spectral shape is applicable for facilities with SSCs in Performance Category 3 or 4. In accordance with the graded approach, the development of site-specific spectral shapes for facilities with SSCs in Performance Category 3 may be relatively less rigorous than those in Performance Category 4.

b. For those sites that choose to develop a site-specific spectral shape, information contained in the probabilistic seismic hazard analysis shall be used to establish the appropriate magnitudes and distances for the controlling (or dominant) earthquakes. Controlling earthquakes are those potential earthquakes that could cause the greatest or governing ground motions at a site. There may be several controlling earthquakes for a site; e.g., a moderate nearby earthquake may control the high-frequency ground motions or the PGA, and a large distant earthquake may control the low-frequency ground motions (e.g., 1-2.5 Hertz) or the peak ground displacement (PGD).

c. For many cases of interest, the primary controlling earthquake is the postulated event that governs the spectral accelerations in the 5 to 10 Hz range. Thus, the primary seismic ground motion parameter is the average spectral acceleration of 5 and 10 Hz, $S_{A\ (5\text{-}10)}$. There may be some instances where the spectrum generated from this controlling earthquake may not be sufficiently broad-banded to capture the contributions from all sources. Therefore, if the controlling earthquake for the frequency range of 1 to 2.5 Hz is from a significantly different source, e.g. a large, distant event, its effect on the spectral shape shall be included. In addition, for sites that have SSCs sensitive to low-frequency seismic response (e.g., below 1 Hz), it may be necessary to include the controlling earthquake based on seismic PGD. It should be noted that these primary frequency ranges of interest may be modified for cases of soft structures or for structures on soft soil sites.

3.1.3.2 Standardized DBE Response Spectra

a. As specified in Section 3.1.1.b, standardized response spectra developed from general site conditions instead of site-specific geotechnical studies are used if site-specific response spectra are unavailable. Acceptable methods to generate site-dependent standardized response spectra include those of Newmark and Hall (1978), Mohraz (1976), Seed et al. (1974), Kiremidjian and Shah (1980), ATC (1984), and BSSC (1988). An example of the application of standardized spectra can be found in Appendix A.

3.1.4 Earthquake-Induced Ground Failure Assessment

a. In addition to ground shaking, another direct effect of earthquakes can be surface expression of fault offset. A probabilistic assessment of this ground failure mode may be necessary if potential fault rupture may occur near a facility. If the annual probability of this ground failure mode is greater than the necessary performance goal, either the site should be avoided, mitigation measures taken, or an evaluation performed of the effects of fault offset. Similar comments can be made for other potential sources of ground failure, such as liquefaction or lateral spreading.

3.1.5 Historical Earthquake Ground Motion Check

a. In assessing the DBE, the review will consider historical earthquakes that may have affected the site and ensure that the DBE is conservative relative to the historical earthquake. This is not meant to be a comparison to the “maximum credible” earthquake, nor should it include infrequent paleoseismic events as part of the historical data set.

b. Historical earthquakes are defined as any earthquake which has been felt or instrumentally recorded. Ground motion estimates will be completed for all historical earthquakes estimated to be equal to or above moment magnitude of 6.0, within a distance of 200 kilometers (124 mi) of the site. The only exception to this requirement is for sites within 500 kilometers (311 mi) of the 1811-1812 New Madrid earthquake sequence, which are required to include the ground motion from a reoccurrence of these events. Ground motion estimates shall be based on the following assumptions:

(1) Magnitude

The historical earthquake magnitude will be a best estimate of the moment magnitude for the earthquake. If instrumentally recorded, the magnitude will be either the recorded moment magnitude or a derived moment magnitude from other estimated magnitudes using accepted published magnitude conversion relationships. If the historical earthquake is a pre-instrumental event, the moment magnitude should be estimated using information such as the total felt area or other applicable intensity information found in the published literature and authoritative unpublished records, diaries, scientists notes, etc. If the ground motion attenuation relationship requires additional source parameters such as stress drop, these parameters should also be defined as best estimates.

(2) Distance

The distance should be based on a best estimate. For instrumentally recorded earthquakes, the distance should be based on the best available location (including depth). For pre-instrumental earthquakes, there is considerable uncertainty in the exact location of the event. In these cases, a reasonably conservative estimate should be provided which considers factors such as the highest intensity and the estimated rupture dimension for the magnitude being considered.

(3) Ground Motion

Both median (50th percentile) and 84th percentile estimates of ground motion should be completed for all frequencies comprising the response spectra. Methods for estimating ground motion should be consistent with the approaches used to derive the spectral shapes as discussed in Section A3.1.3.1.e. For PC 4 facilities, the DBE spectra shall be equal to or greater than the 84th percentile estimate. For PC 3 facilities, the DBE spectra should be equal to or greater than the median estimate. In general, the difference between the median and 84th percentile is about a factor of 1.7 to 2 in ground motion, which approximates the ground motion difference between PC 3 and PC 4 hazard probabilities coupled with typical hazard curve slopes.

3.1.6 Generation of Appropriate Enveloping Accelerograms

For many seismic evaluations of structures and sites, the generation of accelerograms (time histories) which envelope the developed DBE response spectrum must be developed. The guidelines to be used for development of such time histories and acceptance criteria are present in McGuire, et. al. (2001). The time histories need to have sufficient energy content at all frequencies of interest and possess characteristics appropriate for the governing characteristic seismic events comprising the seismic hazard of the site.

3.2 Detailed Criteria for Wind Hazard Assessment

3.2.1 General

a. Design and evaluation criteria for DOE facilities against wind hazards are provided by DOE-STD-2002. In accordance with DOE-STD-1020-2002, (1) the recommended basic wind speed for all PCs; (2) the atmospheric pressure change (APC) associated with a tornado for PC 3 or 4 SSCs; and (3) windborne missile criteria (size, weight, and speed) for PC 3 or 4 SSCs; shall be defined in order to carry out the design/evaluation process.

b. Criteria for the atmospheric pressure change and recommended windborne missiles are contained in DOE-STD-1020-2002.

c. The recommended basic wind speed shall be determined from a mean wind hazard curve developed for the site in accordance with the hazard annual probability specified in DOE-STD-1020-2002. The recommended basic wind speeds for 25 DOE sites have been modified from ASCE 7-98 requirements in DOE-STD-1020-2002. DOE O 420.1 requires that the need for updating the site wind hazard assessment be reviewed at least every 10 years. Therefore, for sites where existing wind hazard assessments are either unavailable or considered out of date, a new wind hazard assessment shall be conducted.

d. The purpose of this Section of the Standard is to provide specific criteria for the DOE facilities with respect to the wind hazard assessment. The criteria are provided to ensure that a consistent approach across DOE sites is achieved for design/evaluation of DOE facilities against wind hazards.

e. For sites containing facilities with SSCs in only PC 1 or 2, missile effects and atmospheric pressure change due to tornadoes need not be considered. Therefore, the only wind hazard design parameter to be established is the basic wind speed.

   1. For sites having no site-specific probabilistic wind hazard assessment, it is sufficient to utilize model building codes, or national consensus standards, such as ASCE (1998a), to define the basic wind speed.

   2. For sites which have site-specific probabilistic wind hazard assessment, the SSCs in PC 1 or 2 shall be evaluated for the greater of the site-specific values or the model code values unless lower site-specific values can be justified and approved by DOE.

f. For sites containing facilities with SSCs in PC 3 or 4, a site-specific probabilistic wind hazard assessment is conducted to establish the wind speed for design and/or evaluation of the facilities.

3.2.2 Criteria for Site-Specific Probabilistic Wind Hazard Assessment

a. For facilities with SSCs in PC 3 or 4, a site-specific probabilistic wind hazard assessment is conducted to establish the wind speed.

b. The results of the probabilistic wind hazard assessment includes a mean wind hazard curve and other information regarding the uncertainty in the hazard assessment. The wind hazard curve represents the annual probability of exceedance as a function of wind speed at the site.

c. There are three types of winds: extreme (straight) wind, hurricane, and tornado. Extreme winds are non-rotating, such as those found in a thunderstorm gust front. Tornadoes and hurricanes both are rotating winds. The potential for all three types of winds shall be determined in the site wind hazard assessment.

d. For practical purposes, the effects of hurricanes are treated the same as those of straight winds in accordance with DOE-STD-1020-2002. As a result, both hurricane winds and straight winds will be represented by a single straight wind hazard curve although different wind hazard models are used for straight winds and hurricanes.

e. The site-specific probabilistic wind hazard assessment is characterized by the following traits:

(1) Probabilistic wind hazard assessments shall be performed for straight winds, hurricanes, and tornadoes.

(2) The wind hazard assessments for straight winds and hurricanes shall be combined to produce a single straight wind hazard curve by assuming the two types of winds are mutually exclusive events. A composite probability distribution may be used to assess probability of exceedance of wind speeds (Changery, 1985). It is recommended to use a Gumbel distribution (Coats and Murray, 1985) to model straight wind hazards and a Weibull distribution (Simiu and Scanlan, 1986) to model hurricane wind hazards.

(3) The wind hazard assessment for tornadoes shall be conducted in a manner consistent with the methodology described in Section A3.2.2.3.

(4) A transition wind speed is defined by the intersection point of the combined straight wind hazard curve and the tornado wind hazard curve.

(5) The combined straight wind hazard curve is used as the actual wind hazard curve for wind speed up to the transition wind speed while the tornado hazard curve is used as the actual wind hazard curve for wind speed above the transition wind speed.

(6) The transition wind speed also determines if other tornado effects (e.g., atmospheric pressure change (APC) and tornado missiles) need to be considered based on criteria specified in DOE-STD-1020-2002.

3.3 Detailed Requirements for Flood Hazard Assessment

3.3.1 General

a. Design and evaluation criteria for DOE facilities against flood hazards are provided by DOE-STD-1020-2002. In accordance with DOE-STD-1020-2002, a Design Basis Flood (DBFL) shall be established in order to carry out the design/evaluation process. The DBFL is a flood level determined from the mean flood hazard curve and the hazard annual probability of exceedance specified in DOE-STD-1020-2002. A probabilistic flood hazard assessment is required to develop the flood hazard curve at the site.

b. In accordance with Section 3.c, for sites containing facilities with SSCs in PC 3 or 4, a site-specific probabilistic flood hazard assessment is required. A site-specific probabilistic flood hazard assessment at a site shall involve the following two steps:

Step 1: Perform a flood screening analysis to evaluate the magnitude of flood hazards that may impact the SSCs under consideration. Specific criteria for a flood screening analysis are provided in Section 3.3.2 of this Standard.

Step 2: Perform a comprehensive flood hazard assessment, if needed, based on the results of the flood screening evaluation. Specific criteria for a comprehensive flood hazard assessment are provided in Section 3.3.3 of this Standard.

c. In accordance with Section 3.a, for sites containing facilities with SSCs in only PC 1 and 2 and having no existing site-specific probabilistic flood hazard assessment, it is sufficient to utilize flood insurance studies or equivalent to estimate the DBFL.

d. However, for sites containing facilities with SSCs in PC 2, a reduced-scope flood hazard assessment is generally required because most flood insurance studies available have not been conducted at a level which is compatible with the hazard annual probability of exceedance (5×10^{-4}) associated with PC 2 SSCs. A reduced-scope site-specific probabilistic flood assessment need contain only a flood screening analysis as specified in Section 3.3.2.

e. For sites which have site-specific flood hazard assessments, the SSCs in PCs 1 and 2 shall be evaluated or designed for the greater of the site-specific values, flood insurance studies, or equivalent unless lower site-specific values can be justified and are approved by DOE.

f. The flood hazard assessment shall consider all the phenomena that can cause flooding (e.g., river flooding, storm surge, dam failure). The identification of potential sources of flooding is addressed in Section A3.3.2.1. In addition, all sites must design a site drainage system to handle the runoff due to local precipitation.

g. If a site-specific flood hazard assessment is conducted, all effects of flooding, including submergence, waves and runups, debris, and hydrodynamic effects (e.g., peak flow velocity), shall be considered for each identified source of potential flooding.

h. For determination of the DBFL, the flood hazard assessment shall consider the possibility of simultaneous occurrence of flood events as specified in Section 3.3.4 of this Standard.

i. In completing a flood hazard assessment, it is extremely important that a site-specific data base be available. DOE-STD-1022-94 provides criteria for the types of data that shall be collected and compiled for such a data base.

3.3.2 Flood Screening Analysis

a. The objective of the flood screening analysis is to conduct a preliminary flood hazard assessment that identifies potential flood hazards including flood induced rise in ground water and to determine whether flooding can take place or whether the site can be considered a flood-dry site (ANS, 1987). A flood-dry site is defined as one where the structures are physically removed from the potential sources of flooding so that safety from flooding is obvious and can be documented with minimal effort.

b. In the case of flood-dry sites, the flood screening analysis will conclude that flooding is not a design basis event.

c. In the case of non-flood-dry sites, the flood screening analysis will provide a preliminary measure of the magnitude and probability of occurrence of extreme floods.

d. The flood screening analysis includes the following three steps:

Step 1: Identification of the sources of flooding.

Step 2: Evaluation of flooding potential.

Step 3: Preliminary flood hazard analysis.

e. Examples of acceptable previous flood screening analyses for 10 DOE sites are presented in McCann and Boissonnade (1988a, 1988b, and 1991) and summarized in Savy and Murray (1988). The elements comprising a flood screening analysis are further described in Appendix A.

3.3.3 Comprehensive Flood Hazard Assessment

a. Results of the flood screening analysis determine whether floods could impact DOE operations. For sites that could be exposed to flooding and do not meet the design basis, a comprehensive flood hazard analysis is required. The need to perform a site comprehensive hazard assessment depends on the potential DBFL impact on the facilities for the flood hazard exceedance probabilities. Guidelines to evaluate these impacts are provided in DOE-STD-1020-2002. These guidelines recommend the design basis for DOE facilities based on the following factors:

(1) Types of potential flood hazard

(2) Performance Category

(3) Reliability of flood protection devices

(4) Acceptable level of risk.

b. The flood hazard is defined in terms of the annual probable frequency of exceeding specified elevations. All uncertainties in estimating flood levels shall be propagated in the flood hazard analysis.

c. A comprehensive flood hazard assessment shall consider detailed meteorologic, hydrologic, and hydraulic assessments of the potential flood hazards determined by the flood screening and an evaluation of the reliability of flood protection systems (e.g., dams, levees), if present. This includes:

(1) Estimation of rainfall and snowfall frequency in watersheds.

(2) Overland flow assessment due to precipitation (Crawford and Kinsley, 1966).

(3) Hydrologic modeling of watershed responses using validated models (IACWD, 1986) and (U.S. Army Corps of Engineers, 1986).

(4) Assessment of discharge (flow rates) and flood elevations using detailed hydraulic modeling techniques, e.g., HEC (1986).

(5) Estimation of joint natural hazard events frequency. For example, a joint probability analysis shall be performed to assess surge level frequencies (Ho, et al., 1987).

(6) Assessment of the likelihood of upstream dams and levees failures. All causes of dam failures should be accounted for (McCann and Boissonnade, 1988b).

(7) Assessment of the uncertainty due to the limited data for estimating model parameters, the modeling of physical processes, and interpretation of the available data.

d. A full-scope probabilistic approach to model river flooding shall include temporal and spatial frequency estimates of the random meteorological parameters that contribute to precipitation and runoff and an estimate of the modeling uncertainty of the watersheds (NRC, 1988).

e. Three of the acceptable approaches are available to evaluate the frequency of extreme flows and/or levels due to hydrologic events (NRC, 1988) and (IACWD, 1986) are:

(1) statistical methods

(2) probabilistic hydrologic modeling (including, Bayesian analysis, joint probability methods, etc.)

(3) paleohydrologic analysis (i.e., evaluating ancient evidence using age dating techniques to deduce early extreme hydrologic events).

f. The causes of dam failure to be evaluated include: hydrologic, seismic, hydrostatic, operation error, random structural failure, upstream dams, and landslides (McCann and Boissonnade, 1988b).

g. Dam failure-induced flood levels shall be determined by analyses using validated dam break models (Fread, 1984). Uncertainty for the dam break model analysis parameters (e.g., breach size, time to failure, flood time arrival) shall be accounted for in the analysis (McCann and Boissonnade, 1988b).

h. Simplified dam failure analysis is acceptable (McCann, et al., 1985) if the analysis accounts for uncertainty.

3.3.4 Flood Event Combinations

a. For each primary potential flood source, the DBFL shall consider several event combination cases as specified below:

(1) River Flooding:	Case 1: Peak flood elevation due to all flooding contributors with the exception of upstream dam failure.
	Case 2: Wind-waves corresponding to winds acting in the most favorable direction and Case 1. The wind should be determined from a probabilistic analysis that considers the joint occurrence of river flooding and wind generated waves and as a minimum corresponds to the 2-year wind.
	Case 3: Ice or debris forces (static and dynamic) and Case 1.
	Case 4: Peak and ground water level and Case 1.
(2) Levee/Dam Failure:	Case 1: Peak flood elevation due to all modes of failure (i.e., overtopping, seismically or landslide induced, random structural failure, upstream dam failure, debris or ice dam failure, etc.)
	Case 2: Wind-waves corresponding to winds acting in the most favorable direction and Case 1. The wind should be determined from a probabilistic analysis that considers the joint occurrence of dam failure and wind generated waves and as a minimum correspond to the 2-year wind.
(3) Storm Surge/Seiche:	Case 1: Peak flood levels plus mean high tide levels.
	Case 2: Surge-associated waves and Case 1.
(4) Tsunami:	Tsunami-tide effects corresponding to the mean high tide level.

(5) Local Precipitation: Case 1: Peak flood based on runoff analysis due to rain and snow melting.

Case 2: Ponding on roof.

Case 3: Peak ground water level and Case 1.

b. If the hazard annual probability of exceedance for a primary potential flood source is less than the maximum annual flood hazard exceedance probabilities acceptable for the PC, it need not be considered.

c. The combination of the potential flood sources is assumed to be perfectly correlated for the purpose of developing flood hazard curves.

3.3.5 Historical Flood Check

a. In assessing the conservatism in the proposed DBFL, the review will consider historical flooding that may have affected the site and ensure that the proposed DBFL conservatively accounts for a recurrence of the event causing the flooding. Since the hydraulic characteristics of the basin might have changed since the maximum historical flood, the flood level itself may not be able to form a direct comparison to the DBFL. Rather, the amount of water produced, or the rainfall intensity and distribution, should be compared to the event leading to the DBFL. For PC-3 and PC-4 facilities, the DBFL event should be equal to or greater than the maximum historical event in the basin.

4. REFERENCES

American Nuclear Society (ANS) (1987), "American National Standard for Determining Design Basis Flooding at Power Reactor Sites," ANSI/ANS-2.8, La Grange Park, Illinois.

American Society of Civil Engineers (ASCE) (1998a), ASCE Standard, "Minimum Design Loads for Buildings and Other Structures," ANSI/ASCE 7-98.

American Society of Civil Engineers (ASCE), (1998b), "Seismic Analysis of Safety Related Nuclear Structures and Commentary," ASCE 4-98.

Applied Technology Council (ATC) (1984), "Tentative Provisions for the Development of Seismic Regulations for Buildings," April, 1984.

Batts, M.E. et al. (1980), "Hurricane Wind Speeds in the United States," NBS Building Science Series 124, U.S. Department of Commerce, Washington, D.C.

Bernreuter, D.L., et al. (1989), "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, Lawrence Livermore National Laboratory, Livermore, CA.

Boissonade, Auguste, et. al., "Development of a Probabilistic Tornado Wind Hazard Model for the Continental United States, July 2000, UCRL-ID-140922, Volume I.

Building Seismic Safety Council (BSSC) (1988), "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA 96, October 1988.

Building Seismic Safety Council (BSSC) (2000) "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings and Other Structures," FEMA 368.

Changery, M. J. (1981), "National Thunderstorm Frequencies for the Contiguous United States," NUREG/CR-2252, National Climatic Center, National Oceanic and Atmospheric Administration (NOAA), November, 1981.

Changery, M.J. (1985), "Historical Extreme Winds for the United States - Atlantic and Gulf of Mexico Coastlines," U.S. Nuclear Regulatory Commission, NUREG/CR-2639.

Coats, D.W. and R.C. Murray (1985), "Natural Phenomena Hazards Modeling Project: Extreme Wind/tornado Hazard Models for Department of Energy Sites," Lawrence Livermore National Laboratory, UCRL-53526, Rev. 1.

Cornell, C.A. (1968), "Engineering Seismic Risk Analysis," Bulletin of the Seismological Society of America V. 58, p 1583-1606.

Crawford, N.H. and R.K. Linsley (1966), "Digital Simulation in Hydrology: Stanford Watershed Model IV," Department of Civil Engineering, Technical Report No. 39, Stanford University, July, 1966.

Electric Power Research Institute (EPRI) (1989a), "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plants Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," NP-6395-D.

Electric Power Research Institute (EPRI) (1989b), "Lower-Bound Magnitude for Probabilistic Seismic Hazard Assessment," EPRI NP-6496. Final Report prepared by Jack R. Benjamin and Associates, Inc., Mountain View, California.

Fread, D.L. (1984), "The NWS DAM-BREAK Flood Forecasting Model," Office of Hydrology, National Weather Service, Silver Spring, Maryland.

Haan, C.T. et al. (1982), "Hydrologic Modeling of Small Watersheds," American Society of Agricultural Engineers.

Heaton, T.H., et al. (1986), "Estimating Ground Motions Using Recorded Accelerograms," Surveys in Geophysics, V. 8, p 25.

Ho, F.P., et al. (1987), "Hurricane Climatology for the Atlantic and Gulf Coast of the United States," NOAA Technical Report NWS38, National Weather Service, April 1987.

Hydrologic Engineering Center (HEC) (1986), "HEC-1 and HEC-2, Users Manual," Water Resources Support Center, Corps of Engineers, U.S. Army, Davis, California.

Interagency Advisory Committee on Water Data (IACWD) (1986), "Feasibility of Assigning a Probability to the Probable Maximum Flood," Office of Water Data Coordination.

International Building Council, IBC 2000, International Building Code.

Kiremidjian, A.S. and H.C. Shah (1980), "Probabilistic Site-Dependent Response Spectra," Journal of the Structural Division, Proceedings of the ASCE, Vol. 106, No. ST1, January 1980, pp. 69-86.

Kite, G.W. (1988), "Frequency and Risk Analyses in Hydrology," Water Resources Publications, Colorado.

MacGorman, D.R., Maier, M.W., and Rust, W.D. (1984), "Lightning Strike Density for the Contiguous United States from Thunderstorm Duration Records," NUREG/CR-3759, U. S. National Severe Storms Laboratory, National Oceanic and Atmospheric Administration (NOAA), Norman, OK, May, 1984.

McCann, M.W., et al. (1985), "Guidelines for Probabilistic Assessment of Dams," Workshop Notes, Stanford University.

McCann, M.W. and A.C. Boissonnade (1988a), "Preliminary Flood Hazard Estimates for Screening Department of Energy Sites," Lawrence Livermore National Laboratory, UCRL-21045.

McCann, M.W. and A.C. Boissonnade (1988b), “Probabilistic Flood Hazard Assessment for the N Reactor, Hanford, Washington,” Lawrence Livermore National Laboratory, UCRL-21069.

McCann, M.W. and A.C. Boissonnade (1991), “Flood Hazard Evaluation for the Department of Energy New Production Reactor Site - Idaho National Engineering Laboratory,” Prepared for Office of New Production Reactors, United States Department of Energy, Prepared for Lawrence Livermore National Laboratory, Jack R. Benjamin and Associates, Inc., July 1991.

McGuire, et. al., 2001, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard and Risk Consistent Ground Motion Spectra Guidelines,” NUREG/CR-6728.

Mohraz, B. (1976), "A Study of Earthquake Response Spectra for Different Geological Conditions," Bulletin of the Seismological Society of America, V 66, No. 3, p 915-935.

National Research Council (NRC) (1988), “Estimating Probabilities of Extreme Floods, Methods and Recommended Research,” Committee on Techniques for Estimating Probabilities of Extreme Floods, National Academy Press, Washington, D.C.

Newmark, N.M. and W.J. Hall (1978), “Development of Criteria for Seismic Review of Selected Nuclear Power Plants,” NUREG/CR-0098, U.S. Nuclear Regulatory Commission, May 1978.

Ramsdell, J.V., Elliott, D.L., Holladay, C.D., and Hubbee, J. M. (1986), “Methodology for Estimating Extreme Winds for PRAs,” NUREG/CR-4492, Pacific Northwest Laboratory, Richland, WA.

Savy, J.B., et al. (1993), “Eastern Seismic Hazard Characterization Update,” UCRL-ID-115111, Lawrence Livermore National Laboratory, CA, June, 1993.

Savy, J.B. (1994), “Seismic Hazard Characterization at the DOE Savannah River Site (SRS) - Status Report,” UCRL-ID-117452, Lawrence Livermore National Laboratory, Livermore, CA, June, 1994.

Savy, J.B. and Murray, R.C. (1988), “Natural Phenomena Hazards Modeling Project: Flood Hazards Models for Department of Energy Sites,” UCRL-53851, Lawrence Livermore National Laboratory, Livermore, CA.

Seed, H.B., et al. (1974), “Site-Dependent Spectra for Earthquake Resistant Design,” Report No. EERC 74-12, University of California, Berkeley.

Senior Seismic Hazard Analysis Committee (SSHAC) (1997), “Recommendation for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts,” NUREG/CR-6372.

Simiu, E. and Scanlan, R.H. (1986), “Wind Effects on Structures,” Second Edition, John Wiley and Sons, New York, NY.

Sobel, P. (1994), “Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains,” NUREG-1488, USNRC, April, 1994.

U.S. Army Corps of Engineers (1984), "Shore Protection Manual, Volumes 1 and 2," Coastal Engineering Research Center, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi.

U.S. Army Corps of Engineers (1986), "User Manual, SSARR, Model Streamflow Synthesis and Reservoir Regulation," U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

U.S. Department of Energy, DOE G 420.1-2, "Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear and Non-nuclear Facilities," March 2000.

U.S. Department of Energy, "Facility Safety," DOE O 420.1, CHG 3 November, 2000.

U.S. Department of Energy, "Performance Categorization Criteria for Structures, Systems, and Components at DOE Facilities Subjected to Natural Phenomena Hazards," DOE-STD-1021-93, July 1993.

U.S. Department of Energy, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," DOE-STD-1020-2002.

U.S. Department of Energy, "Natural Phenomena Hazards Site Characterization Criteria," DOE-STD-1022-94, March 1994.

U.S. Department of Interior (1982), "Guidelines for Determining Flood Flow Frequency," Interagency Advisory Committee on Water Data, Bulletin #17B of the Hydrology Subcommittee, Reston, Virginia.

U. S. Geological Survey (1996), "National Seismic Hazard Maps: Documentation," June 1996, Open File Report 96-532.

U. S. Geological Survey (2001) , "Seismic Hazard Curves and Uniform Hazard Response Spectra for the United States," CD ROM, Open File Report 01-436.

U.S. Nuclear Regulatory Commission (USNRC) (1978), "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," NUREG-0800, June, 1978.

U.S. Nuclear Regulatory Commission (USNRC) (1989), "Severe Accident Risk: An Assessment for Five U.S. Nuclear Plants," NUREG/CR-1150.

U. S. Nuclear Regulatory Commission (USNRC) (1997), Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion."

5. DEFINITIONS

Annual Flood The maximum instantaneous peak discharge or level of flood in each year of record.

Atmospheric Pressure Change (APC) A wind hazard design parameter consisting of a reduction in atmospheric pressure generated by a tornado.

Backwater Effect The rise in water surface elevation in an area caused by an obstruction which limits the water flow from the area.

Basic Wind Speed The wind hazard design parameter used to determine wind pressure on buildings or other facilities.

Basin, Watershed The total area from which surface runoff is carried away by a drainage system.

Deaggregate Determine the fractional contribution of each magnitude-distance pair to the total seismic hazard. To accomplish this, a set of magnitude and distance bins are selected and the annual probability of exceeding selected ground acceleration parameters from each magnitude-distance pair is computed and divided by the total probability.

Design Basis Flood (DBFL) The peak flood level derived from the mean flood hazard curve in accordance with the annual probability of hazard exceedance associated with the SSC. The DBFL is used to design or evaluate SSCs of DOE facilities subjected to flood hazards.

Design/Evaluation Basis Earthquake (DBE) A specification of the mean seismic ground motion at a site; used for the earthquake-resistant design of structures, systems, and components. The DBE is defined by ground motion parameters determined from mean seismic hazard curves and a design response spectrum shape.

Design Basis NPH Event The NPH event used as a basis for the design and/or evaluation of SSCs at DOE facilities. The design/evaluation basis NPH event is called the design/evaluation basis earthquake (DBE) for seismic hazards, design basis flood (DBFL) for flood hazards, or recommended basic wind speed for wind hazards.

Design Response Spectrum A smoothed and broadened response spectrum (compared to a response spectrum associated with any single actual earthquake) used for design purposes. See also the definition of response spectrum in this Section.

Deterministic Method A technique which uses single values of parameters to perform an analysis. Distributions of parameters caused by uncertainty or randomness are not explicitly considered. To account for uncertainty, several evaluations may be conducted with different parameters.

Earthquake A sudden motion or vibration in the earth caused by the abrupt release of energy in the earth's crust (lithosphere).

Facility One or more building(s) or structure(s), including systems and components, dedicated to a common function (includes operating and non-operating facilities and facilities slated for decontamination and decommissioning).

Flood Hazard Boundary Map An official map of a community issued by the Federal Insurance Administration on which the boundaries of the flood plain, mud slide, and/or flood-related erosion areas having special hazards have been drawn.

Flood Hazard Curve A frequency plot that characterizes the flood hazard at a specific site by giving the return period or annual probability of exceedance as a function of the flood level at the site. The mean flood hazard curve is used to determine the design basis flood (DBFL).

Graded Approach An approach in which SSCs are placed into performance categories such that the required level of analysis, documentation, and actions are commensurate with:

(1) The relative importance to safety, safeguards, the environment, and security;

(2) The expected magnitude of any hazard involved;

(3) The life cycle stage of the facility;

(4) The programmatic mission of a facility;

(5) The particular characteristics of the SSCs; and

(6) The cost and replaceability of the SSCs.

Hydrodynamic Loads Dynamic fluid forces imposed on structures by the impact of moving fluid, including floodwater.

Hydrostatic Loads Static fluid forces imposed on structures due to the pressure of contained and surrounding fluids, including flood water.

Model Building Codes Published documents that contain design and construction requirements applicable to normal commercial buildings. Examples are International Building Code, (IBC 2000).

Natural Phenomena Hazard (NPH) An act of nature (for example: earthquake, wind, hurricane, tornado, flood, volcanic eruption, lightning strike, forest fire, snow, or extreme cold) which poses a threat or danger to workers, the public, or to the environment by potential damage to structures, systems, and components (SSCs).

Natural Phenomena Hazard Curve A frequency plot that characterizes the likelihood of occurrence of a natural phenomena hazard at a specific site by giving the return period or annual probability of exceedance as a function of a parameter used to characterize the level of the natural phenomena hazard. The mean NPH curve is used to determine the design basis NPH event.

Near-Field A region within 15 km (9.3 mi) of a seismic source.

NPH Mitigation An action taken to reduce the impacts of natural phenomena hazards (to become less harsh or hostile to workers, the public, facilities, and the environment). This includes NPH resistant design, evaluation, construction requirements, and operational procedures.

One-(Five-)Hundred-Year Flood A flood level which will be equaled or exceeded with a 1.0 (0.2) percent chance in any given year.

Overland Runoff The portion of precipitation which is not absorbed or evaporated and which flows overland into depressions, lakes, rivers, or oceans.

Peak Flow The maximum flow rate that occurs during a flood event.

Peak Ground Acceleration (PGA) The largest ground acceleration produced by an earthquake at a site. Unless otherwise noted, it usually refers to the horizontal ground motion, i.e., the average of the two largest horizontal acceleration components of the earthquake ground motion at a site. The peak ground acceleration, the peak ground velocity (PGV), and the peak ground displacement (PGD) are parameters customarily used to characterize the level of earthquake ground motion.

Peak Ground Displacement (PGD) The largest ground displacements produced by an earthquake at a site.

Peak Ground Velocity (PGV) The largest ground velocity produced by an earthquake at a site.

Performance Category (PC) A classification using a graded approach in which structures, systems, or components in a category are designed to assure similar levels of protection (i.e., meet the same performance goal) during natural phenomena hazard events.

Performance Goal The mean annual probability of exceedance of acceptable behavior limits used as a target to develop natural phenomena hazard mitigation requirements as specified in DOE-STD-1020-2002.

Probabilistic Method A technique which uses distributions of parameters (including uncertainty and randomness) to perform an analysis. Results are expressed in terms of probabilistic distributions which quantify uncertainty.

Probability of Exceedance The probability that a specified level of hazard occurrences or specified social or economic consequences of NPHs, will be exceeded at a site or in a region during a specified exposure time.

Response Spectrum A curve calculated from an earthquake accelerogram that gives the value of peak response in terms of acceleration, velocity, or displacement of a damped linear oscillator (with a given damping ratio) as a function of its period (or frequency) of vibration. For design purposes, a set of response spectra are usually generated for different damping ratios.

Seiche A cyclic oscillation or sloshing of a lake or large body of water due to the effect of winds, seismic forces, and/or atmospheric pressure.

Seismic Hazard One form of natural phenomena hazards caused by earthquakes. The primary effect of the seismic hazard is earthquake ground shaking. Other effects associated with the seismic hazard include differential ground deformation induced by fault displacement, liquefaction, and seismic induced slope instability and ground settlement.

Seismic Hazard Curve (SHC) A frequency of occurrence plot that characterizes the seismic hazard at a specific site by giving the return period or annual probability of exceedance as a function of the peak ground acceleration (PGA) or any other ground motion parameter; e.g., PGV, PGD, or average spectral acceleration, used to characterize the level of earthquake ground motion at the site. The mean seismic hazard curve is used to determine the DBE.

Seismic Sources Portions of the earth that have a potential for abrupt releases of energy in the earth's crust (lithosphere), or to cause earthquakes. Seismic sources may include a region of diffuse seismicity (seismotectonic province) and/or a well-defined tectonic structure which can generate both earthquakes and ground deformation.

Site The area with one or more DOE facilities or activities that can be represented by the same natural phenomena hazard potential with local conditions that can be represented by the same parameters.

Stage Elevation above some arbitrary zero datum of the water surface at a gauging station.

Stage-Discharge Relation (Rating Curve) Relationship giving the discharge for each stage value.

Storm Surge A rise in water surface level above the normal level on a lake or ocean, produced by wind and/or differences in atmospheric pressure during a storm.

Structures, Systems, and Components (SSCs) A structure is an element, or a collection of elements to provide support or enclosure. A component is an item of equipment such as a pump, valve, relay, etc., or an element of a larger array, such as a length of pipe, elbow, reducer, etc. A system is a collection of components assembled to perform a function.

Transition Wind Speed The intersection point of the wind hazard curve based on a straight wind model and the wind hazard curve based on a tornado model.

Tsunami A long period ocean wave caused by an underwater disturbance such as an underwater earthquake, landslide, or volcanic eruption.

Water Surface Elevation The elevation, usually in relation to mean sea level or National Geodetic Vertical Datum, reached by floods of various magnitudes.

Wind Hazard Curve A frequency plot which gives the basic wind speed as a function of the return period or annual probability of exceedance. The mean wind hazard curve shall be used to determine the basic wind speed for the design and/or evaluation of DOE facilities.

Windborne Missiles Wind hazard design parameters referring to debris transported by tornadoes and other types of winds.

6. ACRONYMS

ASCE-	American Society of Civil Engineers
APC -	Atmospheric Pressure Change
ATC -	Applied Technology Council
BSSC -	Building Seismic Safety Council
DBE -	Design/Evaluation Basis Earthquake
DBFL -	Design Basis Flood
DOE -	Department of Energy
ES&H -	Environment, Safety, and Health
EPRI -	Electric Power Research Institute
FEMA -	Federal Emergency Management Agency
HEC -	Hydrologic Engineering Center
IACWD -	Interagency Advisory Committee on Water Data
LLNL -	Lawrence Livermore National Laboratory
NEHRP -	National Earthquake Hazards Reduction Program
NPH -	Natural Phenomena Hazard
NRC -	National Research Council, also Nuclear Regulatory Commission (Referenced as USNRC)
PC -	Performance Category
PGA -	Peak Ground Acceleration
PGD -	Peak Ground Displacement
PGV -	Peak Ground Velocity
PSHA -	Probabilistic Seismic Hazard Assessment
PSV -	Pseudo (response) Spectra Velocity
SHC -	Seismic Hazard Curve
SSCs -	Structures, Systems, and Components
SSHAC -	Senior Seismic Hazard Analysis Committee
UHS -	Uniform Hazard (response) Spectra

APPENDIX A - Guidelines for Acceptable Methods to Meet NPH Acceptance Criteria

Appendix A provides additional guidance on acceptable methods, approaches, and references related to NPH assessment criteria. The section numbers in Appendix A correspond to the exact section numbers in the main section of the standard, when additional guidance is provided.

A1-j As an example of the type of data available for other hazards, there are studies commissioned by the USNRC for nuclear power plant evaluation which may be applicable to DOE facilities. See, for example, MacGorman, et al. (1984) and Changery (1981) for data applicable to lightning hazard definition.

A3.1.1-d. While not a formal part of the seismic hazard assessment, other earthquake-induced ground failure modes should also be considered during site characterization and modeling, such as potential for liquefaction, slope instability, lateral spreading, or subsidence. If such potential is found, it should be noted in the assessment report.

A3.1.2.1-a. When the mean hazard curves from EPRI (1989a) and LLNL (Savy, et al., 1993 and Sobel, 1994) are directly averaged, the average should be based on averaging the mean annual probabilities at a given peak acceleration or spectral acceleration, computing the average at enough ground motion values to draw the entire hazard curve.

A3.1.2.2-c For sites with facilities in PC 3 or less, a simplified PSHA is acceptable. Simplifications are not in the methodology itself, but rather in the extent to which the general principles of the methodology are fulfilled. In practice, the simplification is obtained by reducing the effort of new data collection, reducing the number of experts elicited or the level of peer review and by reducing the sampling and testing in the geotechnical field for the site-specific characterization (see SSHAC, 1997).

The following elements shall be included in the methodology to conduct a new PSHA: (1) Basic Hazard Model; (2) Data Used in the Hazard Modeling; (3) Characterization of Uncertainty in Parameters of the Hazard Model; and (4) Quantifying Uncertainty. Each of these elements is discussed below.

Basic Hazard Model

At a given site, the hazard function SH(g) is defined by the probability $P(G \geq g)$ that the ground motion parameter G, e.g., the PGA or the pseudo response spectral velocity (PSV), exceeds some value g in t years for all earthquakes greater than a value M_o contributing to the hazard, i.e.,

$$SH(g) = P\,(G \geq g, \text{ for } m \geq M_o).$$

For well-engineered structures (built to modern seismic standards) such as commercial nuclear power plants, a lower bound magnitude (M_o) of 5 shall be used (EPRI, 1989b). For those DOE facilities which cannot be classified as built to modern seismic standards, such is not necessarily the case and the analyst should provide estimates of the hazard for $M_o = 5$ and M_o

= 4.6, consistent with the lower bound used for national seismic hazard maps, e.g. BSSC (1988).

The hazard model is developed by examining characteristics of seismic sources and their contribution to the seismic hazard of the site (Cornell 1968). For a detailed description of acceptable methodologies, see SSHAC (1997).

The following discussion summarizes the four standard steps in the methodologies.

Step 1: A zonation map is developed (with possibly additional information on the spatial distribution of earthquakes in any given zone). The zonation is a partition of the entire area of interest into independent seismic source zones. Each zone is assumed to be a unique source of earthquakes and to have its own recurrence distribution. A zone can be described by an area or a fault (such as for western U. S. Sites).

Step 2: The recurrence (frequency-magnitude distribution) is defined for each zone. This step quantifies the total number of earthquakes greater than magnitude M_o expected to occur during the period of interest (usually one year), and it describes the relative frequency of all the magnitudes greater than M_o. An upper bound (maximum) magnitude is defined for each recurrence distribution.

Step 3: The ground motion model provides the probability that g is exceeded at the site (at a hypothetical rock outcrop) when an earthquake of magnitude m has occurred at a given location. Usually, the direction of the origin of the earthquake is neglected and only the distance r to the site is considered in the ground motion modeling:

$$P\ (G \geq g, \text{ for given m and r}).$$

The measure of the source-to-site distance may vary depending upon the procedure used to estimate earthquake attenuation effects.

For a site where the ground motion model is not specifically applicable to the local geology, a site response evaluation should be completed. The site response evaluation should consider field investigations, sampling, and testing as described in DOE-STD-1022-94.

The site correction should be applied consistent with McGuire, et. al. (2001).

Step 4: The hazard curve SH(g) is calculated by integrating the effects of all possible earthquake locations and all possible earthquakes with magnitudes greater than M_o occurring within all seismic source zones. The seismic hazard curve expresses the annual frequency of exceeding particular ground motion levels.

Role of Data

A wide range of earth sciences (geologic, geophysical, and seismologic) data are considered when conducting a seismic hazard analysis. DOE-STD-1022-94 discusses the manner in which these types of data are used to characterize seismic sources and to evaluate ground

motions. The extent to which particular data sets have been gathered in the site region and immediate site vicinity will have a direct impact on the uncertainties in the seismic hazard analysis. In cases where significant uncertainties exist regarding seismic sources or site-specific conditions important to ground motions, additional data may need to be gathered to reduce uncertainties in the site-specific seismic hazard analysis.

Because the development of the basic inputs to seismic hazard analysis requires interpretations of data to develop models and parameter values, there is commonly a considerable range of possible interpretations for any particular data set. For example, for a site in the eastern United States, experts will make variable use of available geophysical data, tectonic information, and historical seismicity data to define the configurations of seismic source zones. Likewise, the available data pertinent to earthquake recurrence rates and maximum magnitudes for the seismic sources will likely allow a range of permissible interpretations.

Seismic hazard analysts should take great care that the models and parameters are consistent with the data, which include all physical information (geophysical, geological, and geotechnical data, etc.) and historical data (earthquake catalogs). Models and hypotheses seemingly in disagreement with data (for example, a recurrence model that predicts recurrence rates several times higher than the empirical data) should be explained. All models and information provided should be thoroughly documented so that an independent party could review the study and understand the manner in which the data have been used to support the seismic hazard interpretations.

Uncertainty in Hazard

Probabilistic seismic hazard analysis incorporates the random variability in the location, size, and ground motions associated with future earthquakes. In addition to this random variability, there is also a component of uncertainty related to lack of knowledge of the models and parameters that characterize the seismic hazard. For example, alternative seismic source maps could be developed, uncertainties in recurrence parameters can be quantified, and alternative ground motion attenuation relationships can be identified. These uncertainties result in a distribution of seismic hazard curves, from which the median (50th percentile) or mean seismic hazard curve may be selected. The mean seismic hazard curve is usually quite sensitive to uncertainties and, therefore, full inclusion of uncertainties in the seismic hazard analysis is necessary.

Two equally-permissible approaches can be used to quantify and propagate uncertainties in models and parameter values: the logic tree approach and the Monte Carlo simulation approach (see SSHAC, 1997). In the logic tree approach, alternative models and alternative parameter values are identified and a relative weight is assigned to each alternative that expresses the relative credibility of that alternative in light of the available data. Elements of the logic tree are sequenced to provide for a logical progression in the assessment from general elements to more specific elements. In the simulation approach, uncertainties in inputs are characterized by continuous distributions, and multiple simulations are run to sample from the distributions. Both approaches have common application in seismic hazard analysis and lead to reliable estimates of mean hazard.

Studies of the results of past hazard analyses have shown that care needs to be taken in accounting for the possible correlation of uncertainties in some input parameters. For example, the correlations in uncertainties in a-values and b-values in earthquake recurrence relationships need to be considered (SSHAC, 1997).

Quantifying Uncertainty

Detailed recommendations for the application of expert elicitation and peer review are contained in SSHAC (1997).

Because the models and parameters of seismic hazard analysis are not known with certainty, hazard assessments should be designed to quantify not only the central tendencies but also uncertainties. Two approaches are acceptable for characterizing and quantifying uncertainties in PSHA: elicitation of multiple experts and peer review (the approaches can be used separately or together). In the first approach, the judgments of multiple experts are elicited regarding the elements of seismic sources and ground motion attenuation. The goal is to assess the uncertainties for any given expert and the range of diversity of interpretations among multiple experts.

A second approach to quantifying uncertainties consists of a single analyst or contractor (such as a consulting company) conducting a seismic hazard analysis and subjecting the study to peer review by an independent panel of experts. The peer review should include review of the process as well as the inputs. The hazard analyst should strive to incorporate the range of scientific interpretations and the peer reviewers should ensure that all reasonable interpretations have been considered. Multiple cycles of peer review, focusing on particular components of the analysis, are often needed to allow for modification and updating of the inputs.

An important aspect of uncertainty characterization is documentation. Regardless of whether the expert elicitation or the peer review procedure is used, the technical basis for all assessments must be documented in a form suitable for third party review. For example, a seismic source map must be supported by a written description of the basis for the source boundaries in terms of evaluations of geologic, geophysical, and seismicity data. Likewise, the basis for alternative source maps must be documented. One purpose of the documentation is to provide a mechanism to examine the impact that new data and interpretations may have on the interpretations as new studies are conducted or new findings are made. For example, a potentially important consideration might be the occurrence of a moderate to large earthquake in the region of a site after the seismic hazard analysis has been completed. The location of the event and its magnitude can be compared with the sources considered in the analysis and the magnitude of earthquakes that were modeled for the source. Likewise, the level of recorded ground motions for the event can be compared with the levels predicted in the seismic hazard analysis. For additional guidance on the content and amount of documentation to support PSHAs, SSHAC (1997) should be consulted.

A3.1.3.1-a. The development of site-specific spectral shapes for PC 3 SSCs may be relatively less rigorous than those in PC 4. For example, the treatment of degradation and uncertainty in soil properties in site response analysis may be made by using generic characteristics rather

than using data from site-specific tests. The bounding limits of magnitudes and distances for collecting data may also be reduced.

A3.1.3.1-b. An acceptable approach for the development of site-specific DBE response spectra includes the steps summarized below:

Step 1: From the site-specific probabilistic seismic hazard analysis results, use the mean seismic hazard curve showing the annual probability of exceedance as a function of the S_A (for additional guidance on this and subsequent steps, see USNRC, 1997 Regulatory Guide 1.165). It is recommended that, as part of the information database, the following deaggregation procedure also be applied to median hazard results.

Step 2: Using the appropriate annual probability of exceedance value, P_H (e.g., $1x10^{-4}$ for PC 4), enter the hazard curve from Step 1 at P_H to determine the corresponding S_A.

Step 3: Deaggregate the mean S_A seismic hazard curve as a function of magnitude and distance and calculate the contribution to this hazard curve for all of the earthquakes in a selected earthquake magnitude and distance set (size M x N) to determine the relative contribution to the hazard. This requires the calculation of the annual probability of exceedance, $H(m_i,r_j)$, for each magnitude/distance bin: magnitude m_i (i =1,2,..,M) and distance r_j, (j =1,2,...,N).

Step 4: Compute the magnitude of the controlling earthquake for the mean estimates of $S_{A\,(5\text{-}10)}$ using the contributions $H(m_i, r_j)$ computed in Step 3 in accordance with the following (or similar) equation:

$$M(1) = \sum_{i=1}^{M} \sum_{j=1}^{N} m_i H(m_i,r_j) \Big/ \sum_{i=1}^{M} \sum_{j=1}^{N} H(m_i,r_j)$$

The distance of the controlling earthquake from the site is next determined from the following (or similar) equation:

$$\log R(1) = \sum_{i=1}^{M} \sum_{j=1}^{N} \log(r_j)\, H(m_i, r_j) \Big/ \sum_{i=1}^{M} \sum_{j=1}^{N} H(m_i, r_j)$$

Step 5: Select, from the site-specific PSHA results, the mean seismic hazard curve for the ground motion parameter $S_{A(1\text{-}2.5)}$, i.e., the average spectral acceleration at 1 and 2.5 Hertz, and use the same P_H and Steps 1 through 4 as above to determine the magnitude m(2) and distance r(2) that control the $S_{A(1\text{-}2.5)}$.

Step 6: Develop the median normalized response spectrum shape for m(1):r(1) and**,** if necessary, m(2):r(2). Acceptable methods are described after Step 8.

Step 7: Scale the normalized median spectrum shape for m(1):r(1) to the mean $S_{A\ (5\text{-}10)}$ with the appropriate annual probability (e.g., $1\text{x}10^{-4}$ for sites not located near tectonic plate boundaries, containing facilities with SSCs in PC 4).

Step 8: Determine if the scaled spectrum shape for m(1): r(1) envelops the 1 to 2.5 Hz region of the m(2): r (2) spectrum shape. If not, envelop the two resulting spectra to create a single response spectrum. The engineer/designer shall either use the above single envelope spectrum or analyze twice, one for each m:r combination, and use the more conservative result for design purposes. It is intended that the resulting envelope will be a smooth, broad spectrum without significant gaps in spectral ordinates when compared to the mean UHS.

After the controlling earthquake magnitudes and distances are determined, the site specific response spectra shapes are developed by any combination of the following methods:

(1) Statistical analysis of ground motion records

The median response spectrum shape is derived from a suite of actual ground motion records judged associated with site similar magnitudes, distances, and soil profiles. When a sufficient amount of suitable ground motion records is not available, the response spectrum shape may be approximated by scaling in accordance with the method suggested by Heaton, et. al. (1986).

(2) Attenuation of spectral ordinates

The median response spectrum shape is derived from regression equations defining median spectral amplifications at various natural frequencies as a function of magnitude, distance, and site soil profile. Recent data shall be used when available.

(3) Numerical modeling

The median response spectrum shape is calculated from numerical models such as band-width-limited-white-noise/random vibration theory models benchmarked against response spectra from actual ground motion records associated with magnitudes, distances, and soil profiles as similar to those of the site under study. For this method, the input parameters, the numerical model used, and the validation of the appropriateness of the model shall be documented.

A3.1.3.2-a. As an example, the procedure for constructing a standardized DBE response spectrum based on Newmark and Hall (1978), using the authors' original units, is summarized below:

(1) Determine the horizontal ground motion parameters: PGA, PGV, and PGD.

a. Obtain the design basis mean peak ground acceleration (PGA) in units of "g" based on a site specific probabilistic seismic hazard assessment.

b. For a competent alluvium site with V_s (shear wave velocity) < 3500 ft/sec, determine the peak ground velocity (PGV) in "in/sec" and peak ground displacement (PGD) in "in" by the following formulas:

$$PGV = 48\ PGA$$
$$PGD = 36\ PGA$$

c. For a rock site with V_s > 3500 ft/sec, determine PGV and PGD by the following formulas:

$$PGV = 36\ PGA$$
$$PGD = 20\ PGA$$

(2) Determine the maximum amplified response acceleration (a_{max}), velocity (v_{max}), and displacement (d_{max}) for median spectra (50th percentile):

$$a_{max} = PGA\ (3.21 - 0.68 \ln ß)$$
$$v_{max} = PGV\ (2.31 - 0.41 \ln ß)$$
$$d_{max} = PGD\ (1.82 - 0.27 \ln ß)$$

where "ß" is the critical damping ratio in "percent" and "ln" is the natural logarithm.

(3) Determine control points and connect control points by straight line segments in log-log space to form the spectrum plot.

Control Point	Frequency (Hz)	Spectral Acceleration (g)
E	0.1	$0.395\ d_{max}/g$
D	$v_{max}/(2\pi\ d_{max})$	$(v_{max})^2/(g\ d_{max})$
C	$(g\ a_{max})/(2\pi\ v_{max})$	a_{max}
B	8.0	a_{max}
A	33.0	PGA
A'	100.0	PGA

(4) The vertical design response spectrum is typically taken as 2/3 of the horizontal spectrum provided that the site is not one of the "near-field" sites, i.e. closer than approximately 15 km (9.3 mi) to a seismic source. For near-field sites, the guidance in ASCE 4 (ASCE, 1998b) should be followed. Local site conditions should be considered when developing appropriate vertical design response spectra.

A3.2.2-e. An acceptable method to estimate the annual probability that specified wind speeds at the site will be exceeded is included in Coats and Murray, 1985, and described by the following:

Step 1: Select a data set of annual extreme wind speeds from a weather station near the site of interest.

Step 2: Correct the annual extreme wind speeds to an anemometer height of 33 ft (10 meters) above ground in flat, open terrain using appropriate methodologies. For example, a power law (Simiu and Scanlan, 1986) could be used to make an adjustment, if needed. No recorded wind speeds from anemometers located on building roofs near the edges, sheltered by parapets or neighboring buildings, or too close to the roof surface (less than 5 feet (1.5 meters)) shall be used.

Step 3: Estimate the annual probability of exceedance of selected wind speeds with associated uncertainty.

Data sets of historical extreme winds shall be obtained from weather stations close enough to sites to represent the site conditions as described in DOE-STD-1022-94 If more than one station is available, they may be combined, provided they represent the same conditions as those at the site.

Several statistical models may be used to estimate frequency of winds. An estimate of the models fitting the data shall be performed. If only one statistical model is to be used, the Fisher-Tippet Type I extreme value distribution (also named Gumbel distribution) (Coats and Murray, 1985) shall be used, unless justified otherwise. Additional guidance may be found in Ramsdell, Elliott, et al. (1986).

The variability associated with estimating the parameters of the statistical models shall be accounted for (Coats and Murray, 1985 and Simiu and Scanlan, 1986).

For sites within 100 km (62 miles) of a coastline, a hurricane wind probabilistic hazard analysis provides estimates of the probability of exceeding wind speeds at a given location and an assessment of the uncertainty in the hazard estimates. Monte Carlo simulation techniques or an alternative method may be used to assess the probability that specified wind speeds will be exceeded at the site (Batts, et al., 1980). This procedure consists of the following steps:

Step 1: Select a data set of hurricanes within 250 km (155 miles) from the site.

Step 2: Estimate the probability distributions of the hurricane parameters (e.g., occurrence, central pressure, direction, landfall location, and forward speed).

Step 3: Select a wind field model to calculate maximum wind speeds as functions of the hurricane parameters (these should include frictional effects of land and local site conditions).

Step 4: Perform a Monte Carlo simulation to simulate the hurricane parameters and determine the associated maximum wind speed at the site.

Step 5: Assess the exceedance probabilities of wind speeds.

A preliminary hurricane wind hazard analysis may be performed to assess the magnitude of hurricane wind speeds by using reported results of hurricane hazard analyses such as those in Batts, et al., (1980).

A tornado hazard analysis consists of the following steps:

Step 1: Compile, obtain, and update as necessary a data set of tornadoes for the area.

Step 2: Develop occurrence-intensity relationship.

Step 3: Develop area-intensity relationship.

Step 4: Calculate probability of a point experiencing tornado intensity.

Step 5: Calculate probability of tornado wind speeds exceeding specified values.

The tornado hazard models described in Boissonnade et. al.(2000), Coats and Murray (1985) are acceptable for use in conducting a site tornado probabilistic hazard analysis.

A3.3.2-d. The following hydrologic events which are potential sources of flooding shall be included in the flood hazard analysis:

(1) River flooding

(2) Levee or dam failure

(3) Flood runoff/drainage

(4) Tsunami

(5) Seiche

(6) Storm surge

(7) Wave and runups

(8) Groundwater

(9) Water-carried debris

(10) Mud flows

For each of these potential sources of flooding, appropriate information on topography, meteorological conditions, results of existing flood analyses, stage-discharge data, etc., that are necessary to determine and analyze the source shall be collected as specified by DOE-STD-1022-94.

The flood screening analyses shall determine potential flooding due to multiple sources and other possible chains of events.

For each of the sources of potential flooding, simple criteria (without performing any analysis other than those collected) shall be provided establishing whether the site is affected by potential flooding from this source. These criteria include the applicable physical arguments that certain sources not present are very unlikely or that their consequences on the site are negligible or nil.

For the sources of flooding for which no clear basis has been established to discard them as potential flood hazards to the site, a preliminary flood hazard analysis shall be performed.

A preliminary flood hazard analysis is performed for all sources of flooding identified as having potential impacts on the site. This analysis shall provide a measure of the magnitude and probability of occurrence of extreme events. This analysis does not need to be comprehensive and can be based on existing studies. For example, it is sufficient to use flood insurance studies or equivalent, that estimate flood probability to $2x10^{-3}$ to measure the magnitude and probability of occurrence of river flooding, and extend these results to a lower probability value (10^{-5} to 10^{-3} (Kite, 1988). Furthermore, the results of any available existing flood frequency analyses should be compared to the results of a preliminary flood hazard analysis.

A preliminary flood hazard analysis provides estimates of the probability of floods and an assessment of the uncertainty in the hazard estimate. Rivers or streams are the most common sources of flooding. For this type of flooding, a simplified acceptable method to estimate the probability that specified elevations at the DOE sites will be exceeded consists of the following steps (McCann and Boissonnade, 1988a):

Step 1: Compile, obtain and update a data base of peak discharge as described in DOE-STD-1022-94.

Step 2: Estimate the probability of exceedance of selected peak discharge levels with associated uncertainty.

An acceptable methodology using streamflow data, and including uncertainty estimates due to the statistical model selected and limited flood data is provided by McCann and Boissonnade, (1986).

Step 3: Determine the stage-discharge relationship (a relationship between flow discharge and flood stage).

Stage-discharge relationships derived from historical floods, hydraulic evaluation (e.g., Manning's equation, step-backwater calculation), and channel geometry data. Uncertainty in estimating these relationships must be accounted for (McCann and Boissonnade, 1988b).

Step 4: Transform the probability-discharge frequency to stage frequency to determine the probability of exceeding selected stage elevations using the stage-discharge relationship.

Existing dam failure analyses performed as part of emergency action plans shall be used if they are available. Otherwise, acceptable simplified analysis methods to assess flooding due to dam failure include those given by Hann et al., 1982 and McCann et al., 1985.

Acceptable hydraulic models to assess runoff or ponding include those given by Crawford and Linsley, (1966) or HEC (1986).

The main results of a preliminary flood hazard assessment consists of the family of flood hazard curves that describes the annual probability that specified flood elevations at the site will be exceeded. A probability weight is assigned to each curve that quantify the uncertainty in the analysis (see for example McCann and Boissonnade 1989). Based on the family of hazard curves, a mean flood hazard curve can be calculated.

Estimates of wave height and runups shall be made using criteria defined in U.S. Army Corps of Engineers (1984).

In the event that more than one cause of flooding has been identified and for which flood hazard curves have been determined, a composite flood hazard assessment shall be performed (McCann and Boissonnade, 1988b).

CONCLUDING MATERIAL

Review Activity:

DOE	Field Offices
NNSA	AL
EH	CH
EM	ID
NE	NV
RW	OR
SC	RL
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CI	Fernald
EE	

National Laboratories
BNL
LLNL
LANL
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Area Offices
Amarillo Area Office
Kirtland Area Office
Princeton Area Office
Rocky Flats Area Office

Preparing Activity:

DOE EH-53

Project Number:

FACR-0009