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Standard Guide for the Estimation of Building Damageability in Earthquakes[1]

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INTRODUCTION

Lenders, insurers and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta earthquake, which caused more than $6 billion in damage, accelerated an already established trend for improved loss estimation in California; the 1994 Northridge event with over $20 billion in damage has completed the process—loss analysis is now an integral part of real estate financial decision making. Financial institutions are in need of specific and consistent measures of future damage loss for this decision process. The long used notion of "probable maximum loss" (PML) has become, for many, a catch phrase to encapsulate all earthquake issues into a simple number that can be used to qualify or disquality a potential commitment. Unfortunately, there has been no previous industry or professional consensus on what PML means or how it is computed. This guide presents specific approaches, which the real estate and technical communities can use to characterize the earthquake vulnerability of buildings. It recommends use of new terms, probable loss (PL), and scenario loss (SL) in the future to make specific the type of damageability measures used. Use of the term Probable Maximum Loss (PML) is not encouraged for future use.

1. Scope

1.1 *Purpose*—This guide defines and establishes good commercial, customary practice, and standard-of-care in the United States for conducting a probabilistic study of expected loss to buildings from damage associated with earthquakes and for the preparation of a narrative report containing the results of the study. As such, this guide permits a user to satisfy, in part, their real estate transactional due-diligence requirements with respect to assessing a property's potential for building losses associated with earthquakes.

1.1.1 *Recognized Earthquake Hazards*—Hazards addressed in this guide include earthquake ground shaking, earthquake caused sit instability, including faulting, land sliding, and densification, and earthquake caused tsunamis and seiches. Earthquake caused fires and toxic materials releases are not considered.

1.1.2 *Other Federal, State, and Local Laws and Regulations*—This guide does not address requirements of any federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the time of the original construction of the building(s).

1.2 *Objectives*—The objectives for this guide are as follows:

1.2.1 To synthesize and document good commercial, customary practice for the estimation of probable loss to buildings from earthquakes for real estate improvements;

1.2.2 To facilitate standardized estimation of probable losses to buildings from earthquakes;

1.2.3 To ensure that the standard of site observations, document review and research is appropriate, practical, sufficient, and reasonable for such an estimation;

1.2.4 To establish what reasonably can be expected of and delivered by a loss estimator in conducting an estimation of probable loss to buildings from earthquakes;

1.2.5 To establish an industry standard for appropriate observations and analysis in an effort to guide legal interpretation of the standard of care to be exercised for the conducting of an estimation of probable loss to buildings from earthquakes; and,

1.2.6 To establish the requirement that a loss estimator communicates observations, opinions, and conclusions in manner meaningful to the user and not misleading either by content or by omission.

1.3 *Considerations beyond the scope*—The use of this guide is limited strictly to the scope set forth herein. Section 3 of this guide identifies, for information purposes, certain conditions that may exist on a property that are beyond the scope of this guide but may warrant consideration by the parties to a real estate transaction.

1.4 *Organization of this guide*—This guide has several parts (see the Table of Contents).

1.5 *Limitations*—This guide does not purport to provide for the preservation of life safety, or prevention of building damage associated with its use, or both. It is the responsibility of the user of this guide to establish appropriate life safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.6 *Commentary*—See Appendix X1 for commentary on Section 1.

2. Terminology

2.1 *Definitions*—This section provides definitions of terms used in this guide. The terms are an integral part of the guide and are critical to an understanding of the guide and its use.

2.1.1 *active earthquake fault*, *n*—an earthquake fault that has exhibited surface displacement within Holocene time (about 11 000 years).

2.1.2 *building code*, *n*—any federal, state, local, recognized design professional, or trade/industry association compilation of systems or rules that govern design or construction practices, or both.

2.1.3 *business interruption*, *n*—a situation when an earthquake causes an interruption to normal business operations; and therefore, potentially or materially causes a loss to the operator of that business. The loss may be partial or total for that period. Business interruption is expressed in days/weeks/months of downtime for the facility as a whole or the equivalent operating value.

2.1.4 *computer assessment tools*, *n*—any of a variety of computer software provided by vendors to identify the seismic hazards of a site, or estimate the earthquake damageability of a building, or both. Some programs may be interactive, using a question/answer format that adjusts the scores based on responses, making default assumptions where specific information is unavailable or not known. Other programs may use spread sheet-type data entry. Such software sometimes may be customizable by the user. These software packages almost always depend on large files of site, earthquake source and building damageability data that usually are updated periodically to reflect new information. The particular method of processing the input data often is proprietary and not available to the user.

2.1.5 *contents*, *n*—contained elements, for example, furniture, fixtures, equipment and contents within the building that are not part of the permanent structure or architectural finishes and equipment of the building.

2.1.6 *correlation*, *n*—the tendency or likelihood of the behavior of one element to be influenced by the known behavior of another element.

2.1.7 *damage distribution*, *n*—the probability function for the possible damage states of a given building type due to a

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given level of earthquake ground motion. Actual damage to a building is random because actual future ground motion, as represented by a given measure and level, is not described completely by that representation, and a particular building has its own resistance, fragility characteristics, and orientation with respect to ground motions that are not completely described by the building structural system type. This probability function allows the evaluation of the conditional probability of the building having a given damage state (a given range of damage ratios, such as 25 % to 50 %) due to a given level of ground motion.(**1-3**).[2]

2.1.8 *damage cost or repair cost*, *n*—the construction cost, including design and construction observation and management costs, required to restore the building to its original condition.

2.1.9 *damage predictor*, *n*—a relation giving a central or mean damage ratio in terms of a measure of the building class or system damage factor, the level of the measure of ground motion, and possible site-structure vibration effects. This relation should have some measure of the scatter of actual damage ratio about the predicted mean, or preferably, provide the damage distribution function. Examples include Steinbrugge, ATC-13, Thiel-Zsutty. Providers may have their own proprietary relations based on their experience and data sources.

2.1.10 *damage ratio*, *n*—the ratio of the cost to repair a building to its original condition divided by its replacement construction cost.

2.1.11 *damage state*, *n*—a range of damage ratios, (for example, 0 to 5 %, or 75 % to 100 %) or generalized building damage condition, for example, a linguistic term such as "low" or "serious" associated with a defined range of damage ratios, that is treated the same for assessment purposes.

2.1.12 *dangerous or adverse conditions*, *n*—situations, which pose a threat or possible injury hazard to the occupants, and also those situations, which require the use of special protective clothing, safety, or access equipment.

2.1.13 *deficiency*, *n*—patent, conspicuous defect in the building or significant deferred maintenance of a building, components, or equipment. This definition specifically excludes routine maintenance, miscellaneous repairs, operating maintenance, etc.

2.1.14 *describe*, *n*—to represent in words sufficient information to visualize a type of system, component, or potentially hazardous condition.

2.1.15 *due-diligence*, *n*—the act of conducting an assessment of a property's physical condition for the purposes of identifying potentially dangerous conditions. The extent of due-diligence exercised on behalf of a user is proportional to the user's uncertainty tolerance level, purpose of the estimate of probable loss assessment, and the resources and time available to the loss estimator to conduct the site visit and research.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

2.1.16 *earthquake*, *n*—the sometimes violent oscillatory motions of the ground caused by the passage of seismic waves radiating from a fault along which sudden movement has taken place.

2.1.17 *earthquake loss (for damage ratio)*, *n*—the property damage loss evaluated as the percentage of the building construction cost to effect restoration to the pre-earthquake condition, including salvage and demolition, to the present-day building cost at the same location, assuming a virgin site condition. Loss includes damage to architectural finishes, partitions, ceilings, and other portions of the permanent building from ground shaking, but not loss of rents or other income, or damage to contents, furnishings, equipment, or other tenant capital assets contained within the building. Loss is expressed in terms of a probability distribution of the damage ratio due to a specific earthquake ground motion affecting the building project or development under consideration.

2.1.18 *estimate of earthquake loss study*, *n*—a study completed in accordance with the requirements of this guide; also sometimes referred to as an Estimate of Earthquake Damageability study.

2.1.19 *expected or mean value*, *n*—of a random variable, such as building damageability, the mathematical centroid of the probability distribution for the random variable; that is, it is determined as the sum (or integral) of all the values, such as damage levels, that can occur times their probability of occurrence. The expected or mean value is not the same as the median value, which is the value that divides the probability function into equal parts, such that the value of the random variable has an equal probability of being above or below the median value.

2.1.20 *fault zone*, *n*—the area within a prescribed distance from any of the surface traces of a fault. The distance depends on the magnitude of earthquakes that could occur on the fault-500 ft (152 m) from major faults, those capable of earthquakes with magnitudes of 6.5 or greater, and 250 ft (761 m) away from other well-defined faults. Within California, use the zones determined by the California Division of Mines and Geology under the Alquist-Priolo Special Studies Zones Act for active and potentially active faults they have identified by the state or other governmental bodies.

2.1.21 *interdependency*, *n*—a condition wherein the function of a facility also is dependent on another facility, utilities, lifelines (example, transportation), which may include a customer, vendor, (for example, supplier of materials), contractor (supplier of services), staff (for example, supplier of staff), information (for example, data processing for accounting or distribution), etc.

2.1.22 *interplate areas*, *n*—regions of the United States where there is poor understanding of the sources of local earthquakes. The plate boundaries along the Pacific coast, Hawaii, the Caribbean, the Basin and Range province (Nevada, Utah, Idaho, Montana) are understood fairly well. In the interplate areas, the balance of the country far removed from plate boundaries, the specific sources and mechanics of earthquake are understood less well, and thereby, more uncertain.

2.1.23 *landslide*, *n*—the rapid downslope movement of soil, or rock material, or both, often lubricated by ground water, over a basal shear zone; also, the tongue of stationary material deposited by such an event.

2.1.24 *level*, *n*—the degree of investigation of the particular earthquake damageability attribute. For each type of assessment, four levels are described in the guide: Level 0 is a screening investigation, while Level 3 is an exhaustive technical investigation; Levels 1 and 2 are intermediate between these two. It is emphasized that the lower the level of investigation the higher the uncertainty in results, given that the same loss estimator undertakes the investigations.

2.1.25 *liquefaction*, *n*—the transformation of loose, saturated, sandy materials under sustained strong cyclical shaking into a fluid-like condition. Damage from liquefaction results primarily from horizontal and vertical displacements of the ground. These displacements occur because sand/water mixtures in a liquefied condition virtually have no strength and provide little or no resistance to compaction, lateral spreading, or down slope movement. This movement of the land surface can damage buildings and buried utility lines, such as gas mains, water lines and sewers, particularly at their connection to the building. Extreme tilting or settlement of the building can occur if liquefaction occurs within the building's foundations.

2.1.26 *magnitude of earthquake*, *n*—any of a variety of measures that indicate the "size" of an earthquake. The most commonly used lay term is the Richter magnitude, which is determined by taking the common logarithm (base 10) of the largest ground motion recorded during the arrival of a "P" wave, or seismic surface wave, and applying a standard correction for the distance to the epicenter of the earthquake.

2.1.27 *maximum capable earthquake (MCE)*, *n*—the earthquake that can occur within the region that produces the largest average ground motion at the site of interest. All faults and features for which there is reasonable professional basis within engineering seismology and geology to assign a maximum earthquake to the fault or feature are to be assessed. The ground motion at the site is determined by application of an appropriate attenuation relationship determined from those available that best represent the specific seismic and tectonic setting of the immediate region. This earthquake is sometimes termed the maximum credible earthquake.

2.1.28 *modified mercalli earthquake intensity (MMI)*, *n*—a qualitative description of the local effects of the earthquake at a site. Normally, it is given as a roman numeral for I to XII, to emphasize its qualitative, not quantitative nature. **(3)**

2.1.29 *nonstructural components*, *n*—the broad definition includes all components of a building other than the structural frame. Nonstructural components sometimes may be categorized further, including more conventional elements, such as non-load bearing wall systems (interior and exterior walls that are not part of the primary vertical or lateral load resisting systems), ceilings, and raised access floors. Other categories include mechanical systems (most commonly related to heating, ventilating, and air conditioning), electrical and power systems, building utility equipment, production equipment, and stock and supplies related to operations.

2.1.30 *observe*, *n*—the act of conducting a visual survey of conditions that are readily accessible and easily visible. The loss estimator is not required to use or provide scaffolding, ladders, magnifying lenses, etc.

2.1.31 *observations*, *n*—the results of loss estimator's actual survey.

2.1.32 *obvious*, *n*—that which is readily accessible and can be seen easily by the reviewer without the aid of any instrument or device and understood by the reviewer as a result of a walk-through survey.

2.1.33 *occupant*, *n*—tenant or owner conducting business or residing in property being studied.

2.1.34 *original construction documents*, *n*—documents used in the original construction and subsequent modification(s) of building(s) for which the estimate of probable loss is prepared. If as-built plans are available, they are preferred.

2.1.35 *other earthquake hazards*, *n*—other earthquake hazards include, but are not limited to, soil liquefaction; ground deformation including subsidence, rupture, differential settlement, sliding, slumping, etc; and, flooding from dam or dike failure, tsunami, or seiche. The significance of such hazards is to be evaluated during earthquakes whose ground motions are comparable to the level prescribed for seismic loadings for the site by the Uniform Building Code.

2.1.36 *owner*, *n*—the entity or individual holding the deed to the property subject to an estimate of probably loss, one's agent, or contractor.

2.1.37 *P-delta effect*, *n*—the condition in which a vertical load resisting element is displaced horizontally from its original position so that instability can result from the vertical load without further consideration of any applied lateral loads.

2.1.38 *peak ground acceleration (PGA)*, *n*—the maximum acceleration at a site for the ground motions caused by an earthquake; it may be the actual recording or an estimate. Most often, PGA is given as the maximum of the horizontal components. Usually, it is expressed as a fraction of gravitational acceleration, 32.2 ft/s^2 (9.8 m/s^2).

2.1.39 *potentially active earthquake fault*, *n*—an earthquake fault that shows evidence of surface displacement during the Quaternary period (approximately the last two million years).

2.1.40 *probabilistic ground motion*, *n*—earthquake ground motions for the building site that are determined from a site-specific evaluation of the seismic exposure over a given time period and are represented by a probability distribution function. Where appropriate, the ground motion assessment process should reflect conditional probabilities of the temporal dependence of earthquakes on specific seismic features where they are known.

2.1.41 *probable loss (PL)*, *n*—the earthquake loss to the building(s), not including contents or equipment, that has a specified probability of being exceeded in a given time period from earthquake shaking. PL values are expressed as a percentage of building replacement construction cost (current). The PL estimates are to be evaluated, in a statistically consistent manner, considering the probability distribution functions of the possible ground motion levels at the site and the probability distribution function for the building's damageability due to each possible level of ground motion. Ground motions are determined from a site-specific evaluation of the seismic exposure and are represented by a probability distribution function. Building damageability and seismic performance depends on the level of study and shall recognize the dynamic response characteristics of the building(s). The building damageability distribution is determined from past performance data, expert estimates of performance, detailed analysis at specific ground motion levels, or a combination thereof. PL values are given either as a value(s) with a specified return period(s), PL_N, or as the value that has specified probability of exceedance (from 1 % to 50 %) in a given time period (1 to 50 years). The most common return periods used are 72, 190 and 475 years, that correspond to a 50 % probability of exceedance in 50 years, and a 10 % probability of exceedance in 20 and 50 years, respectively. The most commonly used probability of exceedance is 10 %, and the most common time periods are 20 and 50 years.

2.1.41.1 *PL values for group of buildings*—must be determined in a statistically consistent manner that fully recognizes the probabilistic damage distributions for the individual buildings and the possible correlations between the buildings' damageability. Where the buildings in a group are located at nearby sites with common expected ground motions, the ground motions for each building's damageability determination may be fully correlated such that the damageability distributions are based on the same ground motions. Where the sites are sufficiently separated, or the buildings' site soil conditions are different, then the damageability determination must consider the degree of correlation in ground motions for the separate sites or site conditions as part of the PL determination.

2.1.42 *probable maximum loss (PML)*, *n*—a term used historically to characterize building damageability in earthquakes. It has had a number of significantly different explicit and implicit definitions. It is recommended that the term not be used in the future, and that the terms probable loss (PL) and scenario loss (SL), whose definitions are precise, be used to characterize the earthquake damageability of buildings and groups of buildings.

2.1.43 *property*, *n*—the real property that is the subject of the estimate of earthquake damageability described in this guide. Real property includes buildings and other fixtures and improvements located on the property.

2.1.44 *report*, *n*—the narrative deliverable written product that results from this guide outlining the loss estimator's observations and opinions of the estimation of probable loss. At the request of the user, the report may include order-of-magnitude cost estimates for retrofit construction aimed at mitigating some or all identified deficiencies and/or reduce the estimated PL or SL values.

2.1.45 *retrofit*, *n*—a preliminary suggestion(s) to correct, mitigate, or repair a physical deficiency in the building that will improve its seismic performance so that it is acceptable to the user.

2.1.46 *return period*, *n*—the return period of a particular value of a random variable is the inverse of the annual probability that the value is equaled or exceeded. It is not the time period between occurrences of the value, but is the long term average of the random times between occurrences. Often, return period is interpreted to mean that if the value was realized in 1994, and the return period is 100 years, then the next occurrence will be in 2094; this is completely wrong. For example, earthquake occurrences usually are considered as Poisson distributed random variables, that is, ones where the probability is near constant from year to year, and the probability of an occurrence this year is independent of what happened last year. For a Poisson random variable, the probability that the value will be equaled or exceeded in its return period term is 63 %.

2.1.47 *scenario expected loss (SEL)*, *n*—the expected value loss in the specified ground motion of the scenario selected. Since the damage probability distribution usually is skewed, rather than symmetrical, it should not be inferred that the probability of exceeding the SEL is 50 %; it can be higher or lower than this amount.

2.1.48 *scenario upper loss (SUL)*, *n*—the scenario loss that has a 10 % percent probability of exceedance due to the specified ground motion of the scenario considered.

2.1.49 *scenario loss (SL)*, *n*—the earthquake loss to the building(s), not including contents or equipment, resulting from a specified scenario event on specific faults affecting the building, or specified ground motions. The specific damageability and ground motion characterizations are to be specified. SL values are expressed as a percentage of building construction cost (current replacement cost). The ground motion used for determination of the SL can be specified in a variety of ways, which must be stated clearly in the report, including:

2.1.49.1 —Ground motion in the maximum capable earthquake (MCE) for the building site;

2.1.49.2 —Ground motion specified as the design ground motion in the applicable building code for the building site;

2.1.49.3 —Ground motion from specific earthquake(s) likely to affect the building site with a specified probability of exceedance, using an accepted attenuation relationship for the seismic setting and with the uncertainty of the estimate clearly indicated; such maximum scenario events are prescribed for various faults based on paleoseismic evidence;

2.1.49.4 —Ground motion with a specified return period as determined from a probabilistic ground motion seismic hazard analysis;

2.1.49.5 —A selected maximum Modified Mercalli Intensity (MMI) for the site determined from published maximum value maps; or,

2.1.49.6 —the MMI for the site as estimated from peak ground acceleration values.

2.1.49.7 —The probability of the SL value being exceeded in the scenario must be stated in the report. The term SEL is used when the reported value is the expected value, while SUL is used when the probability of exceedance is 10 %. Other values may be specified by the user.

2.1.49.8 *SL values for groups of buildings*—must be determined in a statistically consistent manner that fully recognizes the probabilistic damage distributions for the individual buildings and the possible correlations between the buildings' damageabilities. Where the buildings in a group are located at nearby sites with common expected ground motions, the ground motions for each building's damageability determination may be correlated fully such that the damageability distributions are based on the same ground motions. Where the sites are separated significantly, or the building site soil conditions are different, then the damageability determinations must consider the degree of correlation in ground motions for the separate site conditions as part of the SL determination.

2.1.50 *seiche*, *n*—a water wave caused in a closed, or partially closed, body of water in response to the passage of seismic waves.

2.1.51 *significant*, *adj*—important and serious.

2.1.52 *site visit*, *n*—a preliminary, visual reconnaissance or scan of the property to observe and gather information for the purposes of conducting an estimate of probable loss. Also sometimes referred to as a walk-through survey or a field visit.

2.1.53 *statistically consistent manner*, *n*—following the mathematical rules and concepts of probability and statistics.

2.1.54 *structural component*, *n*—a component, which is a part of a building's lateral and/or vertical load-resisting system.

2.1.55 *survey*, *n*—observations or measurements made by the loss estimator as the result of a walk-through or reconnaissance to obtain information on the property's readily accessible and easily visible components or systems.

2.1.56 *tsunami*, *n*—long water waves that are generated impulsively be tectonic displacements of the sea floor associated with earthquakes; tsunamis also may be caused by eruption of a submarine volcanoes, submerged landslides, rock falls into the ocean, and underwater nuclear explosions. Tectonic displacement having substantial vertical (dip-slip) component are more likely to cause tsunamis than strike-slip displacements. Wave heights associated with tsunamis in deep water generally are small; however, as the wave fronts approach coastlines where there is shallow water, the wave heights increase and will run up onto the land. The tsunami run-up can cause loss of life and substantial property damage.

2.1.57 *uncertainty tolerance level*, *n*—the amount of uncertainty in financial exposure that can be incurred by a user resulting from the cost to remedy earthquake damage associated with potentially hazardous conditions not identified by an estimate of probable loss. This is influenced by such factors as initial acquisition cost or equity contribution, mortgage underwriting considerations, specific terms of the equity position, projected term of the hold, etc.

2.1.58 *user*, *n*—is the individual that retains the loss estimator to prepare an estimate of probable loss.

2.1.59 *uncertainty*, *n*—the degree of random behavior represented by an applicable probability distribution and associated parameters.

2.1.60 *walk-through survey*, *n*—the loss estimator's site visit to the property consisting of a visual reconnaissance of readily accessible and easily visible systems and components. This definition implies that such a survey is preliminary, not in-depth, and without the aid of exploratory probing, removal of materials, or testing. It is literally the loss estimator's walk of the property's improvements and resulting observations.

2.1.61 *weak story*, *n*—a story in a building that has significantly greater deformation than any story above it under a given lateral loading. Such weak stories can occur at any level in a building, except the roof.

2.2 *Abbreviations:*

2.2.1 *MCE*—maximum capable earthquake.

2.2.2 *PL*—probable loss

2.2.3 PL_N—probable loss with a return period of *N* years

2.2.4 *PML*—probable maximum loss

2.2.5 *SL*—scenario loss

2.2.6 *SEL*—scenario expected loss

2.2.7 *SUL*—scenario upper loss

2.3 *Commentary*—See Appendix X1 for commentary on Section 2.

3. Significance and Use

3.1 *Uses*—This guide is intended for use on a voluntary basis by parties who wish to estimate damageability from earthquakes to real estate. This guide outlines procedures for conducting an estimate of earthquake loss study for a specific user considering the user's due-diligence requirements and risk tolerance level. The specific purpose of the estimate of earthquake loss study is to provide the user with an adequate measure of possible earthquake losses that may be expected during the anticipated term for holding either the mortgage or the deed. A study prepared in accordance with this guide may reference or state that it complies with this guide provided that it identifies any extraordinary exceptions to same. No implication is intended that a person must use this guide in order to be deemed to have conducted an inquiry in a commercially prudent or reasonable manner in any particular transaction. Nevertheless, this guide is intended to reflect a commercially prudent and reasonable inquiry.

3.1.1 *Building Owners, Tenants/Purchasers and Others*—This guide is designed to assist the user in developing information about the earthquake-related damage potential of a building, or groups of buildings, and as such has utility for a wide range of persons, including, but not be limited to, building owners, building tenants, lenders, insurers, occupants, and potential investors/owners and mortgages.

3.1.2 *Types of investigations*—This guide provides requirements for the performance of five different types of earthquake loss studies intended to serve different financial and management needs of the user. Several of these types of assessment depend on earthquake ground motion characterization as given in Section 4.

3.1.2.1 *Building Stability*—Assessment of the likelihood that the building will remain stable in earthquakes, see Section 5.

3.1.2.2 *Site Stability*—Assessment of the likelihood that the site will remain stable in earthquakes, that is not be subject to failure through faulting, liquefaction, landsliding or other site response that can threaten the building's stability or cause damage, see Section 6.

3.1.2.3 *Damageability*—For assessment of the damageability of the building to earthquake ground motions and the degree of damage expectable over time, and for performing and completing the damageability assessment as either a probable loss or a scenario loss assessment, or both, see Section 7.

3.1.2.4 *Contents Damageability*—For assessment of the damageability of the building's contents to earthquake ground motions, see Section 8.

3.1.2.5 *Business Interruption*—For assessment of the implications for continued use or partial use of the building for its intended purpose due to earthquake damage to the building, contents, equipment, see Section 9.

3.1.3 *Level of Investigation*—The estimate of earthquake loss may consider any level of investigation from 0 to 3 that serves the particular purposes for which the results are desired. Level 0 is termed a screening level of investigation while Level 3 is an exhaustive investigation.

3.1.4 *Extent of Due-Diligence Exercised and Purpose of the Estimate of Earthquake Loss*—A user can rely only on the estimate of earthquake loss for the specific purpose that such study was commissioned and that point in time that the loss estimator's observations are conducted. This guide recognizes that a loss estimator's opinions and observations often are impacted or contingent on information, or the lack thereof, that is readily available to the loss estimator at the time of conducting an investigation. For instance, a loss estimator's observations may be impacted by building occupancy load or the availability of property management to provide information, including but not limited to, original construction documents at the time of the estimate of earthquake loss study.

3.1.5 *Site-Specific*—The guide is site-specific in that it relates to estimation of earthquake loss to building(s) located at a specific site.

3.2 *Principles*—The following principles are an integral part of this guide and are intended to be referred to in resolving any ambiguity or exercising such discretion as is accorded the user or the loss estimator in estimating loss to buildings from earthquakes. Also, it is to be used in judging whether a user or loss estimator has conducted appropriate inquiry or has otherwise conducted an appropriate estimation of loss from earthquakes to buildings.

3.2.1 *Uncertainty Not Eliminated*—No estimate of earthquake loss from earthquakes to buildings can wholly eliminate uncertainty regarding damage resulting from actual earthquakes. The successive levels of study of this guide are intended to reduce, but not to eliminate, uncertainty regarding the estimation of damage resulting from actual earthquakes in connection with a building, or a group of buildings, and the guide recognizes the reasonable limits of time and cost, related to a selected level of study.

3.2.2 *Not Exhaustive*—There is a point at which the cost of information obtained or the time required to gather it outweighs the usefulness of the information and, in fact, may be a detriment to the orderly completion of transactions. One of the purposes of this guide is to identify a balance between the competing goals of limiting the costs and time demands inherent in performing an estimate of earthquake loss to building(s) and the reduction of uncertainty about unknown conditions that may result from the acquisition of additional information.

3.2.3 *Level of Study*—Not every property will warrant the same level of earthquake loss assessment. Consistent with good commercial or customary practice, the appropriate level of estimate of earthquake loss to buildings from earthquakes will be guided by the type of buildings subject to assessment, the resources and time available, the expertise and risk tolerance of the user, and the information developed in the course of the inquiry.

3.3 *Minimum Reporting Requirements*—An earthquake damageability assessment may be performed for an individual building or a group of buildings. When an earthquake damageability assessment is performed under this guide, at the minimum, it should always include an assessment of building stability (BS, Section 5), and site stability (SS, Section 6). Also, it may include a damageability, contents damageability, or business interruption assessment, or both.

3.3.1 The user may select any level for these investigations (0 through 3), but must perform an assessment for each of the two issues—building stability and site stability.

3.3.2 The selection of the level of the investigation performed should be guided by the level of uncertainty in the result that is acceptable to the user. The matrix of Table 1 is offered as a guide to selection of the levels of investigation to match the acceptable level of uncertainty. The zone references are from the map of seismic zones as it appears in the 1994 edition of the Uniform Building Code **(4)**, which is reproduced in Fig. 1. The acceptance levels are not defined, but are given to reflect the progression of investigation levels with changes in acceptable uncertainty.

3.3.3 The damageability portion of the assessment may report a probably loss (PL), with specified probability of exceedance and time period, or a scenario loss (SL), where the specific scenario and the probability of exceedance are given, or both.

3.3.4 When a new investigation is performed that is consistent with this guide and has a higher level than a prior investigation, then the new investigation supersedes the former one.

3.4 *Qualifications of the Loss Estimator*—The estimation of earthquake loss to building(s) may be conducted by either an agent or employee of the user or wholly by a contractor. No practical standard can be designed to eliminate the role of judgment and the value and need for experience by the party performing the inquiry. The user should retain to conduct estimate of earthquake loss studies only those who have the

TABLE 1 Recommended Minimum Levels of Inquiry Based on Seismic Zone of the Property and the Acceptable Level of Uncertainty of the User

Acceptable Uncertainty Level	Seismic zone/UBC-94^A Zones 0, 1, 2A, 2B	Zone 3	Zone 4
Very low	BS0, SS0, D1	BS1, SS1 D1	BS2, SS2 D2
Low	NA	BS1, SS1, D1	BS1, SS2, D2
Moderate	NA	BS0, SS0, D0	BS1, SS1, D1
High	NA	NA	BS0, SS0, D0

^{A}See Fig 1 for the seismic zones. BS refers to the Building Stability assessment (see Section 6), SS to the Site Stability assessment (Section 7), and D to the Damageability Assessment (Section 8); the number following the abbreviation is the level of investigation; that is, BS0 is a Building Stability Level 0 assessment.

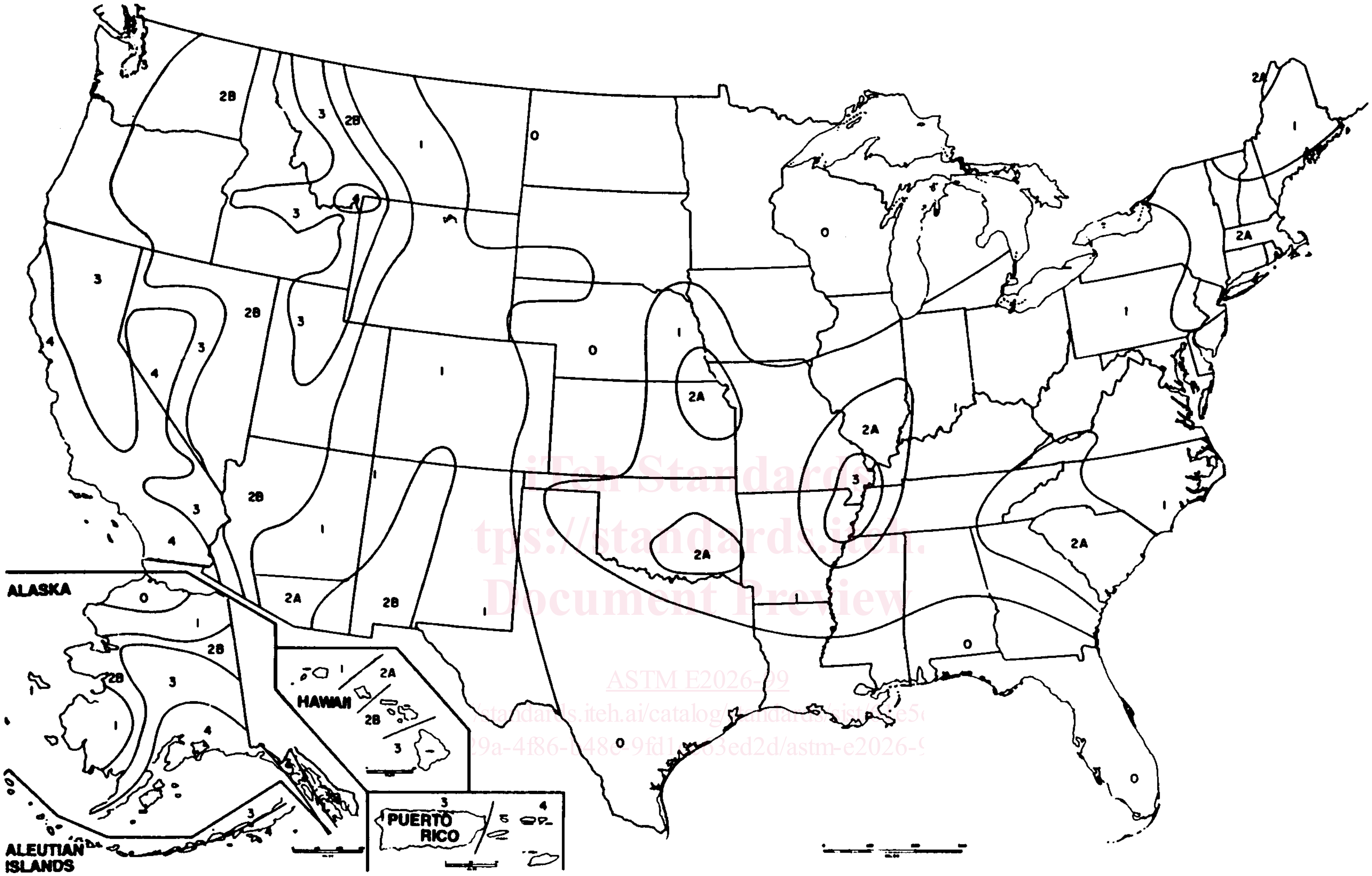

FIG. 1 1 Seismic Zone Map of the United States Taken from the Uniform Building Code requisite knowledge and experience to perform such studies in a reliable manner for the level of investigation specified. There are two main qualifications that bear on the ability of the loss estimator to reliably give professional opinions on the earthquake hazard posed by a site and the damageability of a building:

3.4.1 Knowledge of the current state of knowledge and practice of the underlying professional and scientific disciplines that bear on the particular practice; and

3.4.2 Experience in application of the specific professional skills required for seismic evaluation to the specific buildings and conditions of the subject site or building.

3.4.3 The user shall evaluate the qualifications of the performer (loss estimator) before the performer is retained to complete a study. The following issues are ones for which the user should seek information on qualifications:

3.4.3.1 *Personnel*—Identification of the individuals by task assignment that are to be engaged in the specific study. This should include those professional personnel that will complete the majority of the total effort. Provide evidence of sufficient knowledge of the technical, analytical, and mathematical concepts required for the performance of the level of inquiry undertaken.

3.4.3.2 *Professional Registrations or Licensing*—The state, type, and dates of registration with an inclusion of a statement of whether the registration process included specifically earthquake issues.

3.4.3.3 *Design Experience*—The number of years experience in earthquake related practice with an enumeration of projects and the roles played in these projects that are comparable to the type of conditions that are expected to be encountered. Special note should be made to distinguish the work done by the person with the current employer from that done for another organization, and to distinguish those projects completed by the firm with other personnel than those proposed for the individual project.

3.4.3.4 *Research and Professional Practice Development Experience*—The earthquake hazards related research and professional practice development that bears on the specific professional duties that are to be performed.

3.4.3.5 *Loss Estimation Experience*—The number of years experience in seismic practice with an enumeration of projects and the roles played in these projects that are comparable to the type of conditions that are expected to be encountered. Special note should be made to distinguish the work performed by the person with the current employer from that done for another organization, and to distinguish those projects completed by the firm with other personnel than those proposed for the individual project.

3.4.3.6 *Earthquake Investigation Experience*—A listing of the earthquakes the principal performers of the study have had field experience in investigating, including the citations of reports that they prepared or to which they made contributions.

3.4.4 The following general guidance is given on setting of acceptable qualifications. It should be noted that the qualifications for building stability and damageability assessments are similar, but different from those for ground motion, site stability, contents damageability, and business interruption. It is seldom that one individual will have sufficient expertise and experience to perform all of these types of investigations for Level 2 or Level 3 inquiries.

3.4.4.1 Qualifications should be determined of those individuals performing the majority of the work, as well as the person-in-charge, who reviews and possibly signs the work. The fewer the number of individuals involved, the more important is the experience and qualifications of the person doing the work and making the professional judgments.

3.4.4.2 For a Level 0 investigation there are no specific requirements; however, it is advisable that the individual performing the assessment be a registered professional and that their competence in the related area of the assessment be declared.

3.4.4.3 Level 1 investigations require the highest general experience in professional practice and evaluation, because usually there is little oversight or review of the work product and conclusions. For example, professional experience in the specific professional area of 20 years and in performing loss evaluations of 5 years may be appropriate. Specific experience in the characteristics of the particular site or structural system is not required, but useful. For example, experience in field investigation of earthquake response in four or more damaging level earthquakes is desirable.

3.4.4.4 Level 2 investigations require substantial understanding and experience in the specific technical issues that pertain to the particular type of site or structure. For example, professional experience in the specific professional area of 10 years and in performing loss evaluations of 3 years may be appropriate. Specific experience in the characteristics of the particular site or structural system is not required, but useful. For example, experience in field investigation of earthquake response in two or more damaging level earthquakes is desirable.

3.4.4.5 Level 3 investigations require demonstrated, substantial understanding and experience in the specific technical issues for the specific type of site or structure.

3.5 *Representation of Seismic Risk*—The report shall specify clearly how seismic risk and hazard are evaluated and represented, what assumptions are made in the risk assessment that could substantially influence the results, and what level of overall uncertainties there are in the results.

3.6 *Projects Comprised of Multiple Buildings*—Where projects consist of several buildings or building sections whose damageability is independent of the others, one or more of the following must be presented in the damageability analysis:

3.6.1 Damageability results are given for each individual building only in addition to those of the group; these may be average, mean, range, or statistic, for example, value with 10 % probability of exceedance;

3.6.2 Average and standard deviation of damage given for each building for selected specific events, or for the ground motion probability distribution at the site; and,

3.6.3 Where there is a group of assessed buildings, report how the individual building results are combined statistically to provide the SL or PL values for the group of buildings.

3.7 *Retrofit Scheme Development*—Where the client specifies development and analysis of a retrofit scheme for a