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Comment on NRC-2011-0204, Proposed Generic Communication; Draft NRC Generic Letter 2011-XX: Seismic Risk Evaluations for Operating Reactors

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It is great to see that NRC is pursuing seismic risk evaluations for operating reactors. As shown by the recent Japan and Virginia earthquakes, there is an urgent need for the evaluations. However, I have a great concern on the proposed evaluations because of the methodology for the site-specific seismic hazard estimates: *probabilistic seismic hazard analysis (PSHA)* as identified in 10 CFR 100.23, the Regulatory Guide 1.165, and Regulatory Guide 1.208. PSHA is scientifically flawed; its results are artifacts (Wang, 2011a, and b). Thus, the resulting seismic risk evaluations are not scientifically sound, and might not lead to safe operation of nuclear reactors.

Although PSHA has become a state-of-practice method for seismic hazard and risk assessments of nuclear facilities in the United States, there have always been some serious concerns on PSHA and its results. In 1988, the National Research Council organized a panel, chaired by the late professor K. Aki, to review PSHA in response to concerns raised by several studies, particularly those by the Lawrence Livermore National Laboratory and the Electric Power Research Institute in the early 1980's. The National Research Council panel identified many issues with PSHA, particularly in how to capture earth science information. The panel found that "because the 'aggregated' results of PSHA are not always easily related to the inputs, PSHA may also obscure the unknown and uncertainties of earth sciences data and may lead to an unwarranted sense of accuracy in the value" (National Research Council, 1988, p. 5). In other words, "the concept of a 'design earthquake' is lost; i.e., there is no single event (specified, in simplest terms, by a magnitude and distance) that represents the earthquake threat at, for example, the 10,000-yr ground-motion level" (McGuire, 1995). The so-called de-aggregation method was devised to "find" a design earthquake (McGuire, 1995). The unknowns and uncertainties in PSHA have led to many disagreements about hazard estimates, which in turn led to another review of PSHA in 1997, this time by the Senior Seismic Hazard Analysis Committee, commissioned by NRC, the U.S. Department of Energy, and the Electric Power Research Institute. The committee concluded that "many of the major potential pitfalls on executing a successful PSHA are procedural rather than technical in character" (SSHAC, 1997, p. xiv). As a result, the SSHAC-97 guidelines were established for executing a PSHA.

Thus, the serious concerns with PSHA have never been technically resolved, by either the National Research Council (1988) or SSHAC (1997). This was illustrated by the Yucca Mountain project (Stepp and others, 2001), which is the most comprehensive PSHA ever conducted according to SSHAC-97 guidelines in the United States. It resulted in extremely high ground-motion estimates for the Yucca Mountain nuclear waste repository: >11g PGA and >13 m/s PGV (Hanks, 2011). These extreme estimates triggered more widespread debate among geologists, seismologists, and engineers, even among the top PSHA practitioners (Abrahamson and Bommer, 2005; McGuire and others, 2005). The conclusion, after about 10 years of debate and research, was that the ground motion for Yucca Mountain was overestimated (Abrahamson and Hanks, 2008; Hanks, 2011). Thus, even the most comprehensive PSHA studies, conducted according to SSHAC-97 guidelines, have not resulted in appropriate seismic hazard estimates.

It is clear that there are some intrinsic problems with PSHA, even the basic math. As shown by Cornell (1968, 1971) and McGuire (2004, 2008), PSHA calculates the annual probability of exceedance (i.e., exceedance probability in ONE year [t=1 year]) for a given ground-motion level from the "total probability theorem":

$$P[Y \geq y] \approx \sum v_i t(1\,year) \iint P[Y \geq y | M, R] f_{M,R}(m,r) dmdr, \qquad (1)$$

where Y and y are earthquake ground motions, M and m are magnitudes, R and r are distance, v_i is the rate (*per year*) of earthquakes for source i, $P[Y \geq y|M,R]$ is the conditional exceedance probability, and $f_{M,R}(m,r)$ is the probability density function (PDF), respectively. Equation (1) has been commonly written in PSHA by omitting the precondition of t=1 *year* as (McGuire, 2004, 2008)

$$P[Y \geq y] \approx \sum v_i \iint P[Y \geq y | M, R] f_{M,R}(m,r) dmdr \qquad (2)$$

The annual probability of exceedance is the exceedance probability in ONE year (i.e., t=1 year) and a dimensionless quantity. Unfortunately, the annual probability of exceedance has erroneously been interpreted and used as the annual exceedence frequency or rate and a dimensional quantity with the unit of per year in PSHA (Cornell, 1968, 1971; McGuire, 2004, 2008). This unfortunate error has made the probability (i.e., a dimensionless quantity) becoming the frequency (i.e., a dimensional quantity with unit of per year).

As identified in the draft NRC generic letter, the seismic core damage frequency (SCDF) in the range of 10^{-4} per year to 10^{-5} per year is considered in the current safety/risk assessment for nuclear reactors. As specified by 10 CFR 100.23, the Regulatory Guide 1.165, and Regulatory Guide 1.208, these frequencies are the annual probabilities of exceedance derived from a PSHA. It is simply wrong to equate the annual probabilities of exceedance of 10^{-4} to 10^{-5} to the frequencies of 10^{-4} per year to 10^{-5} per year. In other words, it is a simple mathematical problem to equate 0.01% to 0.01% per year.

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