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A PROPOSED APPROACH TO SEISMIC SCOPE RE-ASSESSMENT FOR INDIVIDUAL PLANT EXAMINATION OF EXTERNAL EVENTS (IPEEE)

Final Draft

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ABSTRACT

Development of binning assessments for establishing IPEEE seismic review-level and review-scope guidelines, as documented in NUREG-1407, has relied on the use of relative, site-to-site comparisons of seismic hazard results. One of the key inputs to this original binning process was the set of 1989 LLNL seismic hazard estimates for 69 eastern U.S. nuclear power plant sites. These hazard results underwent a substantial revision in 1993, generally resulting in significantly lower levels of perceived mean seismic hazard at all sites. This reduction in LLNL seismic hazard results has motivated a re-assessment of the IPEEE binning results, considering the potential for allowable reductions in seismic review scope for some eastern U.S. plants.

This report documents a set of proposed technical bases and methods, binning format and results of IPEEE seismic scope re-assessment, accounting for the revised LLNL hazard results. Because the pattern of site-to-site variations in LLNL hazard results has not altered significantly, the approach for seismic-scope re-binning makes important use of comparisons based on absolute levels of hazard, as opposed to use of comparisons based exclusively on relative (plant-to-plant) levels of hazard. The approach to seismic-scope re-assessment also introduces use of an additional review-scope category, the "modified-scope" review, thus refining the gradation used for IPEEE seismic binning. Assignment of plants to this new review-scope bin is based on demonstrating high likelihood of low contribution to mean seismic core-damage risk and on establishing a consistent and meaningful overall gradation of review-scope binnings for the population of eastern U.S. nuclear power plants.

The proposed procedures and guidelines for performing a modified-scope review are delineated. It is stressed that the binning re-assessment relies on the assumption that the quality of procedural implementation for the proposed modified scope review is of the same high quality as would be implemented in a well executed full-scope or focused-scope seismic review. In other words, only the review scope is altered for plants re-binned into the proposed modified scope category, not the depth and quality of the review. In particular, the comprehensive and detailed walkdown procedural guidelines as discussed in NUREG-1407 remain unchanged. This helps to insure that all potential vulnerabilities are identified and reported as part of the IPEEE process.

Other significant technical concerns and impacts related to IPEEE seismic-scope re-assessment, in general, are presented and discussed in this report. These issues relate primarily to special considerations that must be addressed in a proposed modified-scope review, as well as to potential implications of uncertainty in seismic hazard on stability of the seismic IPEEE process.

Based on the re-assessment approach, 18 plants are re-binned from the focused-scope to the proposed modified-scope review category.

In addition to the re-assignment of a subset of focused-scope plants to a proposed modified-scope review category, specific allowable reductions in seismic IPEEE requirements are proposed for all focused-scope (and modified-scope) plants. These seismic-scope reductions are conveyed in the form of a list of items/components for which seismic margin capacity calculations (i.e., fragilities or HCLPFs) need not generally be performed, unless an unusual condition is noted in the seismic walkdown of the plant. Hence, these components are effectively screened-out of the seismic IPEEE process for focused-scope and modified-scope plants, in consideration of the reductions in perceived seismic hazard based on the 1993 revised LLNL hazard results.

Section 1

INTRODUCTION

1.1 Background on the Issue

NUREG-1407 [1] provides guidance for conducting Individual Plant Examinations of External Events (IPEEEs) of U.S. commercial nuclear power plants, in support of Generic Letter 88-20, Supplement 4 [2] which formally requests plant licensees to respond to relevant concerns outlined in the NRC Severe-Accident Policy Statement [3]. Key elements of the development of IPEEE guidance for seismic events have included assigning the plants to appropriate categories defining earthquake review level and review scope, and delineating appropriate procedures for each seismic review method. In this development, for eastern U.S. (EUS) plants, the process of assigning plants to appropriate review categories -- i.e., plant binning -- has relied largely on the use of available seismic hazard results. The hazard results used in the binning process include those developed by Lawrence Livermore National Laboratories (LLNL) in 1989 [4] for 69 plant sites, and by the Electric Power Research Institute (EPRI) in 1989 [5] for 57 sites (subsequently extended to 59 sites).

The LLNL and EPRI seismic hazard studies were both very significant undertakings, employing extensive and detailed methodologies and expert input assessments which were considered state of the art at the time of their development (and are still considered substantially so). Various comparisons of the 1989 LLNL and EPRI hazard results have been conducted. Generally speaking, these comparisons show that the two sets of hazard results differ greatly (e.g., factors on the order of 10 or more in the mean) in terms of absolute hazard for a given site, but that the relative, gross variations in hazard from site to site are notably similar. Partially for this reason, a plant binning approach predominantly based on relative, site-to-site comparisons of seismic hazard results was employed in NUREG-1407.

Since the time of the development of the 1989 LLNL seismic hazard estimates, a re-elicitation of LLNL ground-motion and seismicity experts has been conducted to refine uncertainty estimates, and revisions to the LLNL seismic hazard analysis computer code have been undertaken (see LLNL Report UCRL-ID-115111 [6]). These modifications to the overall LLNL methodology have led to a 1993 revision of LLNL seismic hazard results for 69 EUS sites, as documented in NUREG-1488 [7].

The revised/1993 LLNL mean hazard results differ considerably in absolute magnitude from the earlier, 1989 LLNL results. Generally speaking, vis-à-vis the 1989 LLNL hazard results, the revised/1993 LLNL seismic hazard results are much closer, in terms of absolute levels of hazard, to the 1989 EPRI hazard results.

Two issues are raised in consideration of the revised LLNL seismic hazard results. First, because the revised LLNL hazard results differ considerably from their predecessors, it is reasonable to ask what effect the differences in hazard might have on the IPEEE binning assignments. Second, because the 1993 LLNL results are much closer in absolute magnitude to the 1989 EPRI results, it is relevant to explore the validity and implications of a binning approach which gives greater consideration to absolute comparisons of seismic hazard.

These issues have been considered in a white paper entitled "Justification for Reduction in IPEEE Program Based on Revised LLNL Seismic Hazard Results" [8] produced by the Nuclear Energy Institute (NEI). That paper describes an approach proposed by utilities for re-assigning plants from the focused-scope seismic review category to the reduced-scope category based on comparisons and criteria that depend on absolute levels of seismic hazard.

Partly in response to the NEI white paper, this study has been undertaken to evaluate the potential impacts of the revised LLNL seismic hazard estimates on IPEEE seismic-scope assessments.

1.2 Purpose of this Study

Given the foregoing background, the purpose of the present study has been to investigate the relevance of comparisons based on absolute levels of seismic hazard to seismic-scope re-assessment. A related objective has been to develop potential guidelines for seismic-scope re-assessment that are designed to meet the objectives of the IPEEE and the intent of severe-accident policy, while meaningfully accounting for reductions in LLNL seismic hazard results.

Because initial comparisons indicate that the relative, site-to-site variations in hazard are similar for the 1989 LLNL results and the revised LLNL results, it is not expected that binning assignments would be significantly altered within the context of the original binning process, which relied predominantly on relative comparisons of seismic hazard. For the revised LLNL hazard results to have a meaningful impact on seismic binning, one obvious alternative to use of relative comparisons of seismic hazard is the use of absolute comparisons. From the outset of this study, therefore, a fundamental intent has been to explore development and evaluation of a seismic-scope re-assessment approach which depends on criteria related to absolute levels of seismic hazard.

Since there exist large uncertainties in absolute levels of seismic hazard estimates (meaning that the "true" state of nature of seismic hazard is still vague), it is not considered reasonable to dismiss the original overall IPEEE binning assignments that were based on relative hazard comparisons. In fact, because the pattern of relative site-to-site variations in hazard are similar for 1989 LLNL, 1989 EPRI, and 1993 LLNL hazard results, the original IPEEE binnings are still considered to be substantially valid. (Correspondingly, it is considered more likely, for instance over the next decade, that the absolute levels of perceived seismic hazard would be altered, as opposed to the relative, site-to-site variations. Hence, largely preserving the overall, relative-based binning approach is expected to help protect, or de-sensitize, plants from increases in seismic review requirements that might be suggested due to future changes in the perception of seismic hazard).

Particularly noteworthy in the present seismic-scope re-assessment effort is the view of continued validity of the basis originally implemented for establishing the reduced-scope bin. In the original IPEEE binning process, certain plants were assigned to a reduced-scope IPEEE review bin based on having a comparatively low seismic hazard. These plant sites have the lowest (relative and absolute) levels of seismic hazard in the U.S. Because the revised LLNL results have not significantly altered the perception of these lowest-hazard sites, it is not considered appropriate to re-bin a larger set of plants to the reduced-scope seismic-review category.

Even though the original binning of reduced-scope plants, based on relative comparisons of seismic hazard, is still viewed as the most appropriate basis for identifying and treating sites with lowest seismic hazard, it is considered reasonable that a group of plants may be re-binned on the basis of minor absolute seismic contribution to risk of core damage. Specifically, because the revised LLNL mean hazard results are "universally" (i.e., for all plants) lower than the 1989 LLNL results, estimated mean seismic core-damage frequencies will correspondingly be lower for all plants, using the 1993 LLNL results. It is thus recognized that, for some plants, the expected reduction in mean seismic core-damage frequency will alter the perception of seismic events from being a notable contributor to being a minor or low contributor to the overall mean risk of core damage. For these plants, it is judged reasonable to consider the potential for adjustment of the original assessment of the IPEEE review scope for seismic events. A convenient, logical, and meaningful format for accommodating this review-scope re-assessment within the original binning format, is to increase the binning gradation by adding an appropriately modified review-scope category and re-assigning plants to this new review-scope bin, as justified. (This approach is akin to the original development of focused-scope and reduced-scope seismic-review sub-categories, as a means of increasing the gradation of seismic IPEEE binning to improve applicability of seismic-scope assessment to plants having a broad range of seismic hazards). As will be clarified later in this paper, it is most appropriate that this modified review-scope category be treated as a sub-division of the original focused-scope review category. In other words, only those plants originally in the focused-scope seismic review category are considered as candidates for a seismic review-scope reduction (to a proposed modified-scope category).

In addition to re-binning a subset of focused-scope plants to a proposed modified-scope review category (based on comparisons related to absolute levels of seismic hazard), it is considered reasonable to also propose an allowable reduction in seismic IPEEE requirements that may be uniformly applied to all focused-scope plants. The justification for this "global" reduction is that the perceived seismic hazard has decreased, thus alleviating concerns that certain (more-rugged) components would be identified as meaningful sources or contributors to seismic severe-accident risk. In other words, a subset of the more rugged components can be effectively screened out from further evaluation, provided the plant seismic walkdown does not indicate an unusual condition. The reduction in seismic IPEEE review requirements for all focused-scope (and proposed modified-scope) plants, therefore, would logically take the form of a list of items/components for which capacity calculations (i.e., fragilities or HCLPFs) need not generally be performed.

Consistent with the foregoing discussion, the specific purposes of the present study are: (1) to define general criteria for identifying plants where the absolute levels of seismic core-damage risk are expected to be minor (in comparison to the risk from all causes or in comparison to safety-goal-related criteria for total core-damage risk); (2) to perform the technical analyses to demonstrate the new sub-division of (original focused-scope) plants that meet these risk criteria; (3) to establish the basis for incorporating an additional review-scope method into the present gradation of review-scope methods for IPEEE binning, with plant assignments in this new review-scope bin being supported by the risk criteria and analyses produced from (1) and (2); (4) to develop an appropriate set of modified procedures and guidelines for the new scope of review; and (5) to develop a preliminary list of components that are expected to be sufficiently rugged such that they can be generally screened out from further consideration in a focused-scope or proposed modified-scope review. (A more detailed investigation of approaches for pre-screening components, and development of potential seismic-scope modifications that may be applied to all focused-scope plants, is presented in a supplementary companion report entitled "Approaches for Modifications of Seismic IPEEE Guidelines for Focused-Scope Plants" [9]).

1.3 Overview of Original IPEEE Review-Scope Gradation and Binning Approach

Appendix A of NUREG-1407 describes the methods and basis used for the original IPEEE review level earthquake (RLE) binning. As mentioned previously, this approach was predominantly based on relative site-to-site comparisons of seismic hazard.

Three sets of hazard results were used for each set of hazard comparisons: (1) the 1989 LLNL four-expert (4GX) results, (2) the 1989 LLNL five-expert (5GX) results, and (3) the 1989 EPRI results. The statistics of seismic hazard used in making comparisons included the mean, median, and 85th percentile. For assigning plants to the 0.5g, 0.3g or reduced-scope bin, the measure of seismic hazard used in the assessment was the composite probability of exceeding the NUREG/CR-0098 [10] 5%-damped median spectral shape anchored to a peak ground acceleration (PGA) of 0.3g. The composite probability was obtained by weighting hazard results as follows: (1/7) weight to PGA hazard, and (2/7) weight each to ground-response-spectral hazards for vibration frequencies of 2.5Hz, 5Hz, and 10Hz. For sub-dividing the 0.3g plants into either the full-scope or focused-scope bin, the composite probabilities of exceeding the plant seismic design basis were used.

In each case of binning (0.5g, 0.3g, and reduced-scope) and sub-binning (full-scope and focused-scope), a relative ranking/grouping of plants, based on each seismic hazard measure, was conducted using a clustering methodology developed by LLNL for the NRC [11,12]. A set of consistency criteria were then applied to the ranking results obtained for each hazard measure, thus developing a unique overall ranking for the plants. When applied to the initial binning among 0.5g and 0.3g plants, the consistency criteria insured that inclusion into the 0.5g bin was supported by all seismic hazard studies. When applied to obtaining the reduced-scope bin, the consistency criteria allowed for two bottom median-based groups, rather than just a single bottom grouping based on median hazard. In addition, plants for which no EPRI hazard results were available were still assigned to the reduced-scope bin, provided that such binning was supported by both the four-expert (4GX) and five-expert (5GX) LLNL studies.

Absolute comparisons of seismic hazard were thus not explicitly employed in performing the initial binning and sub-binning for seismic IPEEE review scopes. In supporting the placement of plants into the 0.5g bin, a check or test based on absolute levels of hazard, however, was introduced. This test provided a "sanity check" that the seismic hazard was sufficiently high (in absolute terms) to warrant inclusion in the 0.5g bin. The test essentially provided that the (minimum) HCLPF (high-confidence of low probability of failure) capacity (of a hypothetical plant located at the site of interest) required to limit the mean seismic core-damage frequency to a level of $1x10^{-5}$ would not be lower than 0.3g (i.e., the 5%-damped, median NUREG/CR-0098 spectrum anchored to a PGA value of 0.3g). In other words, if the hypothetical plant had a HCLPF capacity just equal to 0.3g, and yet its computed mean seismic core-damage frequency equalled, or exceeded, a level of $1x10^{-5}$ core damages per reactor year, only then would a 0.5g binning assignment be confirmed (on an absolute basis). The justification for this check is that if the minimum plant HCLPF capacity required to limit the computed mean seismic core-damage frequency to a low level exceeded 0.3g, then seismic IPEEE review at a level of 0.5g would be warranted in finding plant-specific seismic vulnerabilities. On the other hand, if the minimum HCLPF capacity required to limit the mean seismic core-damage frequency to a low value were less than 0.3g, then there would be no need to perform the seismic IPEEE review at a level as high as 0.5g; rather, seismic IPEEE review at a level of 0.3g would be justifiably sufficient. It is noteworthy that this absolute use of seismic hazard results (and related criteria) was not relied upon as a primary binning basis, nor did it constitute a level of acceptability regarding seismic core-damage frequency. Plant licensees were expected to identify and report all relevant seismic vulnerabilities and dominant contributors, or outliers, for their plants. (For a seismic probabilistic risk assessment [PRA], such reporting would occur for individual systemic sequences having a core-damage frequency equal to, or exceeding, 1×10^{-6}. For a seismic margin assessment [SMA], reporting would occur for all components not screened out at the RLE [or seismic margin earthquake (SME)] level, based on use of conservative seismic-margin screening tables.)

The approach implemented, as discussed in NUREG-1407 and summarized above, for developing the original IPEEE seismic-scope binning still remains valid. Furthermore, since this approach relies predominantly on relative comparisons of hazard, re-implementing it with the revised LLNL seismic hazard results is not expected to significantly alter the overall binning results. There is no clear, compelling technical basis, therefore, to change the original overall binning (0.5g, 0.3g, and reduced-scope bins) strategy and results. Rather, because the approach is still valid, and because many seismic IPEEEs are now well underway (at the time of the writing of this report), it is considered important that the original binning approach and results remain largely undisturbed in the seismic-scope re-assessment.

1.4 Overview of NUREG-1488 Hazard Results

NUREG-1488 [7] presents results of the 1993 revised LLNL seismic hazard analyses for 69 EUS nuclear power plant sites. The results include hazard curves for PGA and uniform hazard spectra (UHS) for return periods of 500, 100, 2000, 5000, and 10,000 years. UHS are delineated by motion amplitudes at vibration frequencies of 1Hz, 2.5Hz, 5Hz, 10Hz, and 25Hz. Hazard-curve and UHS results are presented for the mean hazard and for the 15th, 50th (median), and 85th percentiles of hazard.

Although NUREG-1488 does not present the actual hazard-curve data for the 5 vibration frequencies considered in the seismic hazard analyses, such results were available for use in the present study. Hence, analyses conducted in this study (e.g., producing estimates of mean seismic core-damage frequency, required HCLPFs, etc., as described in Appendix A) are always based on exceedance frequencies obtained from the more-fundamental hazard-curve data, as opposed to the derived UHS results.

As documented in NUREG-1488, the revised LLNL hazard results are to be considered as updates to the earlier LLNL hazard results -- i.e., updated hazard estimates that will be used in future NRC actions. Hence, these revised hazard results are intended to replace the earlier 4GX and 5GX 1989 LLNL hazard results.

1.5 Relationship of NUREG-1488 Results to IPEEE Binning

Even though the revised LLNL hazard curves replace the earlier LLNL hazard curves, as noted earlier seismic-scope binning assessments based on relative, site-to-site comparisons of seismic hazard are not expected to change significantly when using the revised hazard curves. This expectation is supported, for instance, by comparisons such as shown in Figures 1-1 and Figures 1-2. These figures show site-to-site variations in median composite annual probability of exceeding the 0.3g NUREG/CR-0098 spectrum, for the 1993 revised LLNL seismic hazard results vis-à-vis, respectively, the 1989 LLNL 4GX and 5GX results. (Note, the composite annual exceedance probability is defined according to the weighting approach discussed in Section 1.3 above). As can be seen in these two figures, the patterns of relative, site-to-site variations in median seismic hazard are quite similar for the 1989 sets of LLNL results and the 1993 set of LLNL results.

As can perhaps be best seen in the corresponding plots of Figures 1-3 and 1-4 (now based on mean hazard results), however, a substantial change in the absolute level of perceived seismic hazard has occurred for the revised LLNL results. Consequently, the revised LLNL hazard results have a meaningful impact on IPEEE seismic-scope re-binning when some form of absolute comparison of mean seismic hazard is introduced as a criterion in the re-binning process.

The absolute-based re-binning criteria should not be applied to all plants, since relative comparisons serve as the primary basis for developing major/gross plant binnings. Hence, the absolute levels of hazard of the NUREG-1488 results will impact the finer sub-division of the 0.3g bin, in particular, the sub-division of the original focused-scope category into focused-scope and proposed modified-scope review sub-categories.

1.6 Overview of this Document

The remainder of this report documents the technical basis and results of IPEEE seismic scope re-assessments for EUS nuclear power plants, considering the revised LLNL seismic hazard results. Section 2 re-emphasizes the IPEEE objectives, and stresses the critical importance of performing a high-quality seismic review regardless of the particular review category. Specific items of concern that must be given special attention for plants that are re-assigned to a proposed modified-scope bin are identified and discussed.

Although this report describes the basis for seismic-scope reductions in IPEEE reviews of certain plants, the revised status is developed as a minimum procedural guideline, as opposed to a recommended course of action. In this regard, Section 2 also discusses some aspects of the immediate and long-term benefits that are expected to be derived by licensees that elect to perform a more comprehensive seismic review than that dictated by the minimum procedural guideline.

In Section 3, proposed modified-scope evaluation procedures and analyses are described, together with the proposed results for proposed modified-scope re-binning based on the revised LLNL hazard results.

An overview of the overall technical approach for re-assigning plants to the proposed modified-scope category is presented in Section 4. The basis is described for selection of binning criteria that depend on absolute levels of seismic hazard and risk.

Section 5 describes other proposed seismic-scope re-assessment impacts. These impacts take the form of reductions in review requirements for all focused-scope (and proposed modified-scope) plants. The basis and results of the development of a list of components that may be screened out of the seismic IPEEE review process for these plants are presented.

In conclusion, Section 6 provides a summary of the key methods and results of this study, as well as a discussion of their intended application. Section 7 provides a list of references.

An appendix to this report is provided to supplement and support the discussions in the main text. Appendix A presents the technical procedures and results of computations of seismic core-damage frequencies and related measures used in applying the re-binning criteria. Methods based on the use of conservative, generic fragility data are discussed.

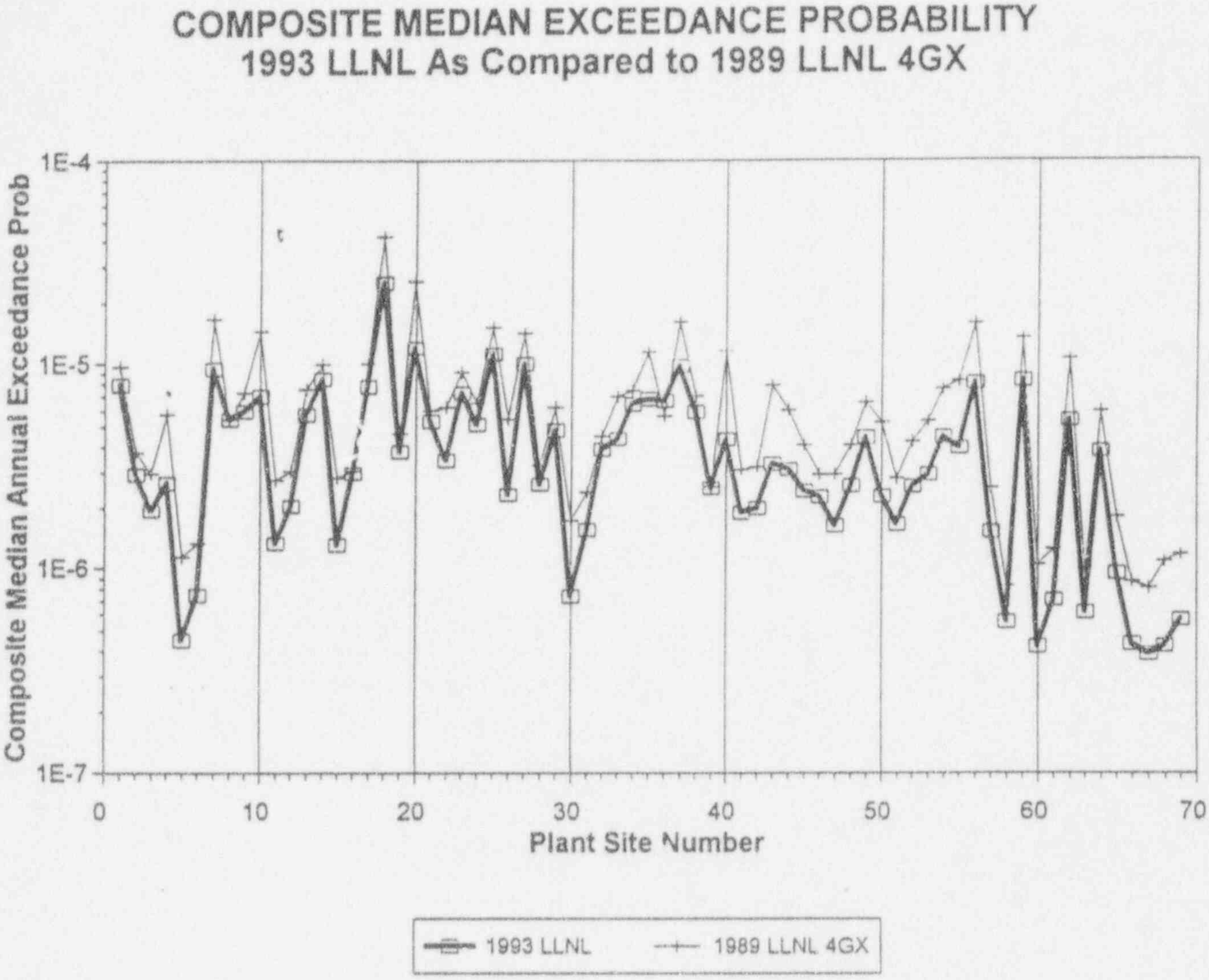

Figure 1-1. Site-to-site variations in composite median seismic hazard results for the 1989 LLNL 4GX seismic hazard analysis, as compared to variations in corresponding results for the 1993 revised LLNL seismic hazard analysis.

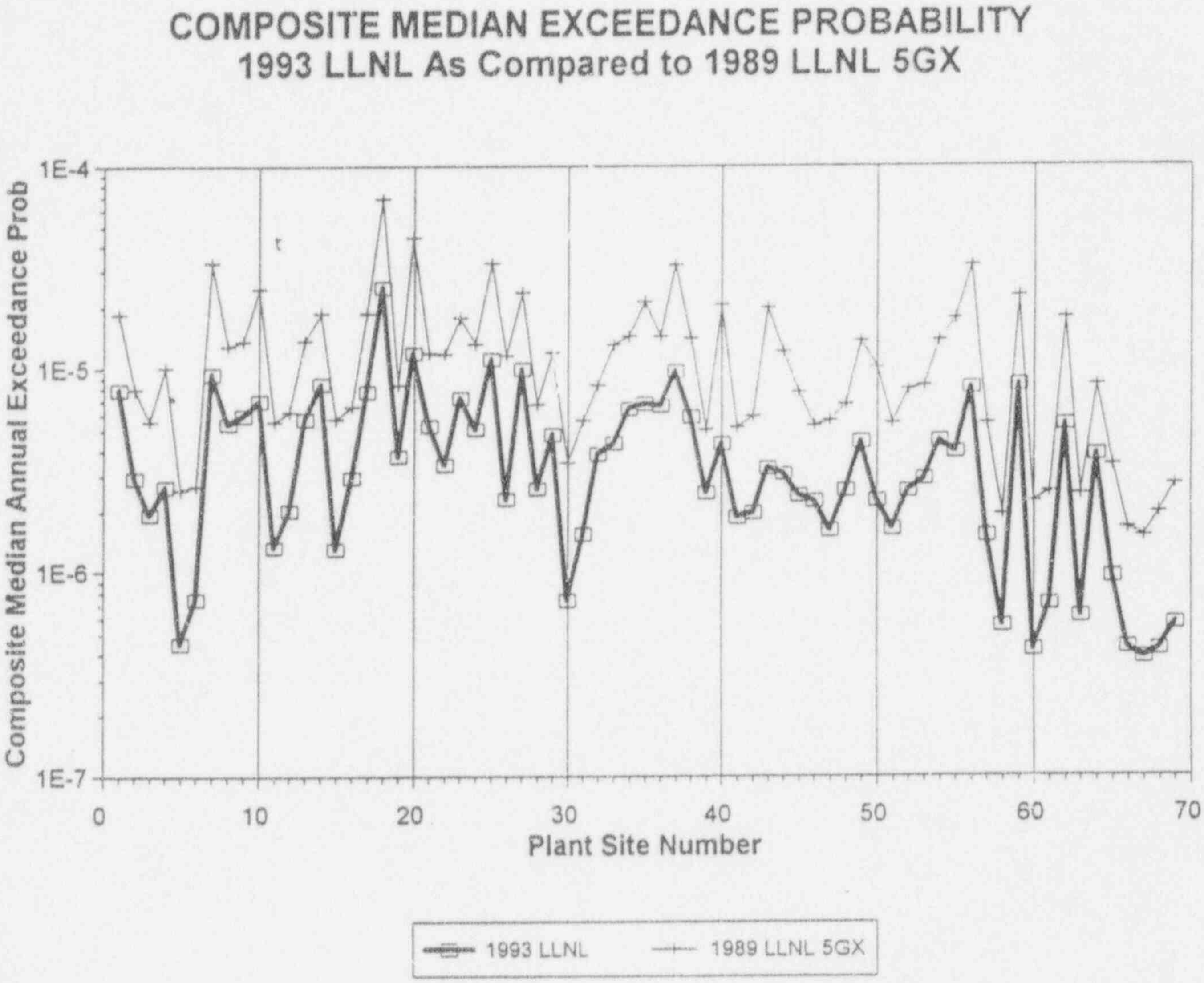

Figure 1-2. Site-to-site variations in composite median seismic hazard results for the 1989 LLNL 5GX seismic hazard analysis, as compared to variations in corresponding results for the 1993 revised LLNL seismic hazard analysis.

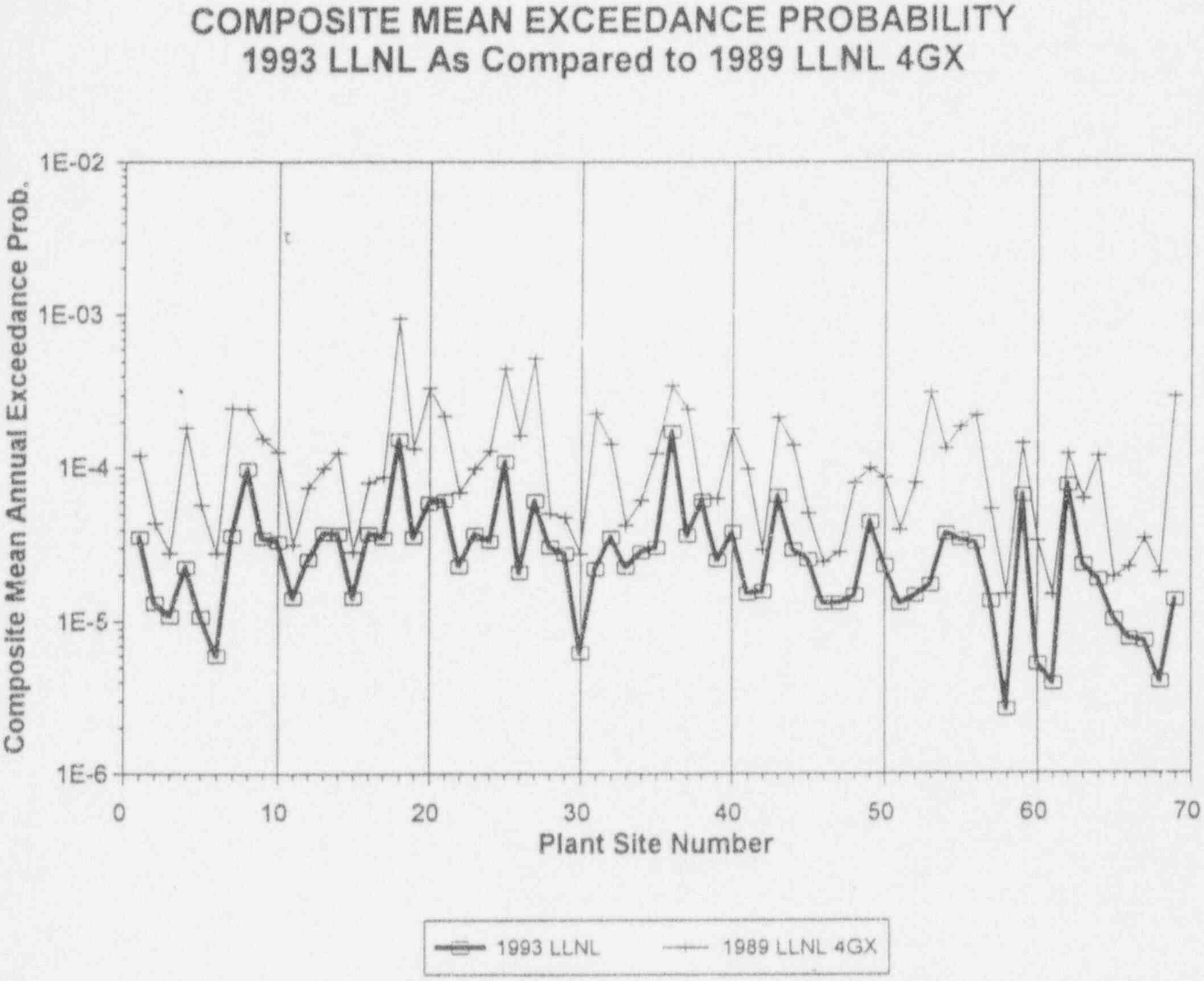

Figure 1-3. Site-to-site variations in composite mean seismic hazard results for the 1989 LLNL 4GX seismic hazard analysis, as compared to variations in corresponding results for the 1993 revised LLNL seismic hazard analysis.

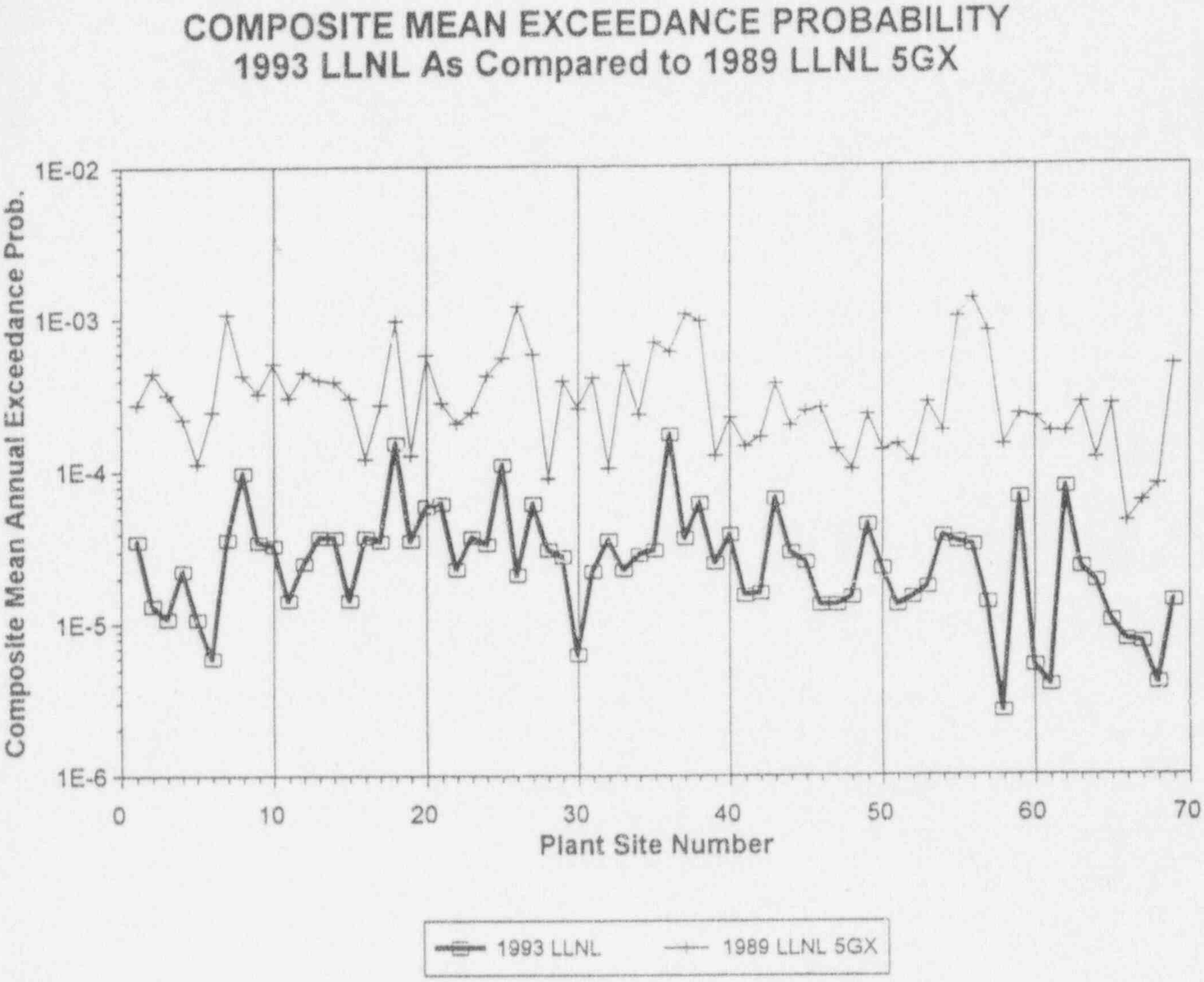

Figure 1-4. Site-to-site variations in composite mean seismic hazard results for the 1989 LLNL 5GX seismic hazard analysis, as compared to variations in corresponding results for the 1993 revised LLNL seismic hazard analysis.

Section 2

TECHNICAL CONCERNS ASSOCIATED WITH RE-BINNING

There arise a number of technical issues and related concerns with respect to the implications of seismic-scope re-binning. As already suggested, the re-binning assessment results in reduced minimum procedural guidelines for conducting seismic IPEEE reviews for some plants. This reduction in scope is intended as an allowance or provision in consideration of reduction in perceived seismic hazard; the re-binning should not be construed as an endorsement or recommendation for reducing the seismic review scope to a level lower than that recommended already in NUREG-1407. Sections 2.2 and 2.3 provide some discussion related to the potential immediate and long-term advantages to plant licensees of not pursuing allowable reductions in seismic review scope provided by re-binning.

It is recognized that a comprehensive, thorough seismic walkdown serves as the foundation of any seismic IPEEE review. The walkdown is the means by which potentially vulnerable conditions are initially identified and screened for further evaluation. Without a plant walkdown, there is obviously little basis for performing such screening, undertaking analytical evaluations, and making decisions concerning plant-specific vulnerabilities. For these reasons, it is generally agreed that the walkdown represents the most important aspect of any seismic review. More relevantly, it is the fundamental element of any meaningful seismic review. Provided that the effort expended in the plant seismic walkdown is not compromised, therefore, a reduction in seismic review scope can be allowed with the expectation that a meaningful seismic review can still be conducted, producing valid insights into potential severe-accident behavior. On this basis primarily, it is not considered irrelevant that a modification to seismic review scope for plants expected to have low perceived seismic risk can be proposed. The modification in review scope, however, places still greater importance (corresponding to the increased reliance) on the plant walkdown. It is thus imperative that no requirements or procedures characteristic of the highest quality walkdown be relaxed in a modified-scope review.

Although, without question, the seismic walkdown is critically important to the seismic review process, this importance does not imply that other elements of a seismic review are neither important, meaningful, nor justified. In fact, it is much more difficult to draw accurate and consistent conclusions regarding dominant contributors, risk-dominant outliers, and other insights important to the objectives of severe-accident policy, without some level of quantitative analysis or evaluation. Furthermore, the basis for making a decision concerning whether or not to modify a potentially vulnerable condition is weakened without quantitative results. In such instances, where quantitative results are unavailable and qualitative judgment is applied, prudence dictates that an appropriate level of conservatism be introduced into the decision process. A situation may thus arise where a component is unnecessarily modified or replaced. That is, if quantitative results were obtained, a decision not to undertake a proposed modification might have been supported as a justified choice. The cost of any such modification may in all likelihood well exceed the cost of conducting the necessary quantitative analyses to better define the significance of potential vulnerabilities.

The foregoing issues are considerations to be kept in mind by plant licensees in deciding the type of seismic IPEEE review to conduct for their plant(s). The primary purpose of this section is to identify and discuss issues and conditions that need to be addressed and satisfied in order for seismic-scope re-binning to be fully applicable and justified. These conditions constitute necessary caveats pertaining to the re-binning approach and results.

2.1 IPEEE Objectives

It is imperative to recognize that the seismic IPEEE objectives, in support of severe-accident policy, remain unaltered in the present re-binning assessment. These objectives are re-stated here for emphasis. As outlined in NUREG-1407, the primary objectives of the IPEEE are for each plant licensee:

1. To develop an appreciation of severe-accident behavior;
2. To understand the most likely severe-accident sequences that could occur at the licensee's plant under full-power operating conditions;
3. To gain a qualitative understanding of the overall likelihood of core-damage and fission-product releases; and
4. If necessary, to reduce the overall likelihood of core damage and radioactive material releases by modifying, where appropriate, hardware and

procedures that would help prevent or mitigate severe accidents.

Ultimate responsibility falls on a plant licensee to insure that the above objectives are all met in the IPEEE submittal. In particular, it must demonstrate in the submittal that the most significant risk contributors or dominant vulnerabilities (or outliers) have been identified and that these are properly addressed by corrective action, as necessary. These objectives may be difficult to achieve fully if quantitative analysis is eliminated from the seismic review procedure.

For reduced-scope plants, where the expected seismic risk is sufficiently negligible compared to the risk from other accident initiators, the SSE design basis itself is considered to be an appropriate severe-accident level. Hence, verification of the design basis (together with other review elements) is considered to be largely sufficient in satisfying IPEEE objectives for these plants. Such is not the case for candidate modified-scope plants where the seismic contribution to core-damage risk is expected to be low, yet of non-negligible significance. For these plants, no simplified surrogate to the IPEEE objectives can be generally applied.

Discussion of the following issues, concerns, and conditions is provided to assist plant licensee's in meeting the IPEEE objectives for cases where a modification to seismic review scope is indicated and opted by the licensee.

2.2 Implications of Hazard Uncertainty

The primary impetus for the present IPEEE seismic-scope re-assessment is the occurrence of a revision to the LLNL seismic hazard results. Two related points are particularly worthy of note relative to the implications of these hazard revisions, other than their immediate impact on expected reductions in estimates of seismic core-damage risk.

First, the revised LLNL hazard results still exhibit large uncertainty bounds. The large uncertainties are symptomatic of the fact that causes and characteristics of seismic ground motions in the eastern U.S. are substantially vague. Significant knowledge and understanding of eastern U.S. seismic hazard has not yet been achieved.

Second, it should be recognized that the current revised LLNL hazard results (or results from any other available seismic hazard analysis) do not convey any sort of notable break-through in knowledge of eastern U.S. seismic hazard, relative to earlier hazard results. Perceptions of seismic hazard in the eastern U.S. have changed steadily over time, and can be expected to change significantly in the future until a high degree of knowledge, and consensus of knowledge, is achieved. (It is not uncommon that updated mean seismic hazard estimates do not even fall within the significant uncertainty bounds developed in previous estimates of the seismic hazard).

Estimates of seismic hazard for the eastern U.S. thus remain highly vulnerable, subject to potential major future changes as additional knowledge and earthquake experience is accumulated. This fact should not instill great confidence in current seismic hazard estimates, so as to encourage one to place great reliance on their implications, particularly in safety-related decision making. It is clearly certain that estimates of seismic hazard will change in the future, with the real possibility that the current estimates will at some time be viewed as (or shown to be) unconservative.

With respect to the actual (yet unknown) state of nature of seismic hazard in the eastern U.S., it is not only possible that current estimates of seismic hazard are truly unconservative, but it also may be the case that the true state of nature of seismic hazard is not even well described by the current uncertainty bounds on hazard. This does not mean that current estimates of seismic hazard are worthless. Rather, they do have notable valuable in decision making provided they are properly used. It is recognized that there may exist the tendency in the use of seismic hazard estimates to view the numerical results (including uncertainty estimates) as being firm, stable values. Any such tendency may likely encourage fallacious reasoning, producing invalid conclusions, and should be avoided.

The preceding facts should not be ignored in responsible seismic safety management and regulation of nuclear power plants; otherwise, a short-term decision process will result, thus increasing the instability of future seismic programs and of long-term seismic decision-making processes. The uncertain present state of knowledge of seismic hazard should rather encourage a more cautious, conservative outlook that increases long-term stability of seismic safety management decisions.

These issues should be kept in mind when conducting seismic IPEEEs; plant licensees are advised to act accordingly in reducing their exposure to potential future changes in perceptions of seismic hazard.

2.3 Completeness and Rigor of Seismic IPEEE Assessment

An additional issue/concern that plant licensee's need to consider in satisfying IPEEE objectives, in cases where a modification to seismic review scope is allowed, pertains to the completeness and rigor employed in the modified-scope seismic IPEEE assessment.

In particular, a licensee needs to insure that the modified seismic review, including plant walkdowns, are performed with the same high quality, detail and comprehensive nature as would be employed in a modern full-scope seismic margin study or seismic PRA study that meets IPEEE guidelines. Licensee staff, and contractors hired by the licensee, should all recognize that the thoroughness and quality of the seismic review should not be relaxed simply because an adjustment in review scope is made.

For reasons noted previously, the plant walkdown is viewed as one of the most important aspects of the seismic IPEEE review. This does not suggest, however, that it can be taken for granted that the walkdown will be a strength of the seismic IPEEE. In past seismic studies, well-experienced seismic review team (SRT) members have generally taken the major role in conducting plant walkdowns. Their experience in a variety of aspects of seismic evaluation, in-depth knowledge of dynamic response, and broad understanding of structural response and potential failure modes are perhaps the most significant reasons why seismic walkdowns are so favorably viewed today. It is recognized, however, that licensees are encouraged to have a meaningful participation in all aspects of IPEEE implementation. Thus, licensee staff will undoubtedly have a more significant involvement in plant seismic walkdowns than has conventionally been the case in the past. While this is a positive aspect of the IPEEE review from a long-term outlook (since licensees understanding of their plant will be considerably enhanced with time), it presents potential shorter-term problems related to the applicability of the walkdown findings. In particular, licensee staff involved in the walkdowns cannot generally be expected to have the same depth and breadth of knowledge as do experienced SRT-member consultants. This observation applies despite the fact that licensee staff have participated in seismic IPEEE training courses.

If experienced SRT members do not have the major role in conducting plant walkdowns -- to insure the validity of the findings -- the plant walkdown could very well represent a significant weakness of the seismic IPEEE review. Hence, the often cited argument that the plant walkdown is the strength of the IPEEE (and hence, the only element of the IPEEE having real significance) cannot be simply presumed. Furthermore, even if the walkdown is well executed, there is still no obvious compelling basis for eliminating other aspects of the seismic IPEEE review which do, in reality, have considerable significance as well.

The preceding points are important for licensees to consider, in order to: first, make sure that the plant walkdown is well executed with oversight and major involvement of experienced SRT members who understand that procedural requirements cannot be relaxed when reviewing modified-scope plants; and second, to recognize that a well-executed plant walkdown does not itself eliminate the need to consider other aspects of seismic review relevant to IPEEE submittal that may be important in meeting IPEEE objectives.

In any case, allowable modification to the seismic IPEEE review scope for a given set of plants, as developed in this paper, should not be viewed as a basis for reducing the quality and thoroughness of the review. For any seismic IPEEE, regardless of scope, it must be insured that a high standard of completeness and rigor is maintained.

2.4 Required Evaluations

As is discussed in greater detail in Section 4, the assessment undertaken for re-binning plants from the existing focused-scope sub-bin to the new modified-scope review category, involves use of generic seismic fragility and seismic margins data, as derived from past seismic studies. The results of capacity evaluations from these past studies apply to the respective plant condition realized after certain modifications were undertaken. To justify use of the plant data, therefore, it is necessary that such conditions be identified and corrected as part of the seismic IPEEE review for a modified-scope plant evaluation.

In addition, NUREG-1407 delineates certain seismic IPEEE evaluation requirements and enhancements that may generally go beyond the elements of review undertaken in past studies. Although these evaluation requirements would generally be included in the scope of modern PRA or SMA methods, enhancement of even these methods may be required. Consequently, to meet the standard of NUREG-1407 guidelines, use of data from past seismic studies needs to be buttressed with relevant caveats.

In evaluating the estimates of mean seismic core-damage frequency which serve as the basis for re-binning the existing focused-scope plants, the conservative-generic estimates of plant fragility, as derived from past studies, have been used with the assumption that all associated caveats would be met. Such applicability of the generic fragility parameters, therefore, requires that the following items are given special consideration in a modified-scope seismic IPEEE review.

2.4.1 Relay chatter.

Relay chatter has been identified as an item of concern, potentially effecting plant seismic safety, in the majority of seismic evaluation studies conducted to date. The seismic IPEEE review must, therefore, involve an appropriate evaluation and corrective treatment of relay chatter for safety-related electrical equipment. The primary objective is that all "bad actor" relays that may potentially impact plant safety be identified and replaced with non-vulnerable, solid-state relays. Elements of relay chatter evaluation for a modified-scope review are described further in Section 3.

2.4.2 Block walls.

The earthquake experience database, together with analytical evaluations of seismic fragility, demonstrate that masonry/block walls are substantially vulnerable to earthquake input. Although this type of construction would not be considered appropriate for use in modern design of nuclear power plants, it has been used in the design and construction of several existing plants. Past PRAs and margin studies have demonstrated that masonry/block-wall failure is an item of significant safety concern in existing nuclear power plants. On a generic basis, therefore, masonry/block walls can be classified as a potential vulnerability at plants where they have been built and where they effect components required for safe plant operation.

Identification and evaluation of masonry/block walls must, therefore, be included as a primary element of the seismic IPEEE review. The objective of this effort is to evaluate (and correct, if necessary) any situation that potentially may present a significant threat to plant safety or that may invalidate the applicability of the generic fragility estimates used in re-binning.

2.4.3 Flat-bottom tanks.

Earthquake experience data and analytical fragility evaluations have also demonstrated flat-bottom tanks to be potentially vulnerable to earthquake ground motion. The typical failure mode of concern is the well-known "elephant foot" buckling at the base of the tank, causing loss of liquid contents and potential tank collapse.

In a nuclear power plant, potential failure of flat-bottom tanks poses the threat of induced flooding in addition to the consequences of loss of function of the tank(s). Past seismic studies of nuclear power plants have identified flat-bottom tanks as low-capacity components. Such components include the refueling water storage tank (RWST) and the condensate storage tank (CST), whose failure(s) often have significant impacts on plant safety.

Identification and margin-capacity evaluation of flat-bottom tanks must, therefore, be included as a fundamental element of the seismic IPEEE review. The objective of this effort is to correct any situation that may present a significant threat to plant safety or that may invalidate the applicability of the generic fragility estimates used in re-binning.

2.4.4 Other items.

The above-mentioned items do not define a comprehensive list of general vulnerabilities that have necessitated correction as a result of past seismic studies. There are several other items that should be considered as well. These pertain mostly to potential cases of inadequate anchorage and/or bracing and potential for adverse physical interactions. Building impact/pounding is just one example of a potentially vulnerable condition that should be corrected as a result of the seismic IPEEE, as has been the case as a result of past seismic studies.

The types of other items of relevance here, that must be identified and corrected so that the generic plant data are applicable, include those items generally identified and corrected as a result of past PRA studies. These other items are easily identified in a well-executed plant walkdown and are comparatively straightforward to rectify or address. The objective of this treatment of such items is to eliminate generally vulnerable conditions that usually require no special analysis to identify, thus insuring that the mean seismic core-damage frequencies computed in this study are applicable and appropriately justified as a basis for plant re-binning.

Section 3

PROPOSED MODIFIED-SCOPE EVALUATION PROCEDURES AND RE-BINNING RESULTS

This section delineates the procedural guidelines of a proposed modified-scope seismic review and presents the results for plants that have been re-binned from the original focused-scope category to the new modified-scope bin. Section 4 describes the overall approach and criteria implemented for the re-binning assessment, in deriving these results.

Before presenting the guidelines for a proposed modified-scope review and the re-binning results, a brief discussion explaining the background for development of the proposed modified-scope category is provided.

3.1 Background on Development of Proposed modified-scope Seismic Review Category

Figures 1-3 and 1-4 indicated that the revised mean LLNL seismic hazard results are lower, for all plant sites, than corresponding mean hazard results from the 1989 LLNL 4GX and 5GX analyses. (Note from Figures 1-1 and 1-2, however, that the median hazard results demonstrate greater similarity, particularly for the 1993 revised LLNL versus 1989 4GX LLNL comparison). These results directly imply that the perceived levels of mean seismic core-damage frequency have decreased for all plants. These decreases may serve as justification, for some plants, for reducing the scope of the minimum required seismic review.

Given that reductions in seismic review scope may be justified as a result of the revised LLNL hazard estimates, there are two major questions that need to be addressed: First, what plants should qualify for an allowable reduction in seismic review-scope; and second, what format should be implemented in defining the allowable reductions in review scope.

These questions relate directly to the review-scope gradation that is available for plant re-binning. At first consideration, it may seem appropriate that a reduction in review scope should be allowed for all plants since, after all, hazard results for all sites have decreased. There are three primary reasons, however, why allowance of a universal reduction in review scope should not generally be permitted. First, there exists a limited set of available review scopes to define the binning for plant gradation. Each plant cannot have its own unique scope of seismic review. Decreases in mean seismic hazard for a given site may not be sufficient to move a plant out of its present review-scope bin. Second, plants that do shift to a lower review-scope bin are vulnerable to shifting back up to a higher review-scope bin if future hazard results suggest that their perceived seismic hazard has increased. Consequently, if the review-scope were reduced for all plants, all plants would be vulnerable to future increases in perceived hazard. Finally, potential reductions in review scope are being based on changes in absolute hazard. This is the case because re-binning would not be meaningfully justified based on relative comparisons of seismic hazard. Relative hazard comparisons, however, serve as a sound (and more-stable) basis for conducting review-scope binning assessments; they should be given substantial consideration in the re-binning process. Hence, relative hazard should still serve as the primary basis for major overall plant binning assessment.

Based on these considerations, it is clear that not all plants may or should qualify for a reduction in seismic review scope. In particular, the existing major binning assignments (0.5g, 0.3g and reduced-scope) need to be preserved. These major binning assignments remain valid on their original grounds of relative hazard comparisons, and they are substantially robust. Within the 0.3g bin, a sub-division into full-scope and focused-scope categories was conducted in the original binning approach. Relatively few plants in the 0.3g bin (7 out of 57 total) were assigned to the full-scope category; the remaining majority of 0.3g plants were placed in the focused-scope bin. Plants in the 0.3g bin were assigned to the full-scope category based on having a comparatively high composite probability of exceeding the plant-specific seismic design basis (i.e., the plant SSE level). Furthermore, the plants in this category have sufficiently high levels of seismic hazard to preclude their having low estimated seismic core-damage frequencies, even with the revised LLNL hazard results. Consequently, the set of plants assigned to the existing 0.3g focused-scope bin should also remain unaltered.

In answer to the question of which plants should qualify for a reduction in seismic review scope, therefore, it is most consistent (with pragmatics and the existing binning basis) that re-binning effects only the original set of focused-scope plants. This approach is also logical, in that plants which were originally binned into a higher review-scope category would not have sufficiently low seismic hazard to result in a low estimated absolute level of seismic core-damage frequency. In other words, the focused-scope category clearly encompasses all plants for which low levels of computed mean seismic core-damage frequency (based on the 1993 revised LLNL hazard results) might possibly be obtained; i.e., plants in other review-scope categories would not generally produce low estimates of mean seismic core-damage frequency. The approach of limiting the applicability of re-binning to the set of focused-scope plants is also very meaningful in that this set of plants encompasses the majority of eastern U.S. nuclear power plants.

A reduced-scope assessment constitutes the least requirement that meaningfully addresses IPEEE objectives. Consequently, it would not be appropriate to reduce the seismic IPEEE review requirements for the existing set of reduced-scope plants. The issue may be raised, however, that in re-binning the existing set of focused-scope plants, re-assignment of qualifying plants to a reduced-scope category should be permitted. This should not be the case, however, because the basis and criteria for the original binning of reduced-scope plants is entirely different from that for re-binning the focused-scope plants. Reduced-scope plants are those which have the lowest levels of hazard in the U.S., sufficiently low such that the earthquake risk may be considered nearly negligible (for most practical purposes) in comparison to the risk from other potential severe-accident initiators. Existing focused-scope plants do not have the lowest levels of seismic hazard, nor do they have nearly negligible levels of seismic hazard (regardless of which set of hazard results [e.g., 1993 LLNL or 1989 EPRI] is considered). Consequently, modified review-scope requirements for qualifying focused-scope plants should still exceed the requirements of a reduced-scope review.

Therefore, in answer to the question of what format should be implemented in defining the allowable reductions for seismic review resulting from re-binning, it is apparent that introducing an additional review-scope category is highly valid. There are a number of advantages of this approach. A significant advantage is that this approach increases the binning gradation, thus improving overall applicability of the binning results. More importantly, though, is the fact that such an approach facilitates re-binning and enhances its meaning. In other words, sub-division of the original focused-scope bin into two review categories -- the existing focused-scope review and a new, proposed modified-scope review -- enables the re-binning assessment to be conducted on an independent basis (from the original binning assessment) that addresses the specific criteria of relevance to re-binning. The re-binning approach does not, as a result, need to re-consider the original basis implemented for establishing the existing review-scope bins and evaluation procedures. In this way, the re-binning format becomes a logical extension of the original binning approach, consistent with the original format of sub-dividing the 0.3g bin into two sub-bins (full-scope and focused-scope). Now, three categories are used to sub-divided the existing 0.3g bin: the full-scope, focused-scope, and the new proposed modified-scope assessment.

With this background justifying the development of a new, proposed modified-scope seismic IPEEE review category, perspective on re-binning is clarified. Its purpose is to sub-divide the original set of focused-scope plants into focused-scope and proposed modified-scope sub-bins. The technical methods and criteria used to conduct this sub-division are described in Section 4. The remainder of this section delineates the procedures of a proposed modified-scope review, and presents the results of the focused-scope/proposed modified-scope sub-division.

Distinct from the development of a proposed modified-scope review category, Section 5 describes additional proposed reductions in seismic IPEEE procedural guidelines that may be applied uniformly to all original focused-scope plants. The proposed modified-scope re-binning and the "global" reductions in procedural requirements for all focused-scope plants, are intended to complement one another in accounting for reductions in perceived seismic hazard. Greater consideration is given in Reference [9] to approaches for globally reducing seismic scope for focused-scope plants.

3.2 Description of Proposed modified-scope Evaluation Procedures

Because re-binning relates to reassigning a sub-set of focused-scope plants to a proposed modified-scope category, it is logical that the proposed modified-scope review represents a reduction in requirements with respect to those items evaluated in a focused-scope review. Consequently, to obtain the elements of a proposed modified-scope review, it is valid and consistent to start with focused-scope review requirements, and reduce items as appropriate, based on the consideration that there is high confidence that the plant poses a low seismic risk.

As discussed earlier, however, the proposed modified-scope requirements should logically exceed those of a reduced-scope review.

The element of a focused-scope review that is not absolutely required in meeting the IPEEE objectives for a proposed modified scope plant pertains to the analytical evaluation of seismic margin capacities for (perhaps several) components expected to have very high seismic ruggedness. A proposed modified-scope plant is one for which there exists a high confidence of low seismic core-damage risk, based on a conservative bounding assessment of mean seismic core-damage frequency (and assuming that certain caveats related to seismic evaluation and plant modifications are addressed, as discussed in Section 2). A generic, conservative plant fragility that is tied to the design-basis level is used to demonstrate the low expected risk. Consequently, if the seismic capacity at the design-basis level is verified for a proposed modified-scope plant, then there is high assurance that the seismic risk is low. Thus, it is not absolutely necessary that beyond-design-basis calculations of the seismic margin (or seismic fragility) of components be executed for components expected to have high ruggedness. Clearly, this conclusion is based on the assumption that a high-quality, well-executed seismic walkdown is conducted that identifies all notable potentially vulnerable conditions that may limit a component's seismic margin.

Although calculations of HCLPF capacities or seismic fragilities are not systematically required for many components in a proposed modified-scope review, calculations (or verifications) of seismic capacities at the design-basis level are required for design-basis outliers. In some cases, a new analysis may be undertaken to determine seismic design capacities; for other cases, experience-based qualification criteria may be applied; and yet in other cases, the plant Final Safety Analysis Report (FSAR) analysis may prove sufficient in demonstrating adequate capacity. For components identified as design-basis outliers, evaluation of seismic margin capacity would be required if the design-basis analysis revealed any condition suggesting a low potential seismic margin.

In all other respects -- i.e., other than the elimination of the requirements of calculating seismic-margin capacities, (using an SME input level) -- a proposed modified-scope review is essentially identical to a focused-scope review. In other words, all other aspects of a focused-scope review are considered requisite in assuring that the assumption of low mean seismic core-damage frequency is met with high confidence for a proposed modified-scope plant.

As compared to a reduced-scope review, the proposed modified-scope review has the similarity that the seismic IPEEE input is the plant's seismic design basis, so that seismic-margin calculations are not generally required. In contrast to a reduced-scope review, however, proposed modified-scope review requirements include the following items: relay chatter evaluation for all plants; evaluation of the potential and impacts of soil failures; and special consideration of generic vulnerabilities as discovered in past seismic PRAs and SMAs.

The aspects of a proposed modified-scope review, using available methods (NRC seismic margin methods or EPRI seismic margin methods) are delineated more-formally, in the format of Sections 3.2.4 to 3.2.6 of NUREG-1407, as presented below. These proposed modified-scope review guidelines are intended to supplement the seismic review-scope descriptions contained in NUREG-1407, Section 3.

3.2.1 NRC seismic margins methodology.

General guidance on the NRC seismic margin methodology is contained in the three reports: NUREG/CR-4334 [13], NUREG/CR-4482 [14], and NUREG/CR-5076 [15]. For IPEEE implementation of a proposed modified-scope review, this guidance is supplemented by the following information and procedural requirements:

3.2.1.1 *Seismic walkdown.*

The walkdown should be performed in accordance with Appendix B, Section B.1(1) through B.1(4) of NUREG-1407, with enhancements as required to identify all plant seismic vulnerabilities..

Emphasis on walkdowns also applies to containment and containment systems (that is, containment functions required to prevent early failure, maintain containment integrity and isolation, and prevent containment bypass sequences), USI A-45, and GI-131.

3.2.1.2 *Relay evaluation.*

Relays in this context include such components as electric relays, contactors, and switches that may be prone to chatter.

USI A-46 Plants: Follow the USI A-46 review procedures. If low-seismic-ruggedness relays are discovered during the USI A-46 review, the relay review should be expanded to include relays outside the scope of USI A-46 but within the scope of the IPEEE.

Non USI A-46 Plants: Locate and evaluate low-seismic-ruggedness relays (bad actor list).

3.2.1.3 *Soil failures.*

Soil failure analyses include an evaluation for instability, settlement, and liquefaction.

EPRI NP-6041 [16] contains guidance on evaluation of soil failures; a review based on appropriate design and construction records is considered adequate. A detailed analysis, as necessary, will be performed if soil failure is deemed significant.

3.2.1.4 *Screening criteria.*

Appendix B of NUREG-1407 contains guidance.

3.2.1.5 *Seismic input.*

For IPEEE evaluation, the SSE ground response spectra (for appropriate soil conditions, damping, etc.) and corresponding in-structure spectra should be used. New in-structure response spectra, if developed, should be mean plus one standard deviation to be consistent with the conservatism in the design input. Any differences between the FSAR and new response spectra should be highlighted and discussed.

3.2.1.6 *Evaluation of outliers.*

Outliers should be evaluated for the provisions in the GIP [17] if the plant is also in the USI A-46 program. For elements outside the USI A-46 scope (i.e., structures and piping), the requirements of the plant FSAR should be used in the evaluation. Since the evaluation is done at the design level, identified outliers should be addressed in accordance with 10 CFR 50.72(b) [18].

3.2.1.7 *Nonseismic failures and human actions.*

These activities should be included in the seismic IPEEE review. Guidance on including non-seismic failures and human actions is provided in NUREG/CR-4826 [19] (Maine Yankee seismic margin evaluation) and in two draft reports by Budnitz [20,21].

Appendix B of NUREG-1407 contains further guidance for proposed modified-scope plants.

3.2.2 EPRI seismic margins methodology.

General guidance on the EPRI seismic margin methodology is contained in EPRI NP-6041 [16]. For IPEEE implementation of a proposed modified-scope review, this guidance is supplemented by the following information and procedural requirements:

3.2.2.1 *Selection of alternative success paths.*

See the guidance in Section 3.2.5.1 of NUREG-1407.

3.2.2.2 *Seismic walkdown.*

Same as Section 3.2.1.1.

3.2.2.3 *Relay evaluation.*

Same as Section 3.2.1.2.

3.2.2.4 *Soil failures.*

Same as Section 3.2.1.3.

3.2.2.5 *Screening criteria.*

Same as Section 3.2.1.4.

3.2.2.6 *Seismic input.*

Same as Section 3.2.1.5.

3.2.2.7 *Evaluation of outliers.*

Same as Section 3.2.1.6.

3.2.2.8 *Nonseismic failures and human actions.*

Refer to the general guidance in Section 3.2.5.8 in NUREG-1407. Refer to Appendix B of NUREG-1407 for specific additional guidance pertaining to a proposed modified-scope review.

3.2.3 Containment performance.

The guidance for containment review of a proposed modified-scope plant is identical to that contained in Section 3.2.6 of NUREG-1407.

3.2.4 Special considerations.

Special attention should be given to required evaluations applicable to a proposed modified-scope review, as discussed in Section 2.4 of this report. These required evaluations include relay chatter, masonry/block walls, flat-bottom tanks, and other item relevant to general vulnerabilities as discovered in walkdowns from past seismic PRAs and SMAs.

Treatment of relay chatter was specifically discussed in Sections 3.2.1.2 and 3.2.2.3.

Any item identified as having a potential low seismic capacity will be evaluated using detailed analysis and will be identified for correction in the IPEEE submittal, as indicated by the analytical results. The analysis will ascertain the HCLPF capacity and/or the seismic fragility for the component(s) of concern.

The development of the foregoing delineation of review-scope requirements for a proposed modified-scope review constitutes a combination of the requirements for focused-scope and reduced-scope procedures. Hence, as expected, the level of effort involved in a proposed modified-scope assessment is between the levels of effort required for a focused-scope and reduced-scope evaluation. Table 3-1 provides a description of the relationship between review requirements for the proposed modified-scope assessment and those for the focused-scope and reduced-scope evaluations.

3.3 Original, 4-Category Binning Assignments

NUREG-1407 documents the results of the original plant RLE binning and 0.3g sub-binning in its Table 3.1. The results for eastern U.S. plants are repeated here in Table 3-2 for purposes of convenience in comparing original-binning results with the present re-binning results. Four review-scope categories are indicated: the 0.5g/PRA group, the reduced-scope category, and the 0.3g full-scope and focused-scope sub-bins.

As indicated in Table 3-2, two (2) plants have committed to perform a seismic PRA (otherwise falling in the 0.5g RLE bin). Ten (10) plants were assigned to the reduced-scope bin, and 57 plants were placed in the 0.3g bin. Of the plants in the 0.3g bin, seven (7) fell into the full-scope category, and the remaining 50 fell in the focused-scope category. The original focused-scope plants, therefore, constitute approximately 70% of the total population of eastern U.S. nuclear power plants.

3.4 Revised, 5-Category Binning Assignments

The re-binning results produced from the present re-assessment are presented in Table 3-3. Five review-scope categories are now indicated: the 0.5g/PRA group, the reduced-scope category, the 0.3g full-scope sub-bin, the 0.3g focused-scope sub-bin, and the 0.3g proposed modified-scope sub-bin.

As shown in Table 3-3, the original major overall RLE binnings to the 0.5g/PRA, 0.3g, and reduced-scope categories have been preserved. Among the 0.3g major category, the full-scope sub-bin has also been maintained. (Note, however, that since the time of publication of NUREG-1407, one focused-scope plant has been reassigned to the reduced-scope category, one focused-scope plant has been removed from the list of operating plants, and one full-scope plant has also been removed from the list of operating plants).

The re-binning analysis has thus effected only the original focused-scope sub-bin. Of 48 plants that were originally assigned to the focused-scope sub-bin, 18 are now re-binned to the proposed modified-scope sub-bin; hence, 30 plants still remain in the focused-scope category.

Table 3-1. Relationship of Modified-Scope Evaluation Procedures to Review Procedures for Focused-Scope and Reduced-Scope Seismic IPEEE Categories

Description of Review Procedural Requirement	Modified-Scope Requirement Characterized By:		
	Focused-Scope Procedures	Reduced-Scope Procedures	Special Review Considerations
Seismic Walkdown	✓	✓	
Relay Evaluation	✓		
Soil Failures	✓		
Screening Criteria		✓	
Seismic Input		✓	
Evaluation of Outliers		✓	✓
Nonseismic Failures and Human Actions		✓	
Containment Performance		✓	
Generic Plant Vulnerabilities	✓		✓

Table 3-2. Original Review Level Earthquake and Review-Scope Assignments for Plant Sites East of the Rocky Mountains

Reduced Scope

- Big Rock Point
- Comanche Peak
- Crystal River
- Duane Arnold*
- Grand Gulf
- River Bend
- South Texas
- St. Lucie
- Turkey Point
- Waterford

0.3g Focused Scope

- Arkansas #2
- Beaver Valley
- Bellefonte
- Braidwood
- Browns Ferry
- Brunswick
- Byron
- Callaway
- Calvert Cliffs
- Catawba*
- Clinton
- Cook
- Cooper
- Davis-Besse
- Dresden
- Farley
- Fermi
- Fitzpatrick
- Fort Calhoun
- Ginna
- Haddam Neck
- Harris
- Hatch
- Hope Creek
- Kewaunee
- LaSalle
- Limerick
- McGuire
- Millstone
- Monticello
- Nine Mile Point
- North Anna*
- Oyster Creek
- Palisades
- Peach Bottom
- Perry
- Point Beach
- Prairie Island
- Quad Cities
- Salem
- Shoreham
- Summer*
- Surry
- Susquehanna
- Three Mile Island
- Vermont Yankee
- Vogtle
- Watts Bar
- Wolf Creek
- Zion

0.3g Full Scope

- Arkansas #1
- Indian Point
- Maine Yankee
- Oconee*
- Robinson
- Yankee Rowe

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- Pilgrim**
- Seabrook**

Notes:

*Special attention to shallow soil conditions is appropriate for these locations (see Section 3.2.2 of NUREG-1407).

**Relay chatter evaluation should be similar to a full-scope review.

Table 3-3.§§ Revised Review Level Earthquake and Review-Scope Assignments for Plant Sites East of the Rocky Mountains

Reduced Scope

Big Rock Point
Comanche Peak
Crystal River
Duane Arnold*
Farley§
Grand Gulf
River Bend
South Texas
St. Lucie
Turkey Point
Waterford

0.3g Proposed Modified Scope*□**

Arkansas #2
Bellefonte
Braidwood
Browns Ferry
Byron
Callaway
Clinton
Davis-Besse
Harris
Hope Creek
LaSalle
Limerick
McGuire
Nine Mile Point
Perry
Quad Cities
Watts Bar
Wolf Creek

0.3g Focused Scope□

Beaver Valley
Brunswick
Calvert Cliffs
Catawba*
Cook
Cooper
Dresden
Fermi
Fitzpatrick
Fort Calhoun
Ginna
Haddam Neck
Hatch
Kewaunee
Millstone
Monticello
Oyster Creek
North Anna*
Palisades
Peach Bottom
Point Beach
Prairie Island
Salem
Summer*
Surry
Susquehanna
Three Mile Island
Vermont Yankee
Vogtle
Zion

0.3g Full Scope

Arkansas #1
Indian Point
Maine Yankee
Oconee*
Robinson

Committed to Perform a Seismic PRA

Pilgrim**
Seabrook**

Notes:

* Special attention to shallow soil conditions is appropriate for these locations (see Section 3.2.2 of NUREG-1407).

** Relay chatter evaluation should be similar to a full-scope review.

*** Special attention should be given to identification and evaluation of masonry/block walls, flat-bottom tanks, and other generic potential vulnerabilities (see Sections 2.4 and 3.2.4). Effort, quality, and detail of seismic walkdowns should be identical to full-scope or focused-scope seismic review.

□ Reductions in evaluation requirements apply (see Section 5).

§ Plant Farley was re-assigned to the reduced-scope bin after publication of NUREG-1407.

§§ Plants Yankee Rowe and Shoreham are not operating, and hence, have been removed from the list.

Section 4

APPROACH AND TECHNICAL BASIS FOR PROPOSED MODIFIED-SCOPE BINNING

This section describes the proposed technical basis and criteria for delineating proposed modified-scope plants from the set of original focused-scope plants. The results of this re-binning have been presented in Table 3-3. Specific analytical methods for implementing the criteria, together with analytical results for the set of original focused-scope plants, are provided in Appendix A.

4.1 Overview: Use of an Absolute Binning Criterion

As stated in Section [illegible], a fundamental mission of this study has been to investigate development of a seismic re-assessment approach which depends on criteria related to absolute levels of seismic hazard. The fact that relative, site-to-site comparisons of hazard have not significantly altered with introduction of the 1993 revised LLNL seismic hazard results precludes a meaningful seismic re-assessment impact based on relative comparisons of hazard. Consequently, the logical possibilities that remain for performing the seismic re-assessment include: (1) making use of comparisons and criteria that depend on absolute levels of seismic hazard in delineating seismic review categories; (2) identifying reductions in procedural requirements for seismic reviews that may be applied within the format of the original review categories and seismic binning; and (3) maintaining the original binning, with no changes to review requirements.

Each among these possible overall approaches has its advantages and disadvantages. The problem with approach (3) is that it is largely unresponsive to the issue of addressing seismic IPEEE impacts of the reductions in perceived seismic hazard; however, this approach does have the advantage of helping to de-sensitizing the seismic IPEEE process from possible future increases in seismic hazard estimates. The primary advantage of approach (1) is that it meaningfully accounts for reductions in seismic hazard within a formal, quantitative seismic re-assessment framework. However, because the seismic hazard results carry large uncertainties, there are limits on the usefulness and validity of the quantitative results. Particularly for cases where quantitative results indicate that a plant falls just short of meeting a quantitative threshold, the significance and fairness of applying the absolute quantitative criteria in a rigid manner are issues subject to considerable debate. Approach (2) has the advantage that it does not require a re-binning assessment to be performed; and hence, the validity of absolute quantitative results and applicability of re-binning criteria are not significant issues of concern. However, because reductions in procedural requirements are uniformly applied, care must be exercised to insure that the reductions are not overly liberal. The extent of procedural reductions should be controlled by the plant having the highest expected seismic risk. In other words, if the reductions are allowable with respect to the highest-risk plant (falling within the given review category), then the reductions will likewise be acceptable for the other plants. It is important to recognize that the basis for developing reductions in procedural requirements relies substantially on qualitative judgment, as opposed to implementation of systematic criteria. Hence, the extent of proposed reductions in procedural requirements may become an issue of some debate. (See Reference [9] for a more detailed discussion related to qualitative-based reductions in review guidelines for focused-scope plants).

Although this section pertains primarily to developing seismic re-assessment aspects related to approach (1), it is important to recognize that the overall approach of this study actually represents a combination of the three approaches noted above. Approach (3) is represented to the extent that the present approach has preserved, to a considerable degree, the original binning format and procedural requirements found in NUREG-1407; the present seismic re-assessment effects only the set of original focused-scope plants. In addition, although this study develops a re-assessment of minimum procedural guidelines that may be followed in conducting seismic IPEEEs, it encourages licensees to conduct their seismic IPEEE(s) in accordance with the guidelines already established in NUREG-1407. Approach (2) is represented by the present overall approach in that uniform reductions in quantitative capacity evaluations are proposed for all focused-scope and proposed modified-scope plants. The basis and results of these proposed reductions are described in Section 5. And finally, approach (1) is represented with the delineation of a proposed modified-scope seismic category that is based on comparisons of quantitative criteria that depend on absolute levels of seismic hazard.

This overall, multi-faceted approach to seismic-scope re-assessment has been developed to eliminate disadvantages associated with implementation of any single one of the approaches described above. Specifically, the potential issues that may arise from placing reliance solely on a rigid, absolute-based approach to re-binning are significantly offset by the implementation of "globally applicable" reductions in capacity evaluation requirements for all original focused-scope plants.

Nonetheless, use of an absolute binning criterion has a significant role in the re-assessment approach of this study. As noted in earlier sections, the gist of the re-binning approach is the identification of plants where there is high likelihood of low seismic core-damage frequency. Simply stated, plants (among the set of original focused-scope plants) so identified as having low estimated seismic core-damage frequency (based on a conservative analysis) are assigned to a new, proposed modified-scope review category.

It is worth noting at this point that seismic-hazard measures (e.g., composite probability of exceedance) are themselves not used directly in re-binning assessments. The most important reasons for this being the case are that seismic core-damage frequency serves as a more-meaningful measure (i.e., more relevant to plant risk) and that a well-founded criterion (and hence, basis) for re-binning, based directly on hazard results, does not exist.

To identify plants likely to have low seismic core-damage frequency, a number of items need to be addressed. First, estimates of seismic core-damage frequency must be obtained to implement the delineation approach. To estimate seismic core-damage frequency, seismic hazard and plant-level capacity information are required. Yet, plant-specific capacity results are unavailable for the majority of plants (indeed, the purpose of the present study is to help guide the development of such results); hence, the technical basis for estimating seismic core-damage frequency in the absence of plant-specific capacity data needs to be clarified. Another item that needs to be explained and justified is the basis for developing the threshold of seismic core-damage frequency which is used as the criterion for re-binning (and which effectively defines a level of expected seismic core-damage frequency corresponding to a "low" or "minor" risk). These items pertaining to the use of an absolute binning criterion in seismic re-assessment are discussed in the following sub-sections.

4.2 Approach for Conservative Generic-Fragility Characterization

To enable an estimation of seismic core-damage frequency where plant-specific fragility data are not available, it becomes necessary to make use of generic seismic capacity data, as derived from past seismic studies (PRAs and SMAs) of nuclear power plants. Use of generic plant-capacity data, together with site-specific seismic hazard results, to assist in safety decision-making and management of nuclear power plants, has been proposed in the published literature (see References [22,23,24]). Generic seismic capacity is effectively characterized by the three parameters of a double-lognormal distribution; i.e., the median-median capacity, $\breve{A}$, the logarithmic standard deviation due to randomness in capacity, β_R, and the logarithmic standard deviation due to uncertainty in capacity, β_U. These three parameters, together with properties of the lognormal probability distribution, adequately describe plant-level fragility, expressing (probabilistically) the plant's capability to resist core-damage from seismic events. Parameters β_R and β_U control the shape of the fragility function, whereas parameter $\breve{A}$ controls the scale of the fragility function.

The studies of past seismic evaluations have shown that plant-to-plant variation in fragility-function shape (i.e., parameters β_R and β_U) is low. Plant-to-plant mean values of β_R=0.22 and β_U=0.24 have been obtained based on a summary of available peer-reviewed studies. The respective coefficients of variation in these parameter values are 0.16 and 0.14. The plant-to-plant mean and coefficient of variation of the composite logarithmic standard deviation, β_C, are respectively, 0.32 and 0.11. Because β_C defines the shape of the mean fragility curve, it is of greater relevance than β_R or β_U (individually) to computations of mean seismic core-damage frequency (see Appendix A for further description on the use of parameter β_C in evaluations of mean seismic core-damage frequency). Consequently, because the plant-to-plant variability in β_C is low, significant errors in estimated mean seismic core-damage frequencies are not expected to be introduced due to generic characterization of variability in plant seismic capacity.

In contrast to this observation concerning plant-to-plant variations in fragility-function shape, variations in absolute scale of the fragility function (from plant-to-plant) are not insignificant. Clearly, because it controls the absolute level of the plant fragility function, parameter $\breve{A}$ is the fragility characterization most pertinent to plant vulnerability. Because some plants are known to be more seismically rugged than others, plant-to-plant variability in

$\tilde{A}$ is expected to be considerable and of critical significance. Statistical studies have failed to demonstrate a strong correlation between $\tilde{A}$ and fundamental plant characteristics. In many cases, specific unique plant features (either related to the plant systems logic or to the fragility of some critical component(s)) have the controlling effect on $\tilde{A}$, as opposed to any generic condition. These facts appear to suggest a weak basis for an accurate generic characterization of $\tilde{A}$.

Despite this situation, it is possible to establish, with confidence, a reasonable conservative (albeit inaccurately low) generic estimate of $\tilde{A}$. The conservative estimate of $\tilde{A}$ used in this study is based both on the results of past seismic evaluation studies and on engineering judgment. Specifically, it can be said with confidence that, provided certain conditions are met, a plant's HCLPF capacity will exceed its seismic design basis by no less than 25%. In other words, no plant has demonstrated, nor should demonstrate, a HCLPF capacity lower than 1.25 times the SSE level. Given the generic parameters governing fragility-function shape, it can be shown that this conservative HCLPF assessment corresponds to a conservative median-median capacity assessment equal to 2.67 times the seismic design basis. The conditions that must be met are that a comprehensive seismic walkdown be performed and all obvious vulnerabilities, of the type revealed in past seismic studies (e.g., block walls, flat-bottom tanks, inadequate anchorages, adverse spacial-systems interactions, etc.), be evaluated and fixed as needed. These conditions have been incorporated specifically as special considerations in a proposed modified-scope review. They help insure that if any plant does happen to possess a spuriously low HCLPF capacity, that all corrective measures will be implemented to help insure that the resulting plant capacity will achieve, at least, the conservative level assessed above.

Consistent with the foregoing discussion, a conservative generic fragility has been assessed for each plant in the original focused-scope category. The median-median parameter of the fragility function is assessed as 2.67 times the SSE ground motion; and variability parameters are given as β_R=0.22 and β_U=0.24.

4.3 Approach for Conservative Estimation of Seismic Core-Damage Frequency

Appendix A describes the overall methodology implemented in this study for evaluation of mean seismic core-damage frequency. The 1993 revised LLNL seismic hazard results are used, together with the above conservative generic fragility functions, to obtain a conservative estimate of a plant's mean seismic core-damage frequency. With respect to any given plant for which this approach is applied, it is likely that if an actual PRA were conducted for the plant (using the 1993 LLNL hazard curves), then the actual computed mean seismic core-damage frequency would be lower than the mean value estimated here. The actual computed value may, in fact, be considerably lower than the estimated value. Similarly, it is to be expected that in very few (if any) cases would the actual value exceed the estimated value; in such cases, the actual value should be only slightly underestimated.

Hence, this conservative approach is considered to be a valid basis for estimating mean seismic core-damage frequencies for purposes of seismic re-binning assessment. As indicated in Section 3, a proposed modified-scope review considers seismic input at the SSE, design-basis level. The approach for conservative estimation of mean seismic core-damage frequency assumes that the plant design basis is met; hence, the proposed modified-scope review insures the validity of this assumption. Unlike the case for a reduced-scope plant, however, the seismic design basis for a proposed modified-scope plant is not itself considered to be an appropriate severe-accident level. In other words, vulnerabilities beyond the design-basis level still need to be identified for proposed modified-scope plants. The search for such beyond-design-basis vulnerabilities, however, is limited; only those items identified as requiring special consideration (as described in Sections 2 and 3) or unusual items identified during the plant seismic walkdowns, require specific margin capacity evaluation. These capacity evaluations are intended to insure that potential vulnerabilities that impact plant behavior beyond the design basis, and that are expected to be of meaningful severe-accident-risk concern, are addressed. Effectively, therefore, the minimum severe-accident seismic input that must be considered by the licensee of a proposed modified-scope plant corresponds to a seismic margin earthquake that is no less than 1.25 times the SSE motion. By demonstrating margin at this level for a proposed modified-scope plant, the seismic review effectively confirms/demonstrates that the plant seismic core-damage risk is low/minor.

4.4 Basis for Core-Damage-Frequency Criterion

To apply the re-binning approach, it is necessary to define a threshold level of mean seismic core-damage frequency for delineating between proposed modified-scope and focused-scope review categories. It is important that this value not be chosen arbitrarily. Small changes in the threshold can have a fairly significant impact on the re-binning results.

Consequently, the core-damage frequency criterion used in this study has substantial basis. The basis makes significant use of policy and supporting development related to safety goals (see References [25,26,27]). Specifically, the reference point for the chosen criterion pertains to the quantitative accident-prevention and accident-mitigation goals that act as conservative surrogates to the more-fundamental qualitative safety goals. The quantitative goals are designated as follows:

(a) Accident Prevention: 10^{-4} per reactor year mean frequency of core damage from all causes; and

(b) Accident Mitigation: Containment performance such that there is less than a 10^{-1} chance for a large release given any among the entire family of possible core-damage scenarios.

The containment performance assessment of the seismic IPEEE addresses appropriate severe-accident concerns associated with accident mitigation. The seismic walkdown of the containment and other aspects of containment-performance procedures, therefore, are considered generally adequate in achieving the second quantitative safety goal mentioned above. The first goal, pertaining to accident prevention, is emphasized in establishing the seismic re-binning criterion.

The 10^{-4} per year overall mean core-damage frequency safety goal is used to establish a general criterion for seismic performance.

One consideration that can assist in the development of such a criterion for seismic performance concerns the fraction of total mean core-damage frequency contributed by seismic events, as determined from past seismic evaluation studies. Studies summarizing the results of past PRAs indicate that seismic initiators, on average for eastern U.S. plants, contribute approximately 20% to total mean core-damage frequency. Hence, $2x10^{-5}$ per year mean core-damage rate should be considered as an upper limit for seismic performance. Clearly, a general seismic performance goal more lenient than this limit would be substantially inconsistent with the overall safety goals. The seismic performance goal should not be considerably more stringent than the $2x10^{-5}$ level, however, since it may not be reasonably achievable.

The objective in establishing a re-binning criterion is to define a threshold of seismic core-damage frequency below which the seismic risk is considered to be low and of minor concern with respect to other risk contributors. The $2x10^{-5}$ value is judged to be somewhat high for this purpose, since it constitutes a fairly significant contribution to the total core-damage frequency goal. Hence, $1x10^{-5}$ per year mean seismic core-damage frequency is considered to be a more appropriate criterion for conducting re-binning assessments.

The $1x10^{-5}$ mean seismic core-damage frequency criterion has more-formal support in the published safety-goal-related evaluation criteria contained in NUREG/BR-0184, *Regulatory Analysis Technical Evaluation Handbook* [28]. That document directly suggests that regulatory initiatives involving actions to prevent core damage should result in a reduction of at least $1x10^{-5}$ in the estimated mean value of core-damage frequency in order to justify proceeding with further analyses. The $1x10^{-5}$ value, therefore, defines a level of regulatory significance; consequently, actions taken to reduce core-damage frequency contributions below this level can generally be considered to be of minor significance or concern.

As has been seen in past PRAs, the total frequency of seismically induced core-damage may be dominated by just a few components, or perhaps by just a single component. In other words, it cannot be ruled out that a single corrective action could result in an order of magnitude reduction in the estimated mean seismic core-damage frequency. Hence, the $1x10^{-5}$ significance threshold is substantially valid and applicable to the objective of establishing a criterion for seismic re-binning based on comparisons dependent on absolute levels of seismic hazard.

Consequently, 10^{-5} per reactor year mean seismic core-damage frequency is used as criterion in this study for delineating the set of proposed modified-scope plants from among the original set of focused-scope plants. Appendix A provides additional details on how this criterion is applied for use with conservative estimations of mean seismic core-damage frequency. In particular, given the uncertainties in seismic hazard and differences that might result from various numerical procedures, for purposes of re-binning, values of estimated mean seismic core-damage frequency are considered to be meaningful to only one significant digit. Hence, prior to re-binning, estimated values of mean seismic core-damage frequency are rounded to one significant digit. The results presented in the tables of Appendix A show the values of mean seismic core-damage frequency estimates carried to three-digit precision. (Reported values of mean core-damage frequency in PRAs generally use two or three digit precision). These results should, however, be rounded to nearest single-digit precision for use in re-binning. An estimated core-damage frequency as high as 1.49×10^{-5} in Table A-3, for instance, would be rounded down to 1×10^{-5} before re-binning. Hence, the resolution in application of the re-binning criterion may allow a plant to exceed the 1×10^{-5} threshold by as much as 49% and still qualify for binning into the proposed modified-scope review category.

It is worth noting here that the NEI approach [8] to IPEEE program reduction and the present approach to seismic-scope re-assessment are both similar in their general development and use of comparisons based on absolute hazard. One significant difference in application of the approaches, however, is that the NEI paper recommends use of a core-damage risk threshold of 5×10^{-5}, whereas this study uses a (rounded) threshold of 1×10^{-5}. The justification presented in this paper for re-assigning plants to a proposed modified-scope review category is that there is high confidence of low or minor seismic contribution to mean core-damage for such plants. A mean seismic core-damage frequency of 5×10^{-5} is not considered to delineate a minor risk threshold, and hence, it has not used in this study. In addition, this study could not identify any sound basis to justify use of 5×10^{-5} as a criterion for seismic re-binning.

Another significant difference between the present approach and the NEI approach is that the NEI approach recommends re-assignment of plants to the reduced-scope review category, whereas the present paper develops an approach for re-assigning plants to a new, proposed modified-scope sub-bin.

Section 5

OTHER SEISMIC SCOPE RE-ASSESSMENT IMPACTS

5.1 Overview

As noted in Section 4, re-binning focused-scope plants to the modified-scope category is not the only aspect of the proposed seismic-scope re-assessment approach. An important element of the overall re-assessment approach is the specification of items (component failure modes) that are unlikely to be identified as significant potential vulnerabilities, pre-dominant outliers, or dominant risk contributors. Hence, for focused-scope plants, these items can be screened out from seismic margin capacity evaluation, provided that no unusual conditions are found in plant seismic walkdowns or in review of plant information.

Hence, the effort required in calculation of seismic capacities for focused-scope plants may be significantly reduced with the present approach. Plant seismic walkdowns of the identified items are, of course, still necessary to confirm that no obvious problems exist that would prevent the items from being screened out from capacity calculations.

The following sub-section explains the basis and results of identification of component failure modes that may be screened-out from capacity evaluation in the seismic IPEEE of focused-scope plants.

5.2 Reductions in Capacity Evaluation Requirements for Focused-Scope Plants

Seismic margin assessment procedures [16] make use of screening tables for purposes of eliminating certain rugged components from evaluation as outliers. Seismic margin screening tables apply at SME review levels of 0.3g and 0.5g. For instance, a plant having an SME of 0.3g would use the 0.3g screening tables to conservatively screen out components from outlier evaluation; the 0.5g screening tables would be similarly applied for a 0.5g plant. The basis for development of the seismic margin screening tables is conservative, and thus, generally insures that all components that are screened out have expected HCLPF capacities notably in excess of the seismic review level.

The present approach for developing a list of components that may be screened out from capacity evaluations is similar to the development and use of seismic margin screening tables. For the approach to achieve a reduction in seismic review effort, however, the list of components identified to be screened out should include items that may be screened-in as outliers in a 0.3g seismic review. This means that some components expected to have HCLPF capacities near, or somewhat below, the level of 0.3g should be included in the list of components for which capacity calculations need not be performed.

The basis for developing this list of components derives from consideration of results of capacity evaluations from past seismic PRAs and SMAs. From these results, a list of components considered in seismic evaluation studies, together with their seismic capacities (i.e., fragility and HCLPF values), has been generated. This list is of the same format presented in Reference [13], Appendix C, but includes a greater number of components, reflecting the addition of more-recent information. The components in this list are designated by major category (type of component, function, etc.). The list was reviewed to identify components that are generally evaluated (with capacity calculations) in seismic reviews, but yet have consistently high capacity levels. Components that exist primarily to achieve accident mitigation, however, were excluded from this consideration.

Based on the foregoing assessment, the following items have been identified as generally not requiring a specific seismic capacity evaluation (i.e., HCLPF assessment) for focused-scope plants:

- Direct Failure of Containment Building, Soil Failures Excluded
- Reinforced Concrete Shear Wall Failure, Flexural Failure Modes Only
- Reinforced Concrete Roof Diaphragm Failure
- Reinforced Concrete Floor Diaphragm Failure, Flexural Failure Modes Only
- Foundation Failure, Excluding Block-Wall Foundations and Excluding Foundations of Containment Buildings
- Reactor Pressure Vessel Failure

- Failure of Reactor Internals, CRDM, and Fuel Assemblies
- Failure of Steam Generator, Including Supports
- Failure of Pressurizer, Including Supports
- Failure of Buried Piping

None of these items has been identified as a notable potential vulnerability, pre-dominant outlier, or dominant risk contributor in past seismic evaluation studies. As noted previously, these items must be considered in the plant seismic walkdown and/or plant review process to insure that no unusual conditions exist that would compromise seismic capacity; the reduction in review requirement for these items applies only to calculation of seismic (HCLPF and/or fragility) capacity.

These reductions in seismic review requirements are intended to apply only to the set of original focused-scope plants (which includes the new set of modified-scope plants) that are effected by the present re-binning assessment.

The guidelines presented in this section concerning seismic-scope reductions for focused scope plants should be viewed as being preliminary. Additional, more-comprehensive investigation into the justifications, approaches and uses of guidelines aimed at reducing the scope of seismic margin capacity evaluations for all focused-scope plants, is presented in Reference [9].

Section 6

CONCLUSIONS

This report has presented the basis and results of an approach for conducting re-assessments of the seismic scope and minimum procedural guidelines that may be applied in IPEEE studies. The impetus for the re-assessment has derived from recent revisions made to LLNL seismic hazard estimates, which have led to reductions in the levels of perceived mean seismic hazard at eastern U.S. nuclear power plant sites. The LLNL seismic hazard estimates have served as key inputs in the original seismic IPEEE binning process, and hence, the reductions in hazard imply the potential for corresponding reductions in seismic review requirements. In consideration of this potential, the Nuclear Energy Institute has formulated a utility position on recommendations for reductions in the IPEEE program.

The present study has evaluated approaches for seismic-scope re-assessment and has described a re-binning basis and set of minimum procedural guidelines designed to both meet IPEEE objectives and meaningfully respond to reductions in LLNL seismic hazard estimates.

Although the revised LLNL hazard estimates have led to notable reductions in levels of mean seismic hazard for all eastern U.S. plants, the relative plant-to-plant variations in seismic hazard have not changed significantly. Since the original IPEEE seismic binning process was based primarily on relative comparisons of seismic hazard, no meaningful change in the original binning assessment would result from simply repeating the original binning process using the revised estimates of seismic hazard. Hence, from the outset of this study, one of the fundamental objectives has been to explore the applicability of a re-binning approach based primarily on comparisons of absolute levels of seismic hazard.

This report describes a multi-faceted overall seismic-scope re-assessment approach that has three primary aspects:

(1) It maintains the overall major (0.5g, 0.3g and reduced-scope) binning results, and preserves other aspects of the original binning results to the extent appropriate;

(2) It delineates procedural guidelines and binning results for a proposed modified-scope category of seismic review; and

(3) It describes potential reductions in seismic capacity evaluation requirements that are uniformly applicable to all original focused-scope plants.

This approach is developed to impact only the original set of focused-scope plants. This set of plants is sub-divided into proposed modified-scope and focused-scope seismic review categories based on comparisons dependent on absolute levels of seismic hazard.

The proposed modified-scope review is a new category of seismic evaluation described in this study for possible use in re-binning. Proposed modified-scope plants are delineated among the set of original focused-scope plants. This delineation is based on a low threshold value of mean seismic core-damage frequency. Original focused-scope plants with an estimated value of mean seismic core-damage frequency falling below the threshold are assigned to the proposed modified-scope category. (Core-damage frequency estimates are rounded to the nearest single significant digit before comparison with the binning threshold). Conservative generic estimates of plant seismic fragility are used in estimating values of mean seismic core-damage frequency. The core-damage frequency criterion used to define the delineation threshold is 1×10^{-5} mean seismic core damages per reactor year. Hence, plants are re-assigned to the proposed modified-scope category based on having high confidence of low, or minor, mean seismic core-damage risk potential.

The delineation of proposed modified-scope plants and modified-scope review procedures is a significant element of the present approach. It is that element which makes use of comparisons based on absolute levels of seismic hazard. Certain special considerations, as discussed in this paper, must be addressed in the licensee's seismic IPEEE review in order for the proposed modified-scope re-assignment to fully apply.

Based on the re-binning approach, 18 plants are re-binned, from the focused-scope to the proposed modified-scope review category.

In addition to the delineation of proposed modified-scope plants based on absolute levels of seismic hazard, it has been considered appropriate and justified to propose reductions in seismic review requirements that are applicable to all focused-scope plants. Hence, a list of components is identified for which specific margin capacity evaluations are not generally required in a focused-scope seismic IPEEE review. These items, however, must be considered in plant seismic walkdowns to confirm that no unusual conditions exist which might compromise seismic capacity. The components considered in the list have sufficiently high general capacities that they are unlikely to be assessed as potential vulnerabilities, predominant outliers, or dominant risk contributors in the seismic review of focused-scope plants. Additional investigation on this aspect of seismic-scope re-assessment is described in a supplementary companion report [9].

A number of caveats pertaining to the use of the presented guidelines are discussed throughout this paper. The guidelines are intended to serve as a set of minimal prescribed procedures, as opposed to an endorsement or recommended course of action. In fact, plant licensee's are strongly encouraged to conduct their seismic IPEEEs in accordance with the guidelines already established in NUREG-1407.

Section 7

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Appendix A

SUPPORTING TECHNICAL ANALYSES AND RESULTS

A.1 Overview

This appendix describes details of the analytical methods and results which support the implementation of re-binning criteria. The overall approach and technical basis of the re-binning process was described in Section 4. There, hypothetical, yet conservative, estimates of mean seismic core-damage frequency were introduced as the primary basis for performing comparisons (that are dependent on the absolute level of seismic hazard) against re-binning criteria.

The procedure implemented for computing mean annual frequencies of seismic core damage, for the original set of focused-scope plants, is described in this appendix. The development of input fragility data from conservative generic evaluation of existing seismic capacity information is described. Results of the mean seismic core-damage frequency computations are presented for each focused-scope plant. These core-damage frequency results are first presented in terms of variations with vibration frequency (i.e., as spectral results). Composite, scalar values of core-damage frequency are then evaluated and presented based on application of weighting criteria to the frequency-dependent results.

Values of required HCLPF capacity, for a limiting mean seismic core-damage frequency of $1x10^{-5}$, are also obtained. For each plant, the required HCLPF spectrum is plotted, together with the plant SSE design-basis spectrum. Ratios of required HCLPF to plant SSE are obtained and tabulated, both as spectral (vibration-frequency-dependent) results and as composite/weighted values. As discussed in Section 4, for conservative generic evaluation of plant fragility, the required HCLPF (corresponding to a limiting mean seismic core-damage frequency of $1x10^{-5}$) should not exceed the plant SSE by more than a factor of about 1.25 for a modified-scope plant. Because (given the uncertainty in seismic hazard and risk estimates) it is not reasonable to delineate estimates of core-damage frequencies or required HCLPF values to three significant digits, results of core-damage frequencies are rounded to the nearest single significant digit. The implication of rounding core-damage frequency estimates is that core-damage risk values as high as $1.49x10^{-5}$ are considered to be the same as $1x10^{-5}$, and that the required HCLPF may exceed the SSE by as much as 37% and yet still effectively satisfy the 1.25 exceedance factor.

Tabulated results of weighted mean seismic core-damage frequency, and weighted ratios of required HCLPF to SSE, are ordered (from highest to lowest) to facilitate identification of those plants which meet the modified-scope re-binning criteria.

A.2 Evaluation of Mean Seismic Core-Damage Frequency

The procedures for evaluating annual frequencies of seismically induced core damage are well established and documented (e.g., see Reference [A-1]). The mathematical details are not repeated here. An overview of the process for obtaining a mean seismic core-damage frequency is given as follows:

1. Obtain the mean plant-level fragility curve, expressed as a failure fraction versus the amplitude of a ground-motion characterization measure. (PGA has been conventionally used as the ground-motion characterization basis. However, spectral acceleration averaged over a vibration-frequency range of interest is an improved ground-motion parameter that has been used in some studies. In this study, spectral accelerations at each vibration frequency, for which seismic hazard results have been obtained, are used).

   A mean plant-level fragility curve can usually be accurately characterized by a lognormal probability distribution having the following parameters: a median capacity, $\check{A}$, and a composite logarithmic standard deviation, β_C.

2. Obtain a site mean seismic hazard curve computed for motion amplitudes corresponding to the location where structural input (as developed in fragility analyses) is defined. The seismic hazard curve expresses, as a function of ground-motion amplitude, the annual rate of exceedance of the ground-motion amplitude.

3. Discretize the seismic hazard curve into a large number of points (1000 point were used in the present study) using a uniform interval of ground-motion amplitude. Use logarithmic interpolation (i.e., linear interpolation in log-log space) to obtain the hazard at each intermediate point.

4. For each ground-motion interval, compute a mean annual rate of occurrence of motion amplitudes in that interval by subtracting the mean hazard at the higher

amplitude of the interval from the mean hazard at the lower amplitude of the interval.

5. Evaluate a mean plant-level (core-damage) failure fraction, from the mean plant-level fragility curve, at each amplitude corresponding to the midpoint of each ground-motion interval used to discretize the hazard curve.

6. For each ground-motion interval, multiply the mean ground-motion probability determined in Step (4) by the corresponding conditional mean failure probability determined in Step (5), in order to obtain the contribution to mean failure rate coming from each given ground-motion interval.

7. Compute the sum of mean failure rate contributions over all ground-motion intervals, to obtain the total mean seismic core-damage frequency.

Lower and upper cut-offs are often applied to the tails of component-level fragility curves. The impact of the cut-offs on total mean plant failure frequency is usually small. In addition, a plant-level fragility curve will generally not follow exactly the lognormal model, and plant-level cut-offs will depend both on the plant logic and on individual component-level fragility cut-offs. Hence, no cut-offs were applied to the plant fragility curves used in this study.

In implementing the above steps for evaluating mean seismic core-damage frequency, it is critical that the entire range of ground motions having a contribution of significance be considered. In other words, a plot of contribution to mean seismic core-damage frequency, as a function of ground-motion amplitude should generally exhibit defined tails at either end. At the lower-amplitude end, therefore, the fragility must have negligible value; at the upper amplitude end, the hazard should be negligibly low or the fragility value should be negligibly different from unity. In the latter case where the hazard is not negligibly low, but the fragility has effectively reached unity, a contribution to mean failure rate, equal to the mean seismic hazard at the upper value of the motion-amplitude range (i.e., the upper limit of ground-motion used in numerical evaluation of the failure frequency), should be added to the sum of contributions obtained from Step (7) above.

In implementing the above approach (or any approach that evaluates a seismic core-damage frequency), it may on occasion be necessary to numerically extrapolate the seismic hazard curve, particularly over high motion amplitudes, to capture (approximately) the entire contribution to mean seismic core-damage frequency. The need for extrapolation depends both on the magnitude of plant capacity and on the amplitude range of the seismic hazard curve. In the present investigation, plant capacities of interest are generally not unusually high compared to the upper amplitude defining the hazard curve. Since evaluation of mean seismic core-damage frequency focuses on the $1\text{x}10^{-5}$ level, it is important that the mean hazard curve drops well below $1\text{x}10^{-5}$ (say, no higher than $1\text{x}10^{-7}$). This condition is generally met by the revised LLNL seismic hazard curves. Consequently, hazard-curve extrapolation, although occasionally employed in this study, has not been a major concern. When employed, extrapolation involved extending the last segment of the hazard curve (defined by the last two points) assuming a linear trend in logarithmic (log-log) hazard space.

Conservative estimates of mean seismic core damage frequency have been evaluated in this study for the 48 focused-scope plant sites. This evaluation has used the mean 1993 LLNL hazard curves for PGA and for PSV (pseudo spectral velocity) at the following five vibration frequencies: 25Hz, 10Hz, 5.0Hz, 2.5Hz and 1.0Hz. For convenience in later comparisons, PSV amplitudes of the hazard curves have been converted to S_a (or PSA, pseudo spectral acceleration) values in percent of gravity (g).

For each site and each hazard curve, a mean seismic core-damage frequency has been computed using a conservative generic fragility curve. Six values of mean seismic core-damage frequency (corresponding to the five vibration frequencies and PGA) are thus obtained for each plant, defining a spectrum of results. Clearly, these six different values do not imply different core-damage frequencies for the plant; rather, they convey the dependence of estimated seismic core-damage frequency on the ground-motion parameter of interest in defining plant fragility. If, for instance, the plant response is dominated by failure of a component having a predominant effective vibration frequency of 5.0Hz, say, then the core-damage frequency estimate based on the 5.0Hz analysis would produce the most relevant estimate of risk. Generally, plants are sensitive to motions across a range of vibration frequencies. It is thus appropriate to weight the various frequency-dependent estimates of mean seismic core-damage frequency to obtain the most meaningful result. Various weighting methods may be proposed. The one employed in this study is the same as that implemented in the analyses of NUREG-1407, as described in Section 1.3 of this paper. That is, one-seventh (1/7) weight is given to the PGA-based results, whereas two-sevenths (2/7) weight is given to each of the results for 10Hz, 5.0Hz, and 2.5Hz.

PRA studies often evaluate seismic core-damage frequency using PGA-based hazard and fragility results alone, with an assumed spectral shape used in fragility assessment. The approach here, of computing mean seismic core-damage frequency for all spectral ordinates, provides a more directly relevant and consistent approach for accounting for the impacts of frequency-related variations.

A.2.1 Use of Generic Plant-Level Fragility Data.

In the foregoing evaluation of mean seismic core-damage frequencies, because plant-specific data is generally not available, a conservative generic estimate of seismic fragility was employed. The assumed fragility function is derived from results based on past PRAs, as documented in the published literature [A-2,A-3,A-4].

Specifically, the generic fragility is described by a double-lognormal distribution model, with distribution parameters as follows: a median capacity, $\breve{A}$, a logarithmic standard deviation reflecting variability due to randomness, β_R, and a logarithmic standard deviation reflecting variability due to uncertainty, β_U.

Based on the average of results from past PRAs, generic values of $\beta_R=0.22$ and $\beta_U=0.24$ are used. These values are considered to be highly representative, as comparatively low PRA-to-PRA variability have been observed for these parameters.

Obviously, the plant median capacity shows much greater variability from PRA to PRA. In evaluating a generic value for $\breve{A}$ using past PRA data, therefore, substantial conservatism needs to be introduced. Based on available data, specifically plant HCLPF data as derived from past SMAs and PRAs, it may be concluded that no plant has been shown to possess a HCLPF capacity less than 1.25 times its SSE. Hence, it is reasonably safe to assume (without further specific evaluation, and for the purposes only of assessing the scope of seismic review for re-binning) that the HCLPF capacity for every plant in the original focused-scope seismic IPEEE bin will at least equal a level defined by 1.25 times its corresponding SSE value. This level defines a (generally) conservative generic plant HCLPF capacity. The corresponding conservative generic median capacity implied by this HCLPF level, together with the generic values of β_R and β_U, is thus obtained as:

$$\begin{aligned}\breve{A} &= HCLPF \times e^{1.65(\beta_R + \beta_U)} \\ &= 1.25 \times SSE \times e^{1.65(0.22 + 0.24)} \\ &= 2.67 \times SSE\end{aligned}$$

The composite logarithmic standard deviation, β_C, is simply obtained as the square root of the sum of the squared values of β_R and β_U. The mean plant-level generic fragility curve is, therefore, defined by a lognormal probability distribution model having the following parameters:

$$\breve{A} = 2.67 \times SSE$$

$$\begin{aligned}\beta_C &= \sqrt{(\beta_R)^2 + (\beta_U)^2} \\ &= \sqrt{(0.22)^2 + (0.24)^2} \\ &= 0.33\end{aligned}$$

This conservative generic mean plant-level fragility is used in the evaluations of mean seismic core-damage frequency, as described above.

A.2.2 Mean Seismic Core-Damage Frequency Results.

Results of the mean seismic core-damage frequency evaluations are summarized in Tables A-1 to A-3. These results are based on the 1993 revised LLNL seismic hazard inputs. In Table A-1 are presented frequency-dependent results of computed mean seismic core-damage frequency for the 48 focused scope sites. Table A-1 identifies the LLNL site number associated with each evaluation result. The plant name corresponding to the LLNL site number can be determined from Table A-2. Table A-2 presents weighted/composite results of mean seismic core-damage frequency using the (NUREG-1407) weighting procedure as was summarized above. Table A-3 contains information identical to that in Table A-2, except the data have been re-ordered in terms of decreasing composite mean seismic core-damage frequency. This re-ordering clarifies determination of the set of plants re-binned to the modified-scope category on the basis of having a computed mean seismic core-damage frequency that does not exceed, when rounded (to one significant digit), the value of 1×10^{-5}.

A.3 Evaluation of Required HCLPF Capacity

A useful basis for clearly establishing the level of seismic capacity a plant needs to demonstrate in order to satisfy a specific target level of seismic safety is the required HCLPF spectrum [A-2]. The required HCLPF spectrum is simply that capacity level which, if just achieved for a given plant, results in a core-damage risk that meets the specified safety target, given the plant-specific seismic hazard. In other words, if the actual plant HCLPF capacity equals the required HCLPF spectrum, then the computed seismic core-damage frequency, using the plant seismic hazard as input, will just match the specified safety target.

Although expressed in terms of a plant capacity, the required HCLPF spectrum is actually a characterization of the seismic hazard. It is a way of weighting the input seismic hazard curve in such a way that has greatest meaning to core-damage risk. The only assumption regarding plant capacity that is introduced in the required HCLPF assessment pertains to the plant-level values selected for β_R and β_U. As discussed earlier, however, generic values of these parameters exhibit low variability, meaning that the required HCLPF is an accurate measure of the plant capacity required to limit core-damage frequency to the specified safety level. The only input to the assessment of required HCLPF that changes meaningfully from plant to plant is the seismic hazard. Hence, the required HCLPF is predominantly a measure of seismic hazard (conveyed as a plant capacity). The required HCLPF capacity is an exceptionally meaningful and convenient basis for presenting the seismic hazard, because embedded in it is a desired safety level (and the supporting risk analyses of seismic core-damage frequency) and because it is expressed in the format of a relevant seismic capacity measure, i.e., as a seismic margin earthquake (SME) input. In fact, one significant use of the required HCLPF spectrum is to assess plant-specific SMEs that are consistent with a desired level of seismic safety.

The approach for obtaining a required HCLPF spectrum for a given plant is described as follows:

1. Select a safety target or goal in terms of a specified mean seismic core-damage frequency.

2. Obtain the set of mean seismic hazard curves for the given site of interest. Mean seismic hazard curves should be obtained for PGA and for spectral responses for an appropriate set of vibration frequencies.

3. Construct a trial mean plant-level fragility curve by using generic values for variability parameters and by assuming a trial plant-level median capacity.

4. For the given trial mean fragility curve and a given mean seismic hazard curve, evaluate the mean seismic core-damage frequency using the procedure described in Section A.2.

5. Compare the computed mean seismic core-damage frequency with the selected seismic safety target. Select a new trial median capacity based on the comparison. For instance, if the computed mean seismic core-damage frequency exceeds the specified safety goal, then select a new trial median capacity higher than that used in the previous trial. Otherwise, select a new trial median capacity less than that used in the previous trial.

6. Repeat Steps (3) to (5) until the median capacity is ascertained where the computed mean core-damage frequency just matches the safety target.

7. Convert the resulting value of required median capacity to an equivalent value of required HCLPF capacity, using the following equation:

   $$HCLPF = \check{A}\ e^{-1.65(\beta_R + \beta_U)}$$

   Substituting the generic values, presented earlier, into this equation, the required HCLPF is simply equal to 0.468 times the required median capacity.

8. Repeat Steps (3) to (7) for seismic hazard results pertaining to all vibration frequencies. The results will be a set of vibration-frequency-dependent ordinates of required HCLPF capacity.

9. Construct the plant required-HCLPF spectrum (associated with the desired safety target) by plotting the ordinates of required HCLPF capacity at their corresponding vibration frequencies.

For the present study, a mean seismic core-damage frequency target of 1×10^{-5} was used, corresponding to the re-binning criterion discussed in Section 4. Using the 1993 revised LLNL results as seismic hazard inputs, required-HCLPF spectra were obtained for the set of 48 original focused-scope sites.

A.3.1 Required HCLPF Spectrum Plots and Related Results.

The set of 48 required-HCLPF spectrum results are plotted (correspondingly) in Figures A-1 to A-48. The appropriate plant SSE spectrum is also plotted on the same graph for comparison. These plots are useful in delineating the details of frequency-dependent (i.e., spectral) variations in required-HCLPF capacities vis-à-vis SSE design levels.

As noted in Section A.2.1, a HCLPF level of 1.25 times the SSE has been identified as a conservative generic characterization of plant capacity. In other words, there exists substantial reason for having high confidence that actual plant HCLPF capacities will exceed this conservative level. Consequently, if a required HCLPF spectrum does not exceed (over the frequency range of interest) the SSE spectrum by more than a factor of 1.25, then the resulting estimated mean seismic core-damage frequency will not be expected to exceed the target value of $1x10^{-5}$. It is useful, therefore, to normalize the required HCLPF spectrum by the SSE spectrum, in performing seismic-scope re-assessments. This normalization has been performed, with the resulting ratios shown in Table A-4 for PGA and for the 5 vibration frequencies. The ratios in Table A-4 have been weighted, according to the weighting criteria described previously, to produce the set of scalar composite results presented in Table A-5. Table A-6 contains results identical to those in Table A-5, except the data have been re-ordered in terms of decreasing composite ratio of required HCLPF to SSE.

Table A-6 confirms the identification of plants re-binned to the modified-scope category on the basis of having a low computed mean seismic core-damage frequency (not exceeding $1.49x10^{-5}$). Comparing Tables A-3 and A-6, it is seen that the effect of rounding estimates of core-damage frequency to the nearest single significant digit, is that plants with required-HCLPF to SSE ratios as high as 1.37 (exceeding 1.25 by about 10%) still satisfy the absolute re-binning criteria.

A.4 References

[A-1] USNRC, NUREG/CR-2300, "PRA Procedures Guide," January, 1983.

[A-2] EPRI, EPRI TR-103126, "Use of Probabilistic Seismic Hazard Results: General Decision Making, the Charleston Earthquake Issue, and Severe Accident Evaluations," October 1993.

[A-3] Sewell, R., et al., "Approaches that Use Seismic Hazard Results to Address Topics of Nuclear Power Plant Seismic Safety, with Application to the Charleston Earthquake Issue," *Nuclear Engineering and Design*, p. 129-141, 1990.

[A-4] EPRI, EPRI NP-6395-D, Appendix C, "Approaches to Evaluate the Influence of Possible Large Earthquakes in the Eastern United States on Seismic Safety of Nuclear Power Plants," April 1989.

TABLE A-1: Computed Frequency-Dependent Values of Mean Seismic Core-Damage Frequency for 48 Focused-Scope Sites

	Site				Frequency:		
	No.	PGA	25.Hz	10.Hz	5.0Hz	2.5Hz	1.0Hz
Focused	55	1.648E-05	4.435E-05	1.571E-05	1.320E-05	8.043E-06	4.341E-06
Focused	40	5.302E-05	1.076E-04	5.940E-05	2.667E-05	6.989E-06	1.630E-06
Focused	56	2.255E-05	4.861E-05	7.520E-06	6.200E-06	2.783E-06	2.027E-06
Focused	03	5.114E-06	1.239E-05	1.795E-06	1.590E-06	7.256E-07	4.248E-07
Focused	26	8.831E-06	3.343E-05	1.227E-05	1.285E-05	1.189E-05	4.680E-06
Focused	27	4.026E-05	1.104E-04	6.736E-05	1.662E-05	7.238E-06	2.987E-06
Focused	42	6.846E-06	1.615E-05	2.683E-06	2.568E-06	1.291E-06	7.554E-07
Focused	57	5.178E-06	9.641E-06	1.830E-06	1.778E-06	9.374E-07	5.663E-07
Focused	28	2.853E-05	4.865E-05	4.184E-05	3.838E-05	4.051E-05	1.830E-05
Focused	29	2.780E-05	9.099E-05	1.872E-05	1.315E-05	8.483E-06	4.292E-06
Focused	43	2.450E-05	2.363E-05	4.178E-06	1.048E-05	4.677E-06	3.514E-06
Focused	44	9.772E-06	2.991E-05	4.623E-05	1.869E-05	1.697E-05	2.328E-06
Focused	59	4.045E-05	8.026E-05	4.977E-05	2.676E-05	4.646E-06	4.305E-06
Focused	45	2.303E-05	7.266E-05	1.306E-05	1.065E-05	6.690E-06	4.625E-06
Focused	46	1.913E-05	5.645E-05	2.473E-05	1.132E-05	8.361E-06	1.642E-06
Focused	47	1.088E-05	3.534E-05	2.607E-05	1.673E-05	1.355E-05	3.926E-06
Focused	11	1.198E-05	5.976E-05	3.748E-05	2.302E-05	1.508E-05	4.674E-06
Focused	62	4.504E-05	1.605E-04	1.562E-04	6.968E-05	3.948E-05	1.368E-05
Focused	12	1.166E-05	4.002E-05	3.049E-05	2.004E-05	1.080E-05	5.287E-06
Focused	13	2.586E-05	7.894E-05	5.780E-05	4.005E-05	2.216E-05	9.603E-06
Focused	02	1.322E-05	2.921E-05	4.583E-06	3.983E-06	1.831E-06	1.031E-06
Focused	31	1.785E-05	4.272E-05	2.478E-05	3.842E-05	2.996E-05	2.773E-05
Focused	32	1.868E-05	2.419E-05	4.718E-06	5.789E-06	5.468E-06	4.642E-06
Focused	48	2.080E-05	4.274E-05	4.165E-05	3.126E-05	1.158E-05	3.102E-06
Focused	49	1.895E-05	5.896E-05	1.736E-05	1.106E-05	8.265E-06	2.228E-06
Focused	01	3.737E-05	7.047E-05	9.784E-06	1.282E-05	7.932E-06	3.988E-06
Focused	33	2.234E-05	7.990E-05	1.539E-05	1.063E-05	6.832E-06	3.292E-06
Focused	09	2.201E-05	4.129E-05	2.738E-05	2.694E-05	2.096E-05	7.036E-06
Focused	64	2.635E-05	5.798E-05	2.794E-05	1.217E-05	5.768E-06	3.603E-06
Focused	15	2.555E-05	5.162E-05	1.155E-05	1.038E-05	5.088E-06	2.712E-06
Focused	34	5.501E-05	8.100E-05	1.333E-05	1.620E-05	1.004E-05	1.025E-05
Focused	16	2.387E-05	4.764E-05	2.392E-05	2.008E-05	2.323E-05	1.212E-05
Focused	50	7.987E-06	2.570E-05	2.333E-05	2.088E-05	1.344E-05	1.939E-06
Focused	17	5.375E-05	1.077E-04	5.329E-05	4.568E-05	3.561E-05	1.506E-05
Focused	51	1.195E-05	2.775E-05	4.837E-06	4.420E-06	2.106E-06	1.195E-06
Focused	52	2.122E-05	4.595E-05	3.812E-05	2.559E-05	9.735E-06	2.567E-06
Focused	53	2.445E-05	5.089E-05	4.428E-05	3.120E-05	1.886E-05	3.250E-06
Focused	65	2.500E-06	6.255E-06	2.522E-07	6.672E-07	1.213E-05	3.122E-05
Focused	19	1.834E-05	3.470E-05	2.591E-05	2.035E-05	3.066E-05	1.444E-05
Focused	38	4.370E-05	1.433E-04	4.714E-05	2.605E-05	1.807E-05	1.006E-05
Focused	39	2.058E-05	4.941E-05	4.395E-05	3.138E-05	3.125E-05	1.242E-05
Focused	22	5.749E-05	1.222E-04	4.610E-05	3.650E-05	2.230E-05	1.004E-05
Focused	23	5.629E-05	4.116E-05	9.400E-06	1.559E-05	1.741E-05	6.302E-06
Focused	24	3.649E-05	5.866E-05	3.945E-05	3.946E-05	3.174E-05	8.809E-06
Focused	08	3.901E-05	5.666E-05	1.039E-05	2.019E-05	1.699E-05	1.649E-05
Focused	07	2.361E-05	5.208E-05	1.325E-05	8.897E-06	5.459E-06	2.713E-06
Focused	06	1.133E-05	1.988E-05	3.671E-06	3.150E-06	1.511E-06	8.065E-07
Focused	54	2.639E-05	7.002E-05	6.083E-05	3.997E-05	2.170E-05	3.691E-06

TABLE A-2: Composite/Weighted Values of Mean Seismic Core-Damage Frequency for 48 Focused-Scope Plants

	Site No.	Site/SSE Description	Mean SCDF
Focused	55	Arkansas #2	1.29E-05
Focused	40	Beaver Valley	3.42E-05
Focused	56	Bellefonte	7.94E-06
Focused	03	Braidwood	1.90E-06
Focused	26	Browns Ferry	1.18E-05
Focused	27	Brunswick	3.18E-05
Focused	42	Byron	2.85E-06
Focused	57	Callaway	2.04E-06
Focused	28	Calvert Cliffs	3.86E-05
Focused	29	Catawba	1.55E-05
Focused	43	Clinton	9.02E-06
Focused	44	Cook	2.48E-05
Focused	59	Cooper	2.90E-05
Focused	45	Davis Besse	1.20E-05
Focused	46	Dresden	1.54E-05
Focused	47	Fermi	1.77E-05
Focused	11	Fitzpatrick	2.33E-05
Focused	62	Fort Calhoun	8.22E-05
Focused	12	Ginna	1.92E-05
Focused	13	Haddam Neck	3.80E-05
Focused	02	Harris	4.86E-06
Focused	31	Hatch	2.92E-05
Focused	32	Hope Creek	7.23E-06
Focused	48	Kewaunee	2.71E-05
Focused	49	La Salle	1.32E-05
Focused	01	Limerick	1.41E-05
Focused	33	McGuire	1.26E-05
Focused	09	Millstone	2.47E-05
Focused	64	Monticello	1.69E-05
Focused	15	Nine Mile Point	1.14E-05
Focused	34	North Anna	1.92E-05
Focused	16	Oyster Creek	2.26E-05
Focused	50	Palisades	1.76E-05
Focused	17	Peach Bottom	4.61E-05
Focused	51	Perry	4.95E-06
Focused	52	Point Beach	2.40E-05
Focused	53	Prairie Island	3.04E-05
Focused	65	Quad Cities	4.09E-06
Focused	19	Salem	2.46E-05
Focused	38	Summer	3.23E-05
Focused	39	Surry	3.34E-05
Focused	22	Susquehanna	3.82E-05
Focused	23	Three Mile Island	2.02E-05
Focused	24	Vermont Yankee	3.68E-05
Focused	08	Vogtle	1.92E-05
Focused	07	Watts Bar	1.13E-05
Focused	06	Wolf Creek	4.00E-06
Focused	54	Zion	3.88E-05

TABLE A-3: Ordered Composite/Weighted Results of Mean Seismic Core-Damage Frequency for 48 Focused-Scope Plants

	Site No.	Site/SSE Description	Mean SCDF
Focused	62	Fort Calhoun	8.22E-05
Focused	17	Peach Bottom	4.61E-05
Focused	54	Zion	3.88E-05
Focused	28	Calvert Cliffs	3.86E-05
Focused	22	Susquehanna	3.82E-05
Focused	13	Haddam Neck	3.80E-05
Focused	24	Vermont Yankee	3.68E-05
Focused	40	Beaver Valley	3.42E-05
Focused	39	Surry	3.34E-05
Focused	38	Summer	3.23E-05
Focused	27	Brunswick	3.18E-05
Focused	53	Prairie Island	3.04E-05
Focused	31	Hatch	2.92E-05
Focused	59	Cooper	2.90E-05
Focused	48	Kewaunee	2.71E-05
Focused	44	Cook	2.48E-05
Focused	09	Millstone	2.47E-05
Focused	19	Salem	2.46E-05
Focused	52	Point Beach	2.40E-05
Focused	11	Fitzpatrick	2.33E-05
Focused	16	Oyster Creek	2.26E-05
Focused	23	Three Mile Island	2.02E-05
Focused	34	North Anna	1.92E-05
Focused	12	Ginna	1.92E-05
Focused	08	Vogtle	1.92E-05
Focused	47	Fermi	1.77E-05
Focused	50	Palisades	1.76E-05
Focused	64	Monticello	1.69E-05
Focused	29	Catawba	1.55E-05
Focused	46	Dresden	1.54E-05
Focused	01	Limerick	1.41E-05
Focused	49	La Salle	1.32E-05
Focused	55	Arkansas #2	1.29E-05
Focused	33	McGuire	1.26E-05
Focused	45	Davis Besse	1.20E-05
Focused	26	Browns Ferry	1.18E-05
Focused	15	Nine Mile Point	1.14E-05
Focused	07	Watts Bar	1.13E-05
Focused	43	Clinton	9.02E-06
Focused	56	Bellefonte	7.94E-06
Focused	32	Hope Creek	7.23E-06
Focused	51	Perry	4.95E-06
Focused	02	Harris	4.86E-06
Focused	65	Quad Cities	4.09E-06
Focused	06	Wolf Creek	4.00E-06
Focused	42	Byron	2.85E-06
Focused	57	Callaway	2.04E-06
Focused	03	Braidwood	1.90E-06

TABLE A-4: Computed Frequency-Dependent Values of the Ratio of Required HCLPF to SSE for 48 Focused-Scope Sites

	Site		Frequency:				
	No.	PGA	25.Hz	10.Hz	5.0Hz	2.5Hz	1.0Hz
Focused	55	1.52	2.23	1.49	1.40	1.14	0.87
Focused	40	2.89	4.21	2.95	2.07	1.04	0.50
Focused	56	1.70	2.18	1.13	1.04	0.76	0.64
Focused	03	0.96	1.35	0.66	0.59	0.43	0.31
Focused	26	1.19	1.97	1.35	1.39	1.35	0.91
Focused	27	2.42	3.97	2.88	1.56	1.08	0.71
Focused	42	1.08	1.50	0.76	0.72	0.53	0.38
Focused	57	0.99	1.23	0.71	0.68	0.53	0.44
Focused	28	2.04	2.56	2.48	2.45	2.56	1.75
Focused	29	1.86	3.00	1.60	1.40	1.17	0.86
Focused	43	1.84	1.81	0.91	1.27	0.90	0.80
Focused	44	1.24	2.14	2.79	1.72	1.65	0.60
Focused	59	2.44	3.48	2.45	2.05	0.90	0.82
Focused	45	1.72	2.66	1.39	1.28	1.06	0.87
Focused	46	1.65	2.61	1.87	1.33	1.15	0.52
Focused	47	1.29	2.09	1.89	1.58	1.44	0.79
Focused	11	1.34	2.57	2.14	1.79	1.49	0.88
Focused	62	2.67	5.02	4.87	3.44	2.57	1.48
Focused	12	1.33	2.14	2.01	1.70	1.29	0.92
Focused	13	1.82	2.85	2.67	2.39	1.79	1.23
Focused	02	1.39	1.86	0.94	0.86	0.64	0.46
Focused	31	1.65	2.50	1.90	2.51	2.12	2.14
Focused	32	1.64	1.79	0.93	1.00	0.96	0.86
Focused	48	1.85	2.85	2.83	2.56	1.37	0.63
Focused	49	1.68	2.92	1.60	1.31	1.14	0.57
Focused	01	2.10	2.62	1.24	1.39	1.14	0.81
Focused	33	1.69	2.77	1.47	1.28	1.07	0.76
Focused	09	1.70	2.13	1.89	1.96	1.75	1.05
Focused	64	2.12	3.49	2.17	1.40	0.92	0.62
Focused	15	1.83	2.41	1.32	1.27	0.95	0.70
Focused	34	2.43	2.70	1.39	1.53	1.25	1.27
Focused	16	1.85	2.51	1.86	1.72	1.91	1.38
Focused	50	1.12	2.02	1.90	1.85	1.46	0.55
Focused	17	2.48	3.21	2.54	2.53	2.26	1.55
Focused	51	1.35	1.88	0.94	0.88	0.65	0.45
Focused	52	1.87	2.98	2.67	2.24	1.23	0.57
Focused	53	2.05	3.17	2.95	2.56	1.85	0.63
Focused	65	0.73	1.05	0.37	0.45	1.37	2.30
Focused	19	1.63	2.10	1.91	1.72	2.13	1.52
Focused	38	2.22	3.63	2.31	1.83	1.59	1.25
Focused	39	1.74	2.69	2.59	2.25	2.25	1.41
Focused	22	2.63	3.68	2.46	2.35	1.85	1.25
Focused	23	2.55	2.07	1.22	1.50	1.58	1.01
Focused	24	2.12	2.52	2.23	2.35	2.13	1.17
Focused	08	2.23	2.56	1.27	1.65	1.58	1.56
Focused	07	1.73	2.23	1.38	1.20	0.98	0.71
Focused	06	1.32	1.69	0.82	0.74	0.54	0.38
Focused	54	2.01	3.43	3.14	2.59	1.89	0.74

TABLE A-5: Composite/Weighted Values of the Ratio of Required HCLPF to SSE for 48 Focused-Scope Sites

	Site No.	Site/SSE Description	HCLPF/SSE Ratio
Focused	55	Arkansas #2	1.37
Focused	40	Beaver Valley	2.14
Focused	56	Bellefonte	1.08
Focused	03	Braidwood	0.62
Focused	26	Browns Ferry	1.34
Focused	27	Brunswick	1.92
Focused	42	Byron	0.73
Focused	57	Callaway	0.69
Focused	28	Calvert Cliffs	2.43
Focused	29	Catawba	1.46
Focused	43	Clinton	1.14
Focused	44	Cook	1.94
Focused	59	Cooper	1.89
Focused	45	Davis Besse	1.31
Focused	46	Dresden	1.48
Focused	47	Fermi	1.59
Focused	11	Fitzpatrick	1.74
Focused	62	Fort Calhoun	3.49
Focused	12	Ginna	1.62
Focused	13	Haddam Neck	2.22
Focused	02	Harris	0.90
Focused	31	Hatch	2.10
Focused	32	Hope Creek	1.06
Focused	48	Kewaunee	2.20
Focused	49	La Salle	1.40
Focused	01	Limerick	1.37
Focused	33	McGuire	1.34
Focused	09	Millstone	1.84
Focused	64	Monticello	1.59
Focused	15	Nine Mile Point	1.27
Focused	34	North Anna	1.54
Focused	16	Oyster Creek	1.83
Focused	50	Palisades	1.65
Focused	17	Peach Bottom	2.45
Focused	51	Perry	0.90
Focused	52	Point Beach	2.02
Focused	53	Prairie Island	2.39
Focused	65	Quad Cities	0.73
Focused	19	Salem	1.88
Focused	38	Summer	1.96
Focused	39	Surry	2.28
Focused	22	Susquehanna	2.28
Focused	23	Three Mile Island	1.59
Focused	24	Vermont Yankee	2.22
Focused	08	Vogtle	1.61
Focused	07	Watts Bar	1.26
Focused	06	Wolf Creek	0.79
Focused	54	Zion	2.46

TABLE A-6: Ordered Composite/Weighted Values of the Ratio of Required HCLPF to SSE for 48 Focused-Scope Sites

	Site No.	Site/SSE Description	HCLPF/SSE Ratio
Focused	62	Fort Calhoun	3.49
Focused	54	Zion	2.46
Focused	17	Peach Bottom	2.45
Focused	28	Calvert Cliffs	2.43
Focused	53	Prairie Island	2.39
Focused	22	Susquehanna	2.28
Focused	39	Surry	2.28
Focused	24	Vermont Yankee	2.22
Focused	13	Haddam Neck	2.22
Focused	48	Kewaunee	2.20
Focused	40	Beaver Valley	2.14
Focused	31	Hatch	2.10
Focused	52	Point Beach	2.02
Focused	38	Summer	1.96
Focused	44	Cook	1.94
Focused	27	Brunswick	1.92
Focused	59	Cooper	1.89
Focused	19	Salem	1.88
Focused	09	Millstone	1.84
Focused	16	Oyster Creek	1.83
Focused	11	Fitzpatrick	1.74
Focused	50	Palisades	1.65
Focused	12	Ginna	1.62
Focused	08	Vogtle	1.61
Focused	64	Monticello	1.59
Focused	23	Three Mile Island	1.59
Focused	47	Fermi	1.59
Focused	34	North Anna	1.54
Focused	46	Dresden	1.48
Focused	29	Catawba	1.46
Focused	49	La Salle	1.40
Focused	01	Limerick	1.37
Focused	55	Arkansas #2	1.37
Focused	33	McGuire	1.34
Focused	26	Browns Ferry	1.34
Focused	45	Davis Besse	1.31
Focused	15	Nine Mile Point	1.27
Focused	07	Watts Bar	1.26
Focused	43	Clinton	1.16
Focused	56	Bellefonte	1.08
Focused	32	Hope Creek	1.06
Focused	02	Harris	0.90
Focused	51	Perry	0.90
Focused	06	Wolf Creek	0.79
Focused	65	Quad Cities	0.73
Focused	42	Byron	0.73
Focused	57	Callaway	0.69
Focused	03	Braidwood	0.62

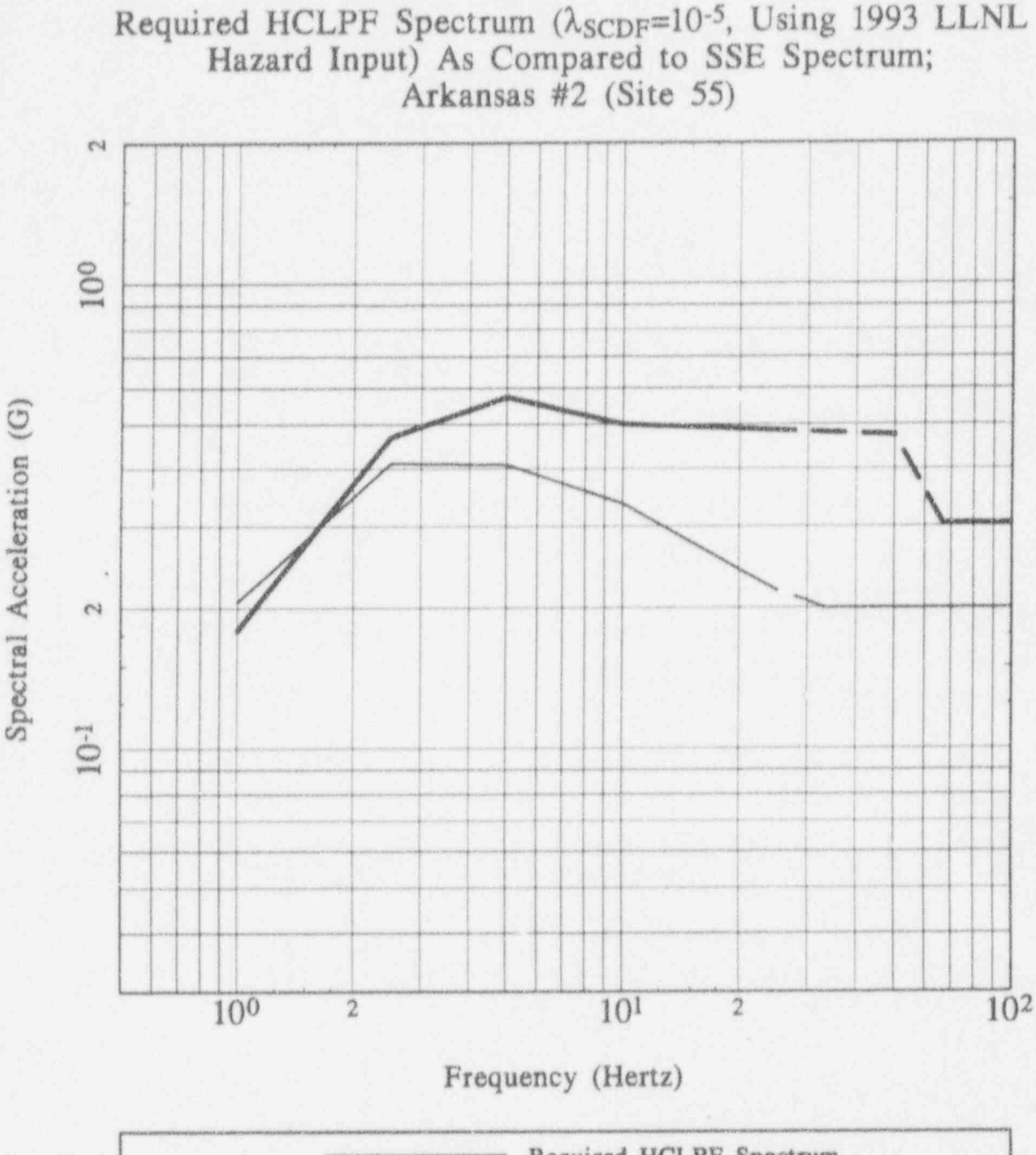


Figure A-1. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 55, Arkansas #2.

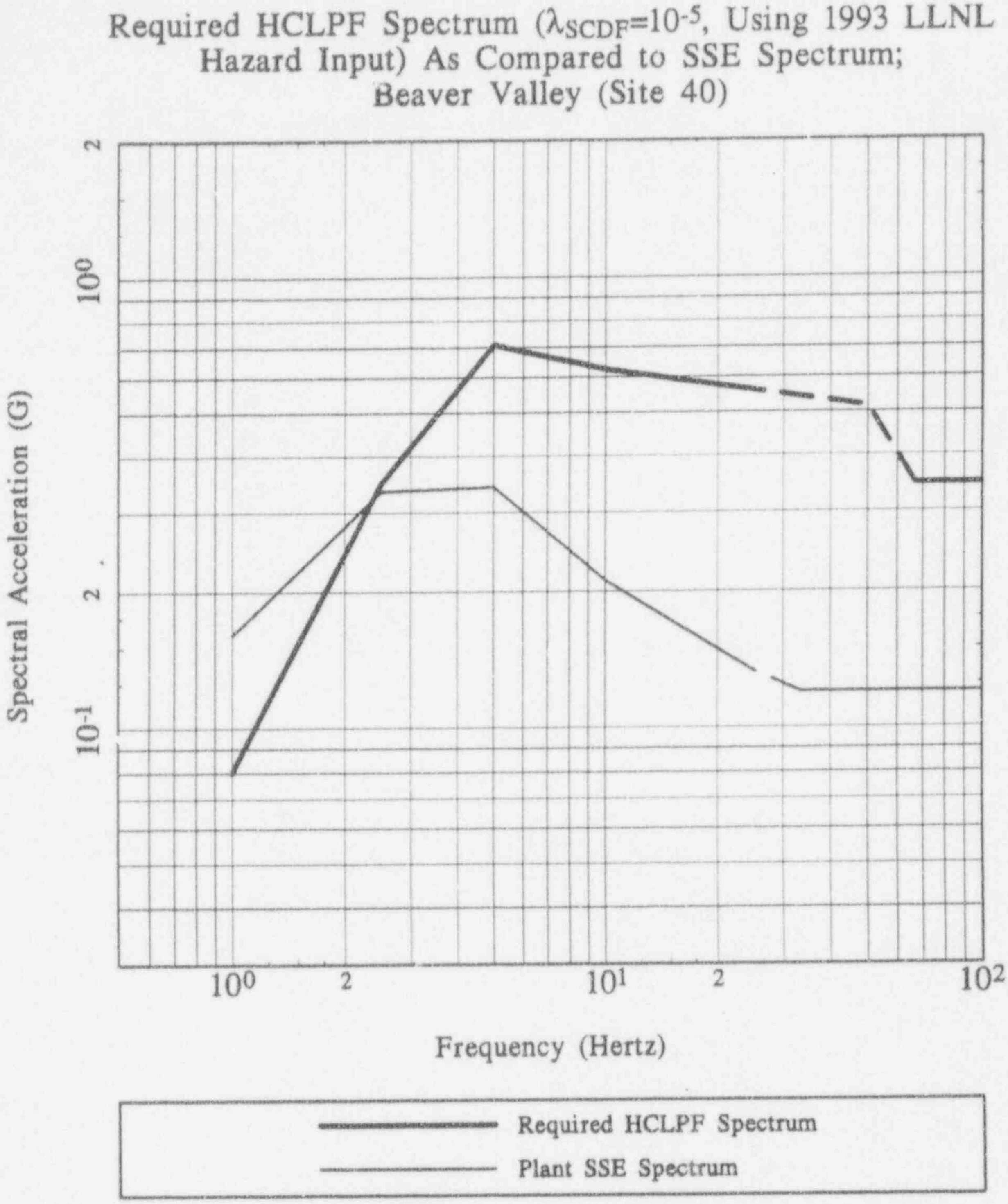


Figure A-2. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 40, Beaver Valley.

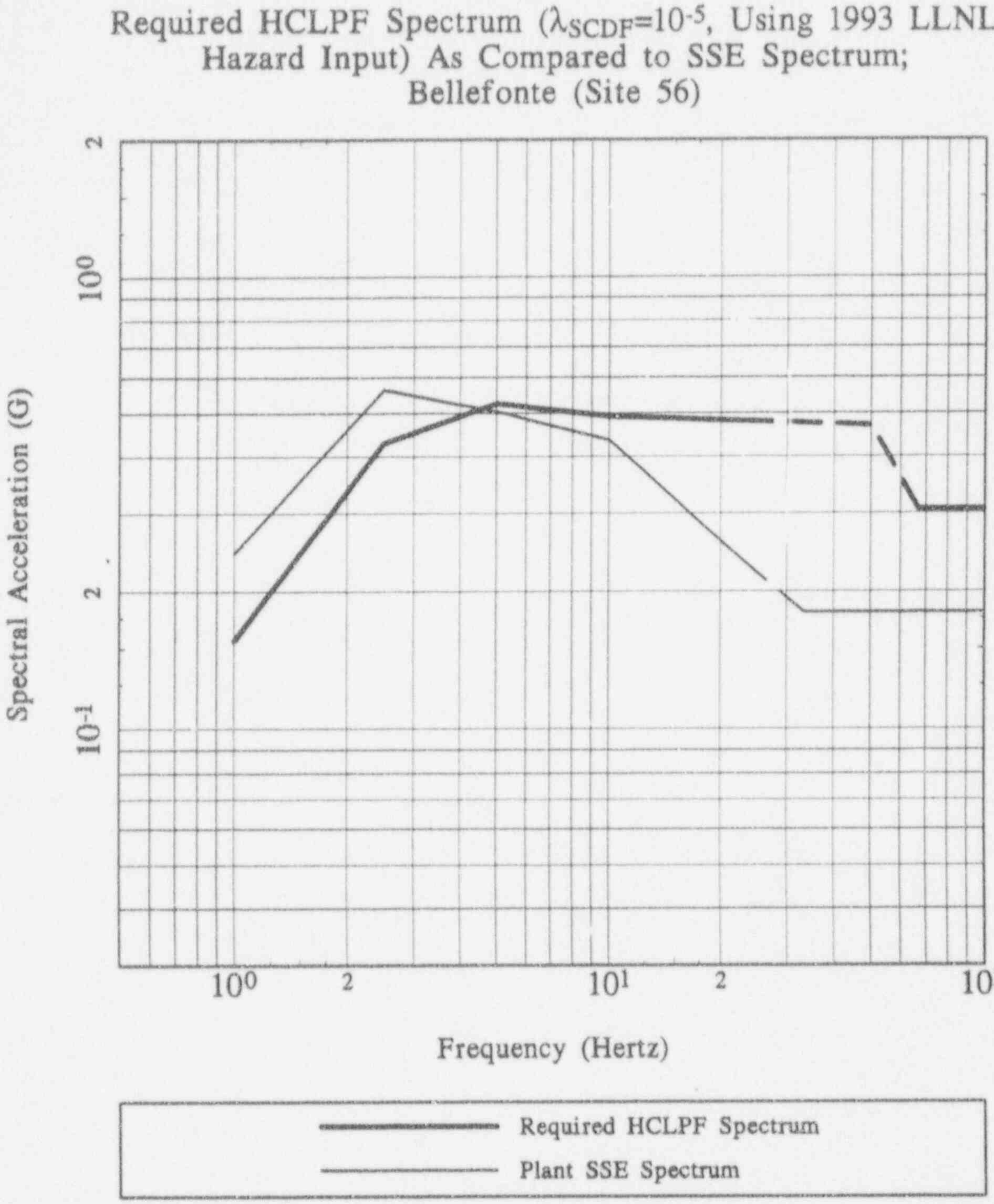


Figure A-3. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 56, Bellefonte.

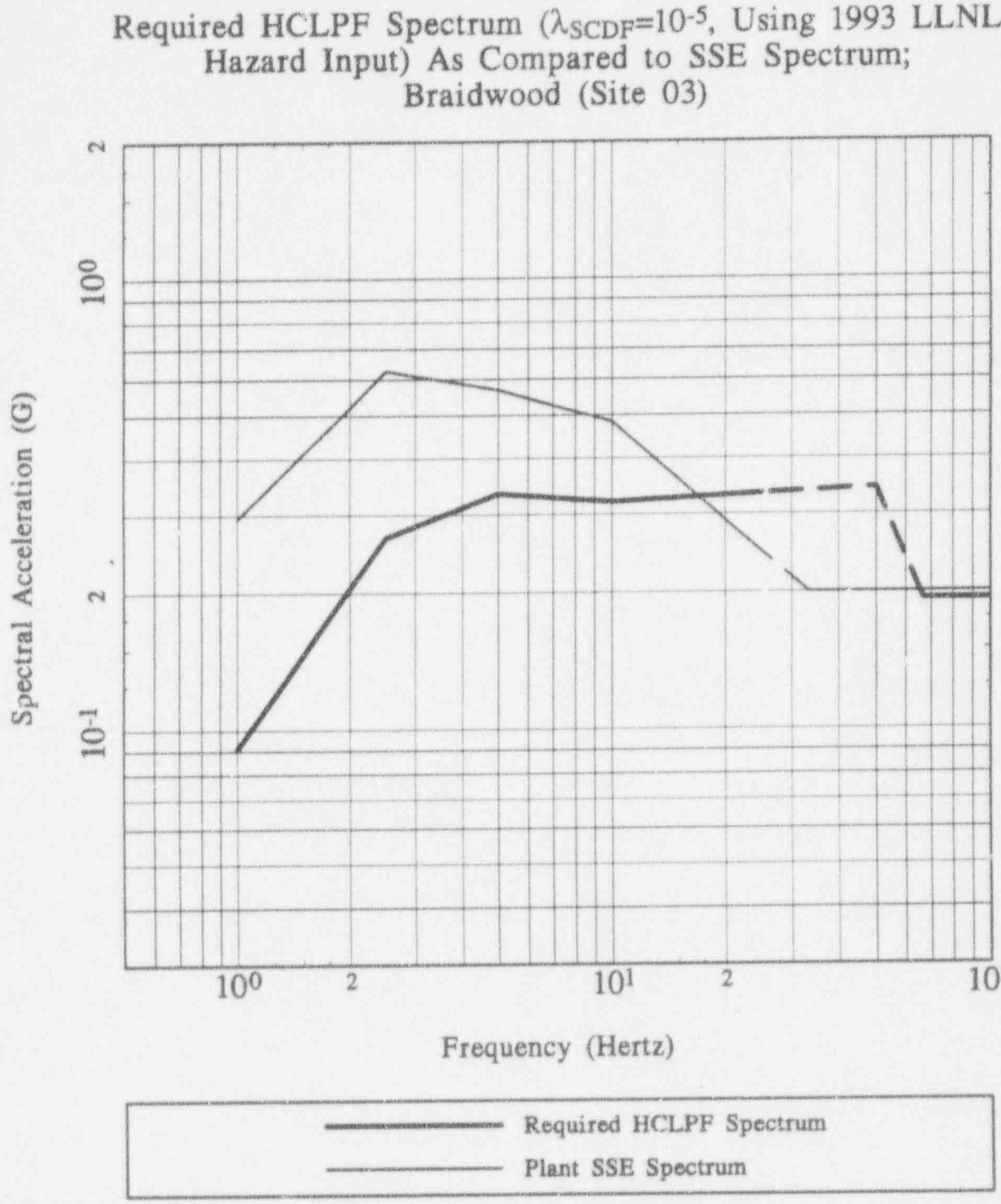


Figure A-4. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 03, Braidwood.

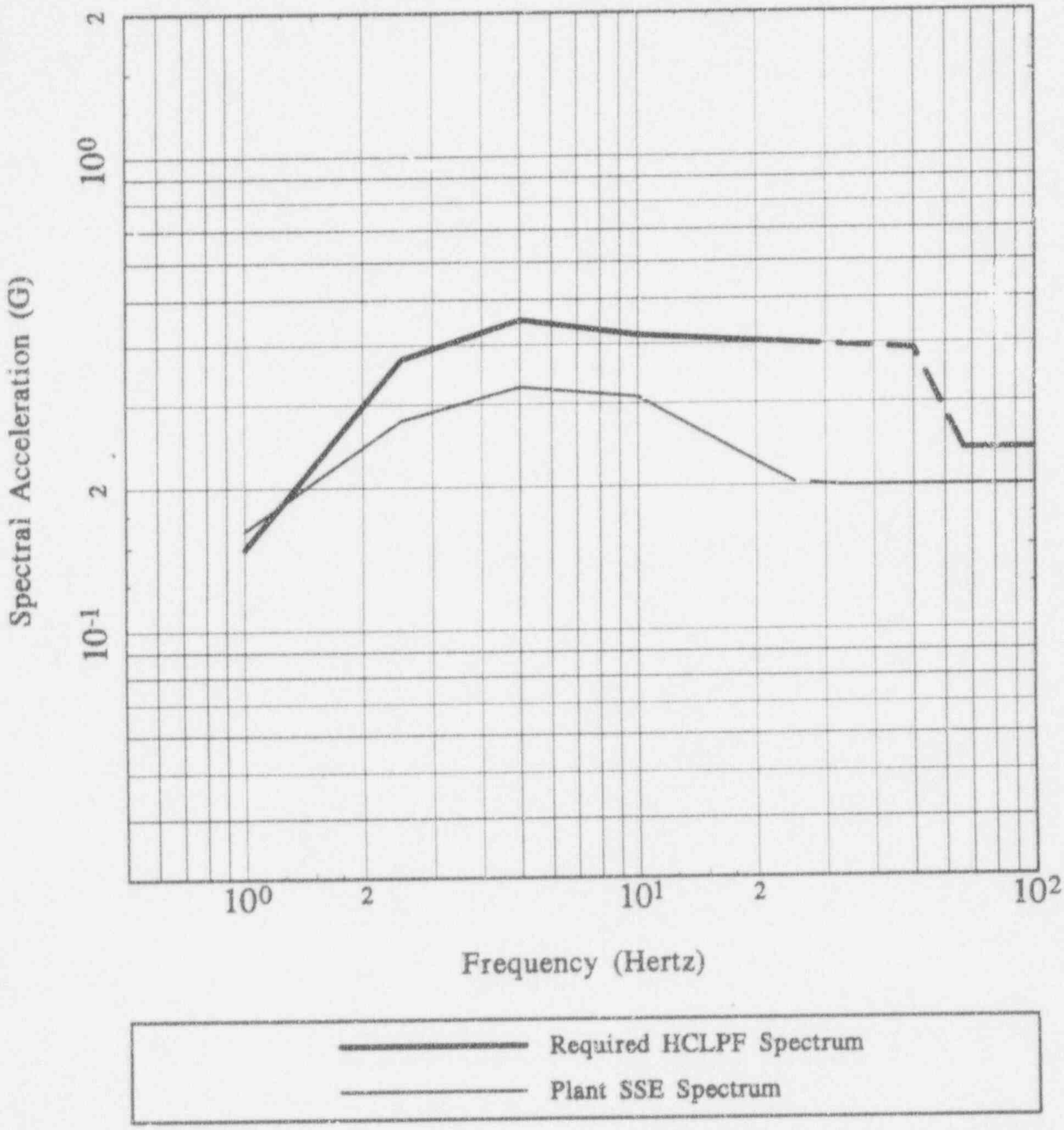

Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Browns Ferry (Site 26)

Figure A-5. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 26, Browns Ferry.

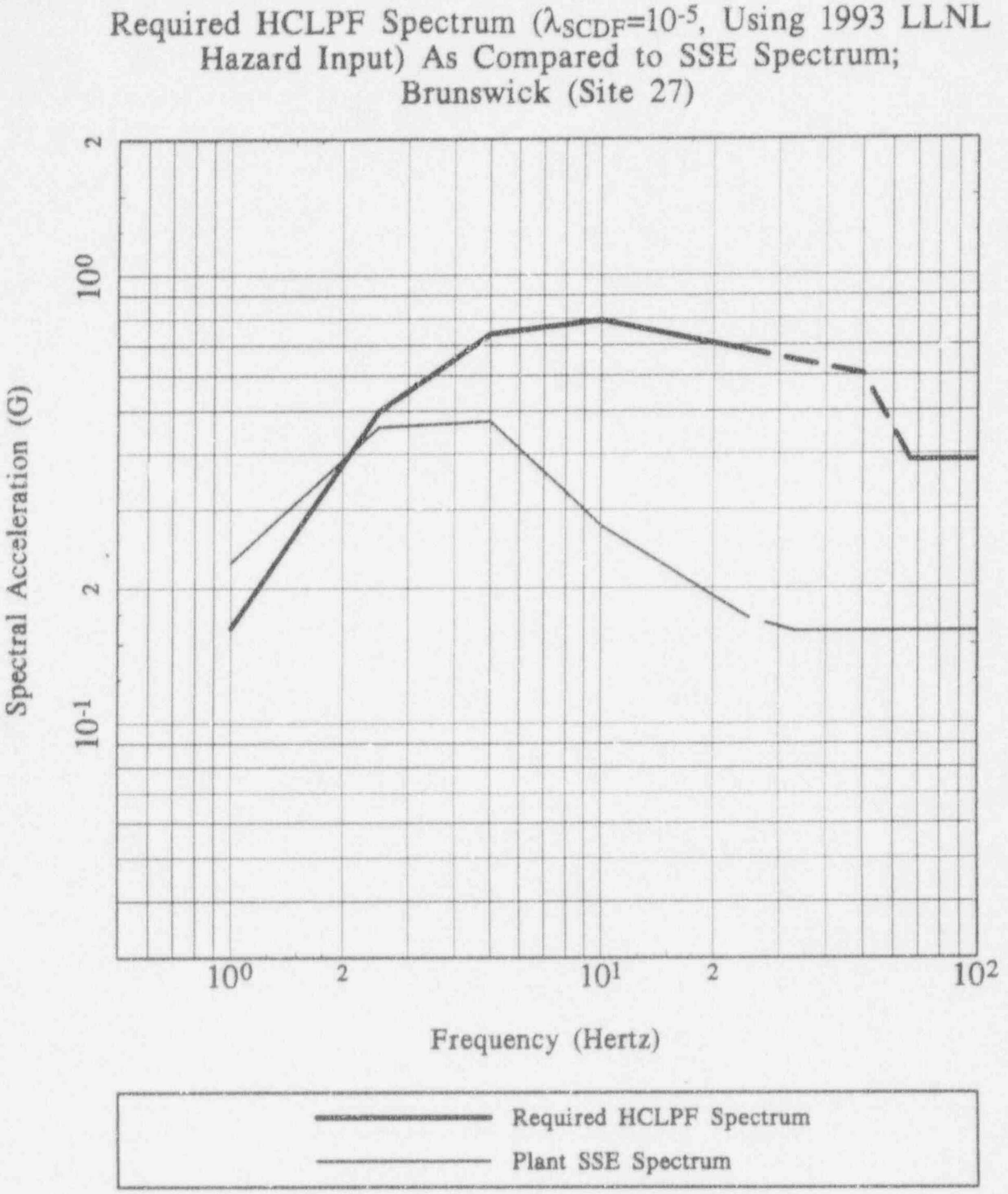


Figure A-6. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 27, Brunswick.

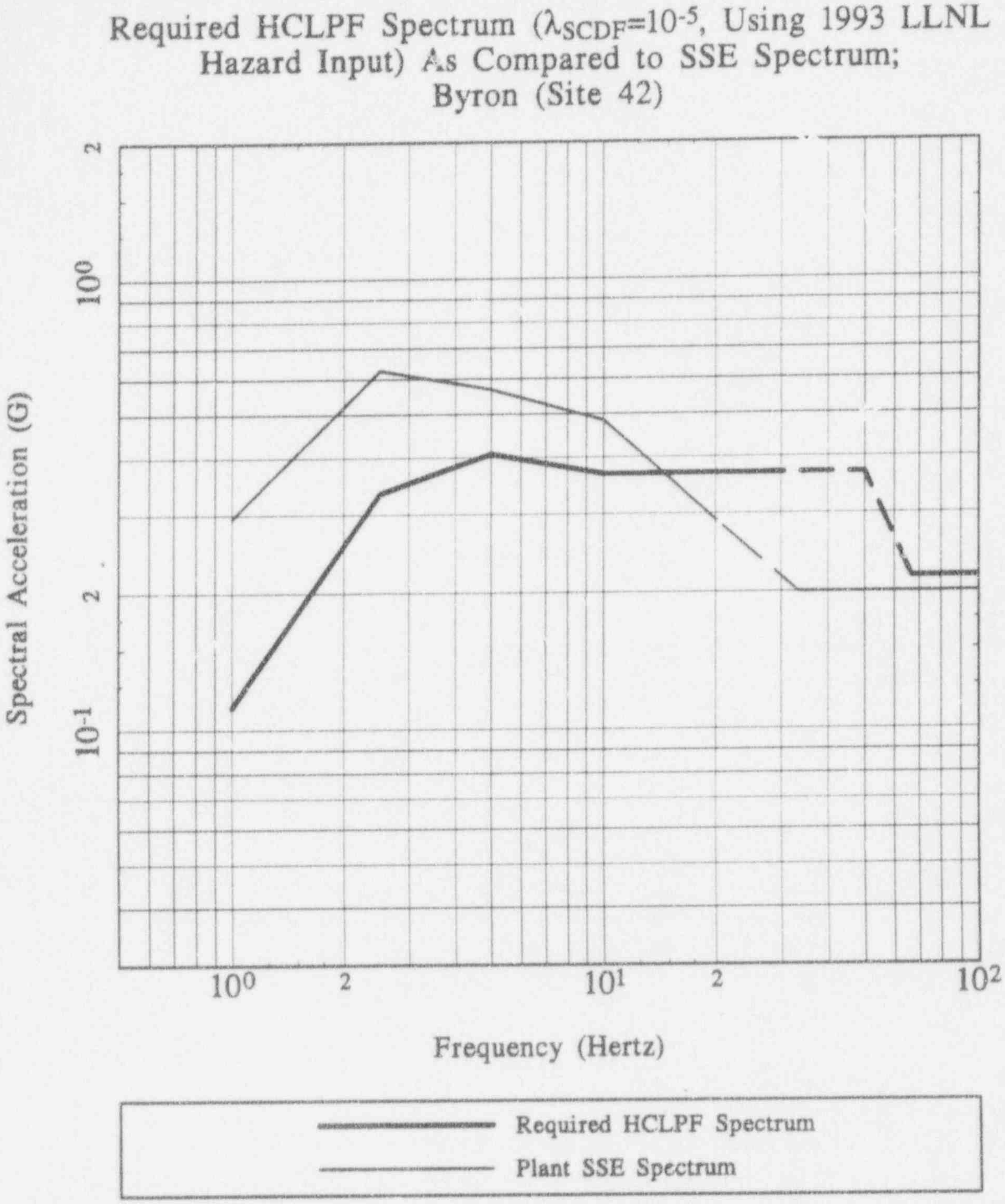


Figure A-7. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 42, Byron.

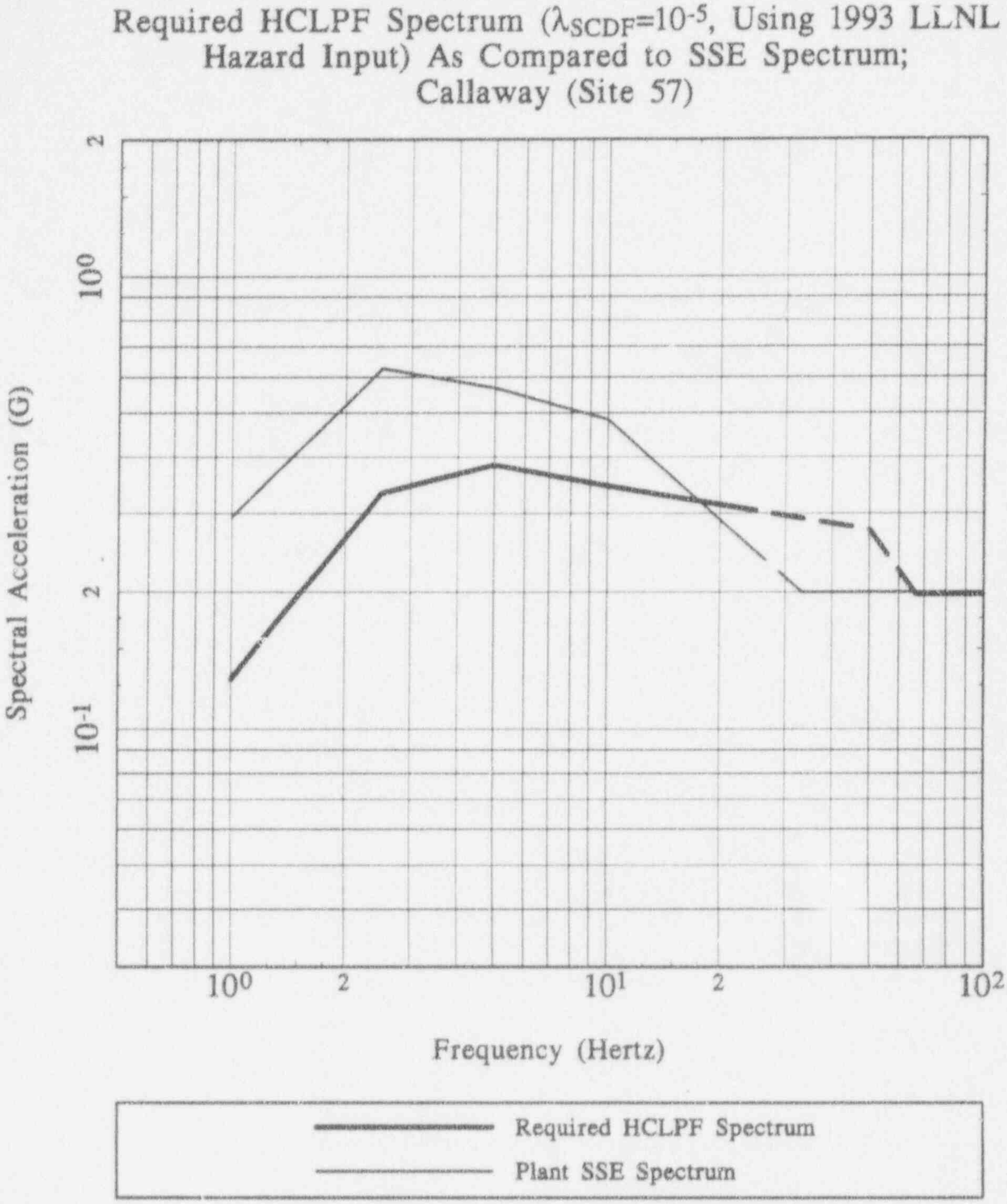


Figure A-8. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of $1x10^{-5}$), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 57, Callaway.

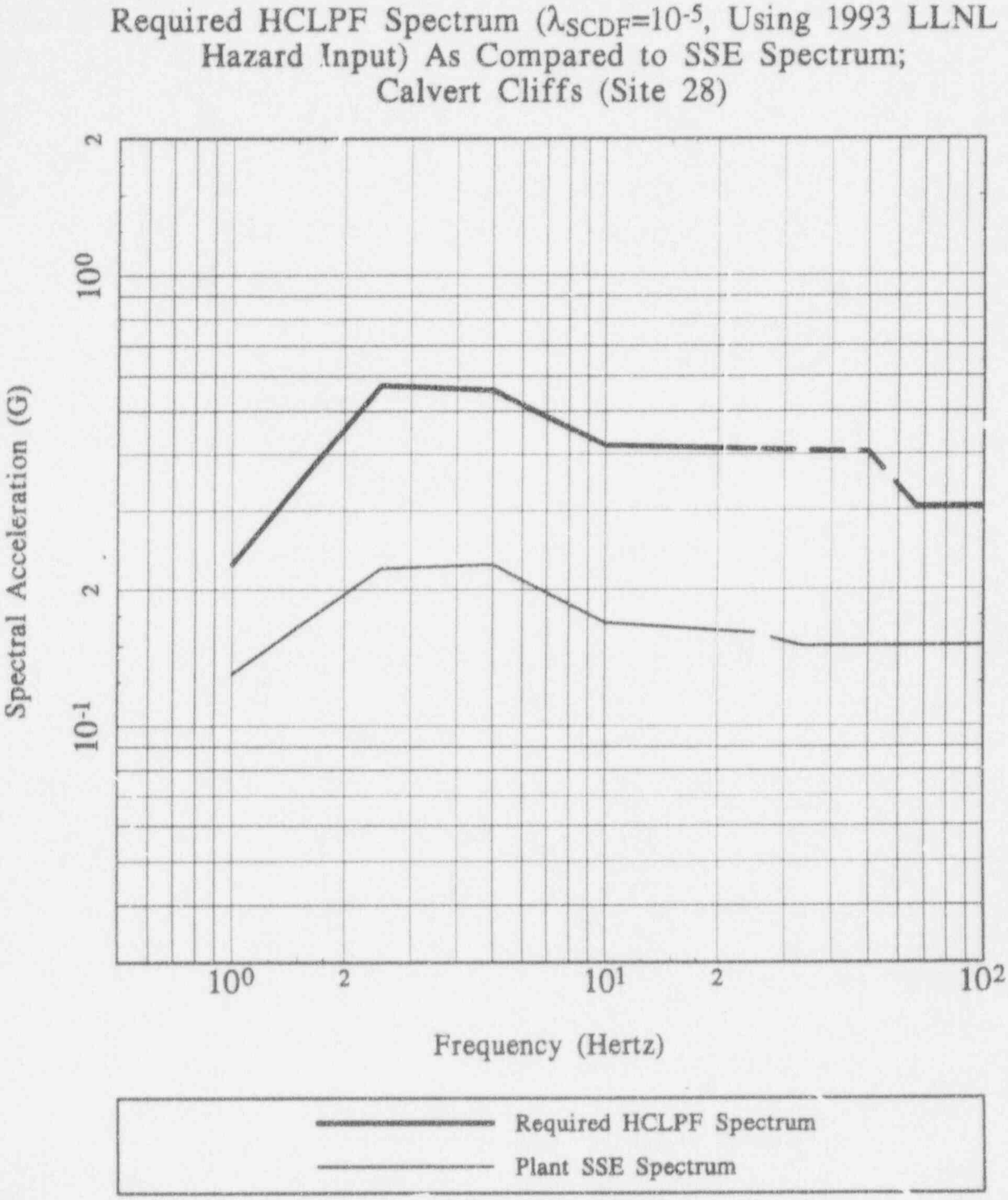


Figure A-9. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 28, Calvert Cliffs.

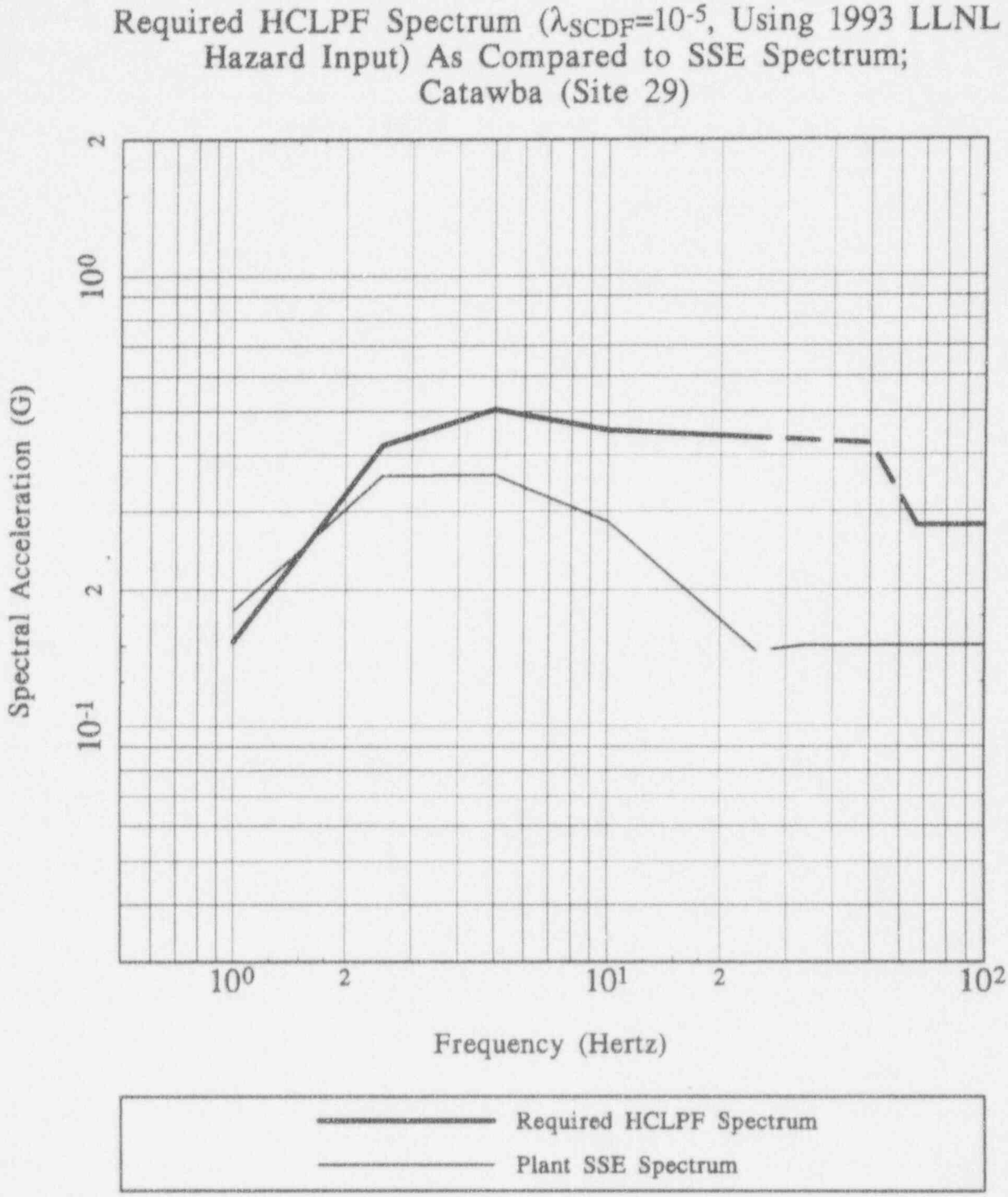
 Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Catawba (Site 29)

Figure A-10. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 29, Catawba.

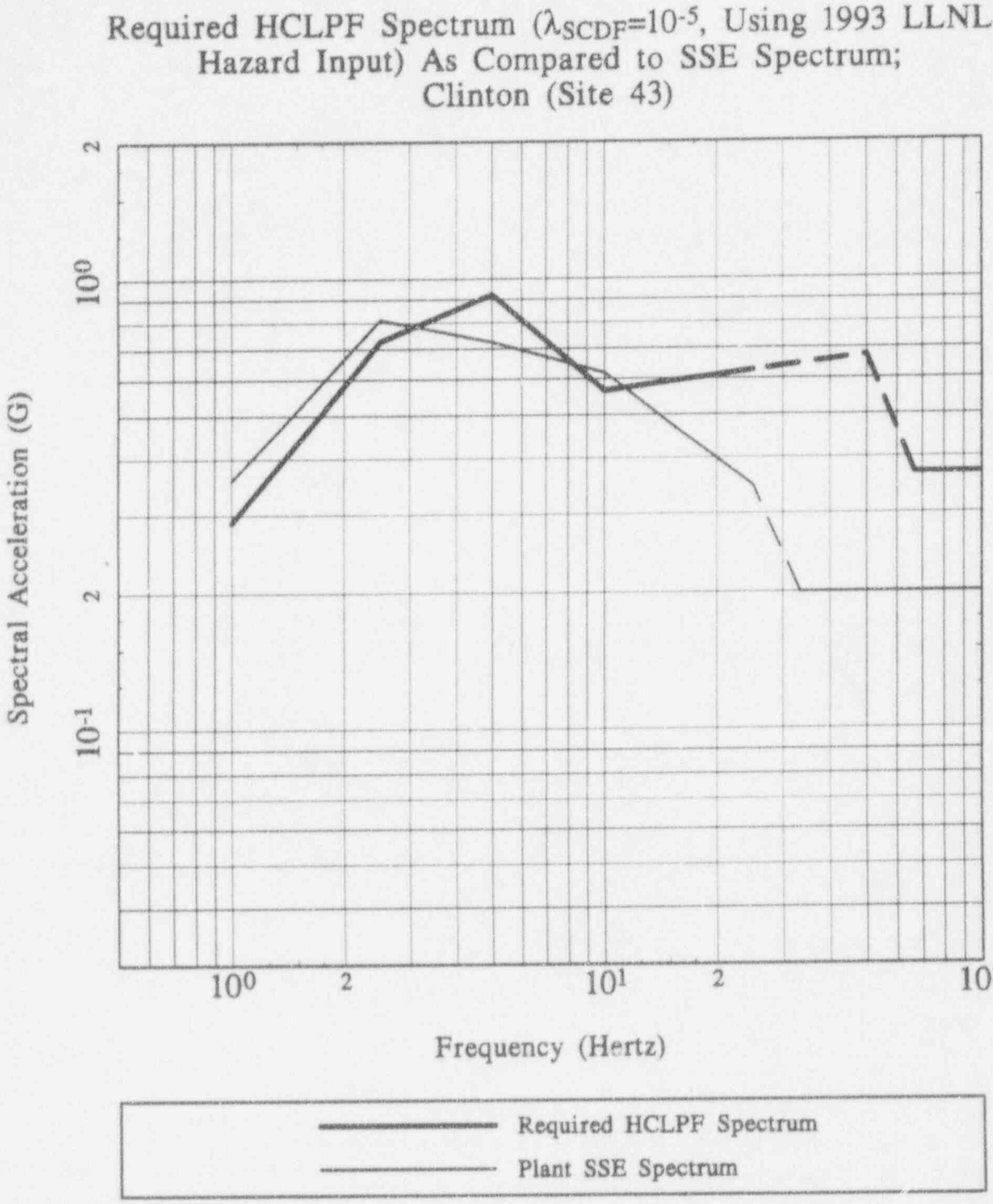


Figure A-11. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 43, Clinton.

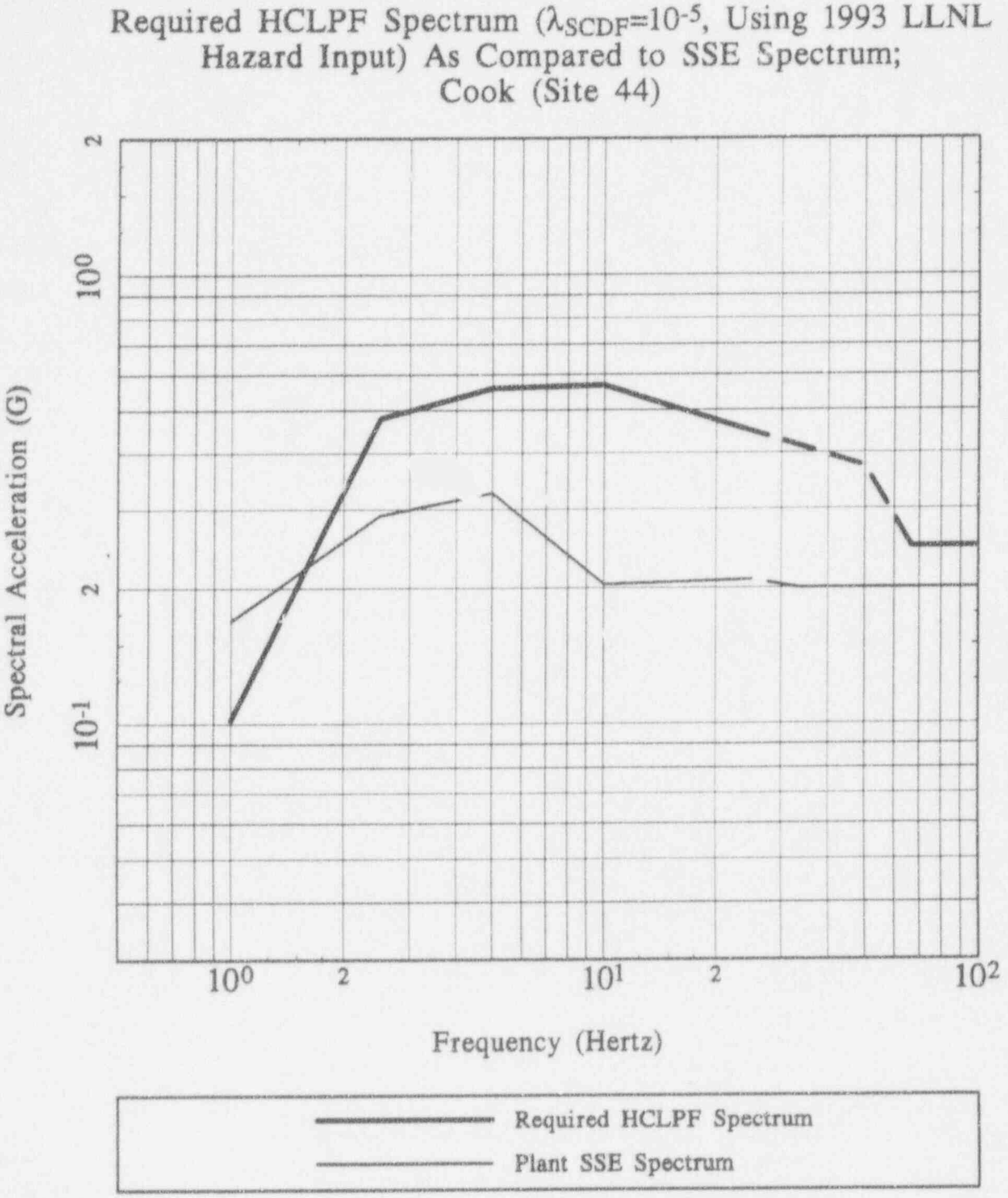
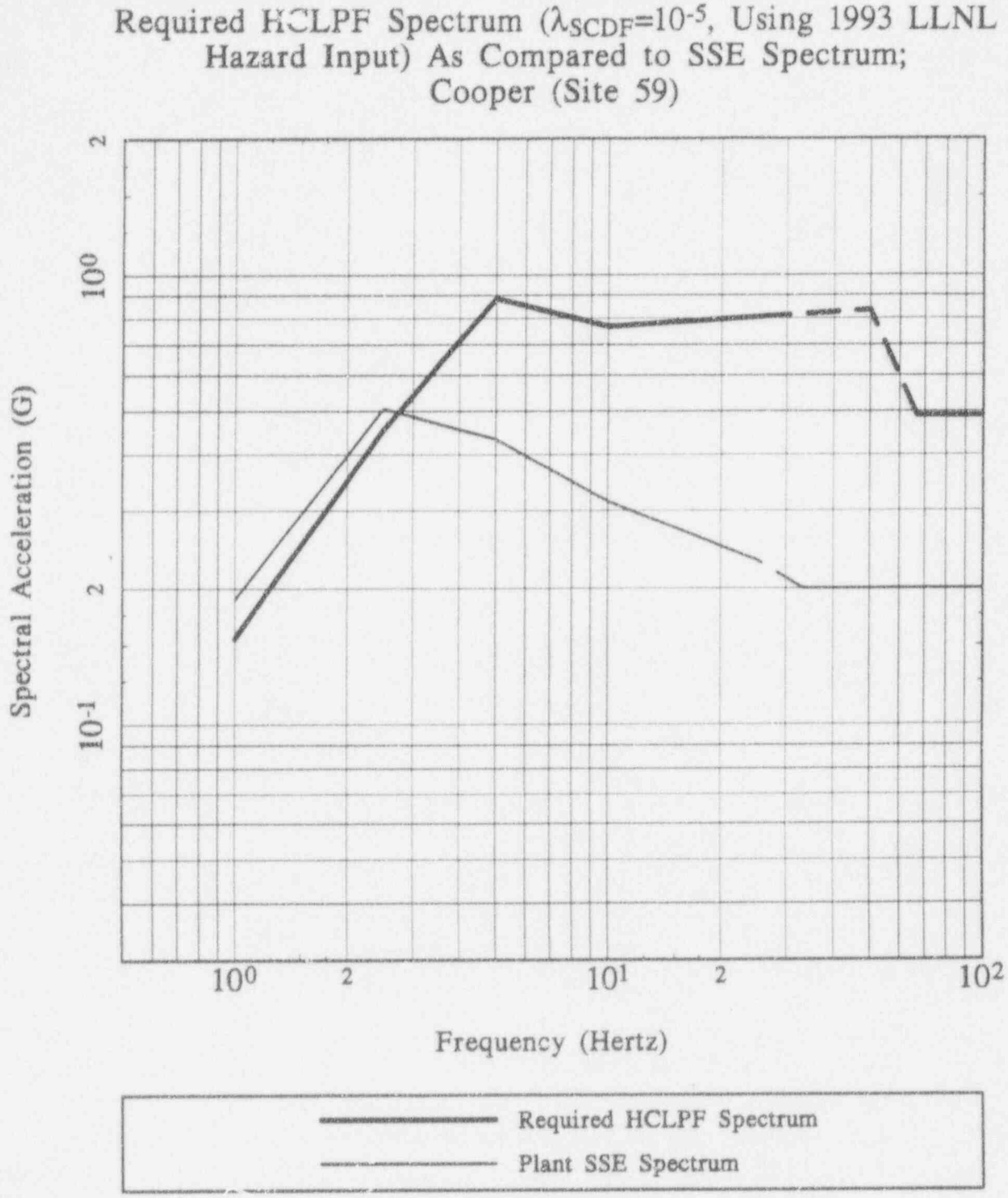
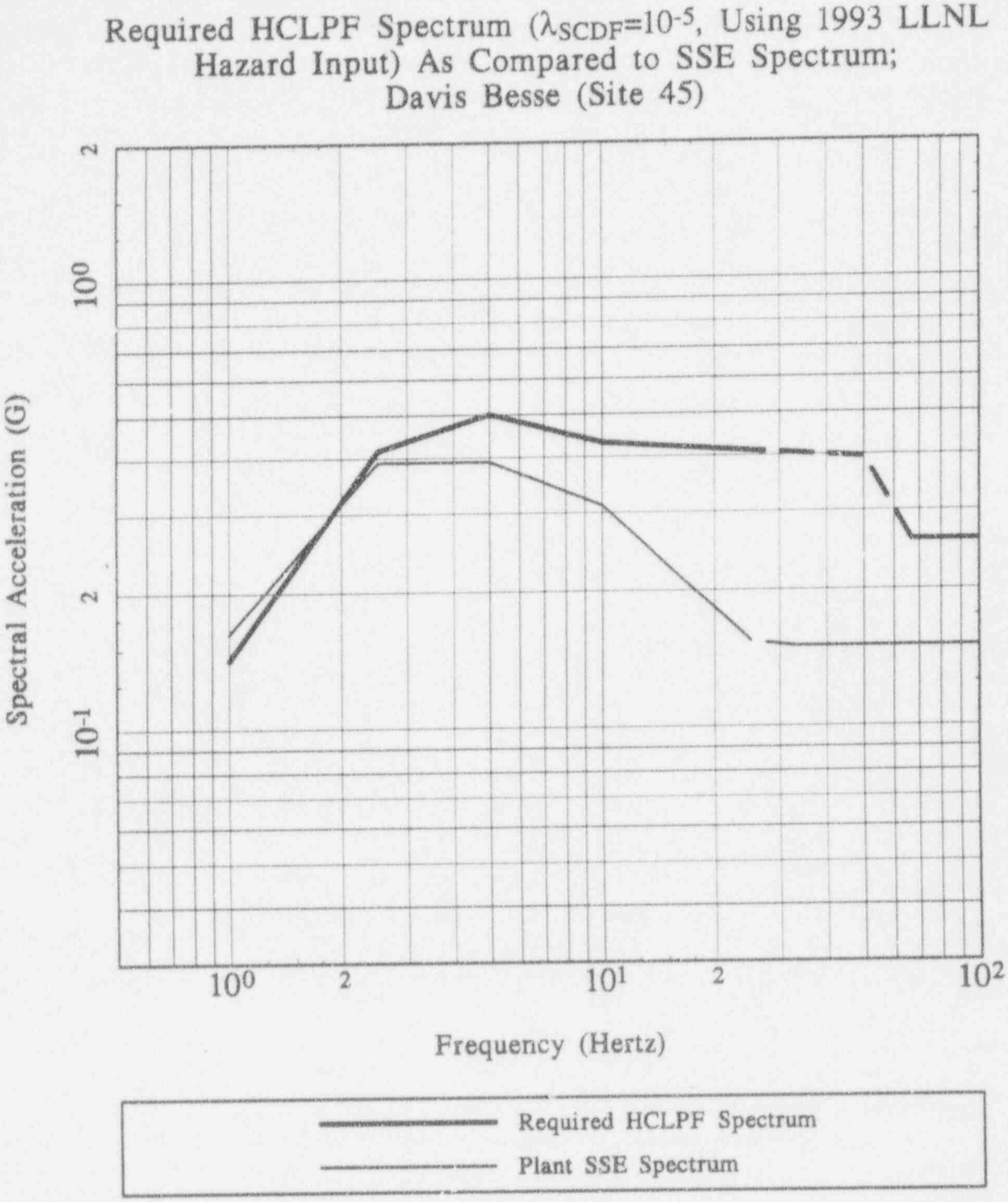


Figure A-12. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 44, Cook.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Cooper (Site 59)

Figure A-13. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 59, Cooper.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Davis Besse (Site 45)

Figure A-14. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 45, Davis-Besse.

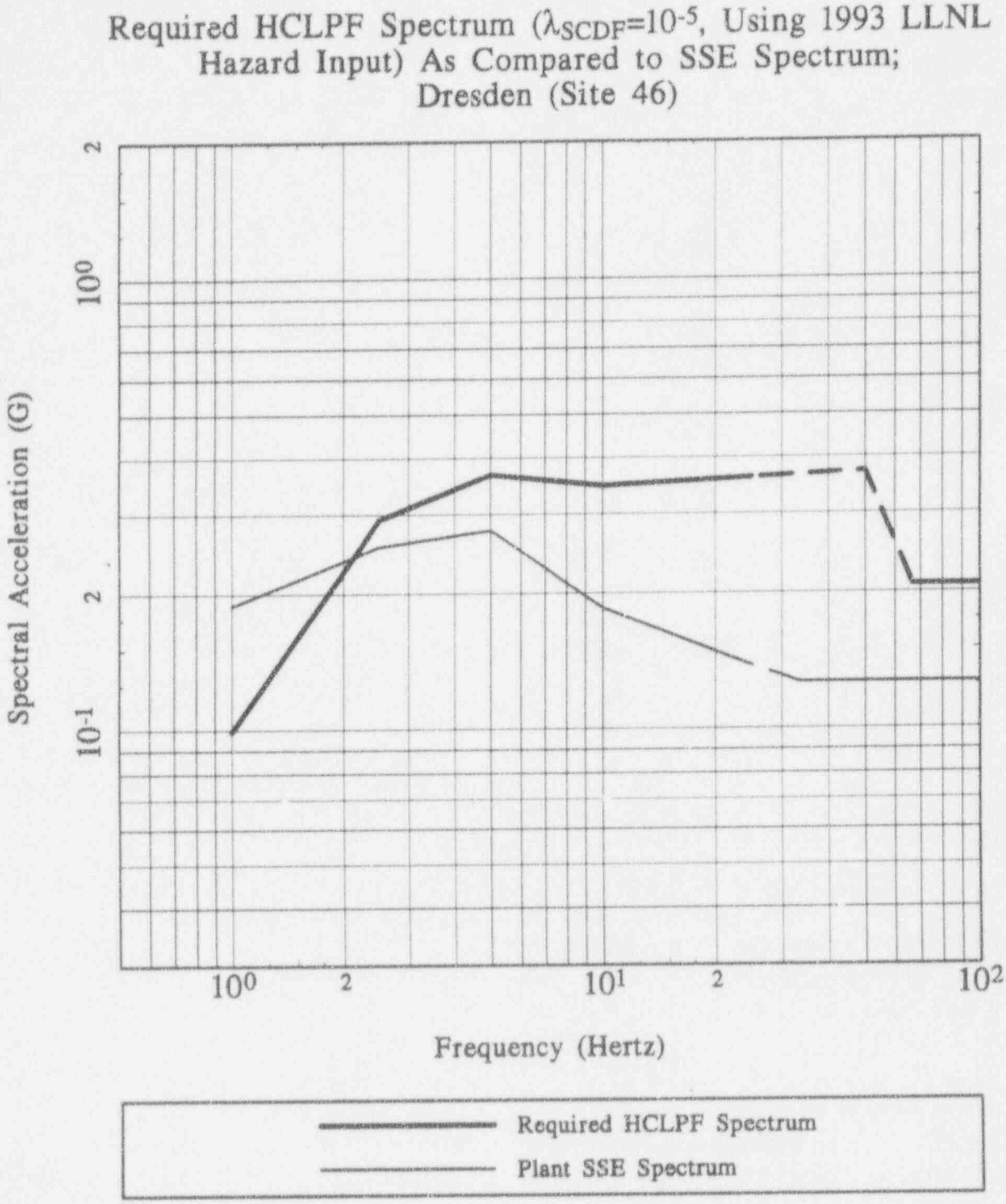


Figure A-15. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 46, Dresden.

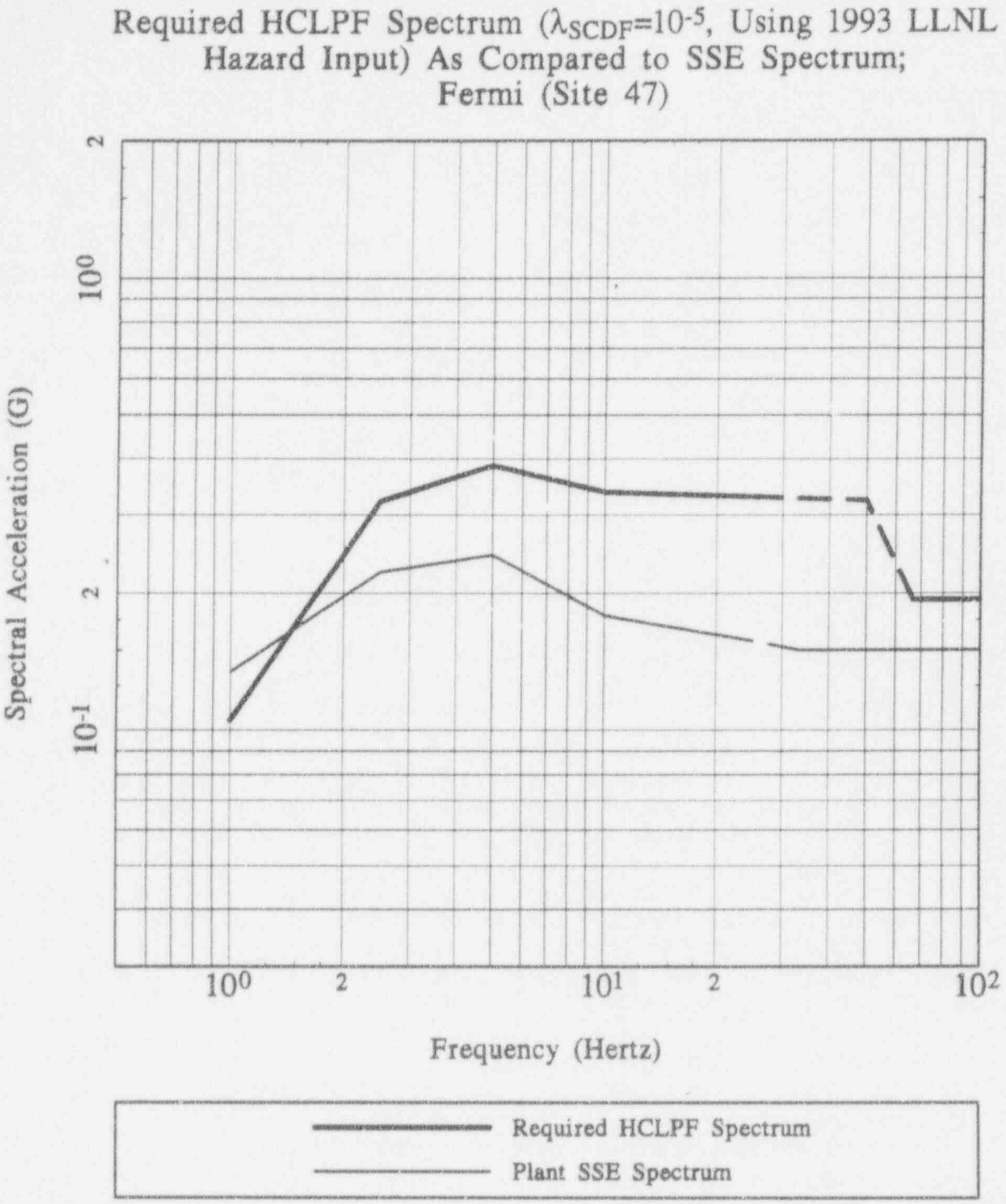


Figure A-16. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 47, Fermi.

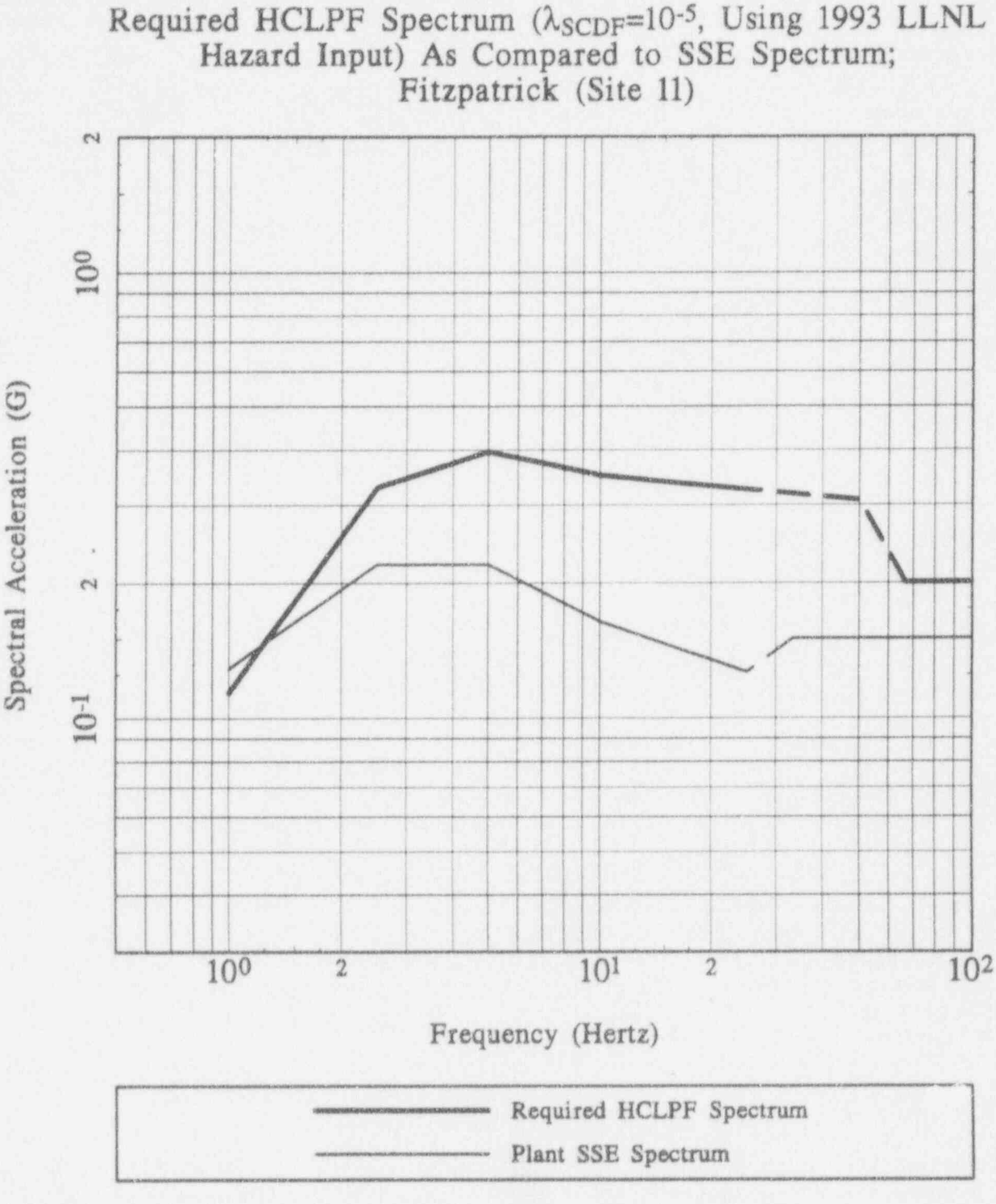


Figure A-17. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 11, Fitzpatrick.

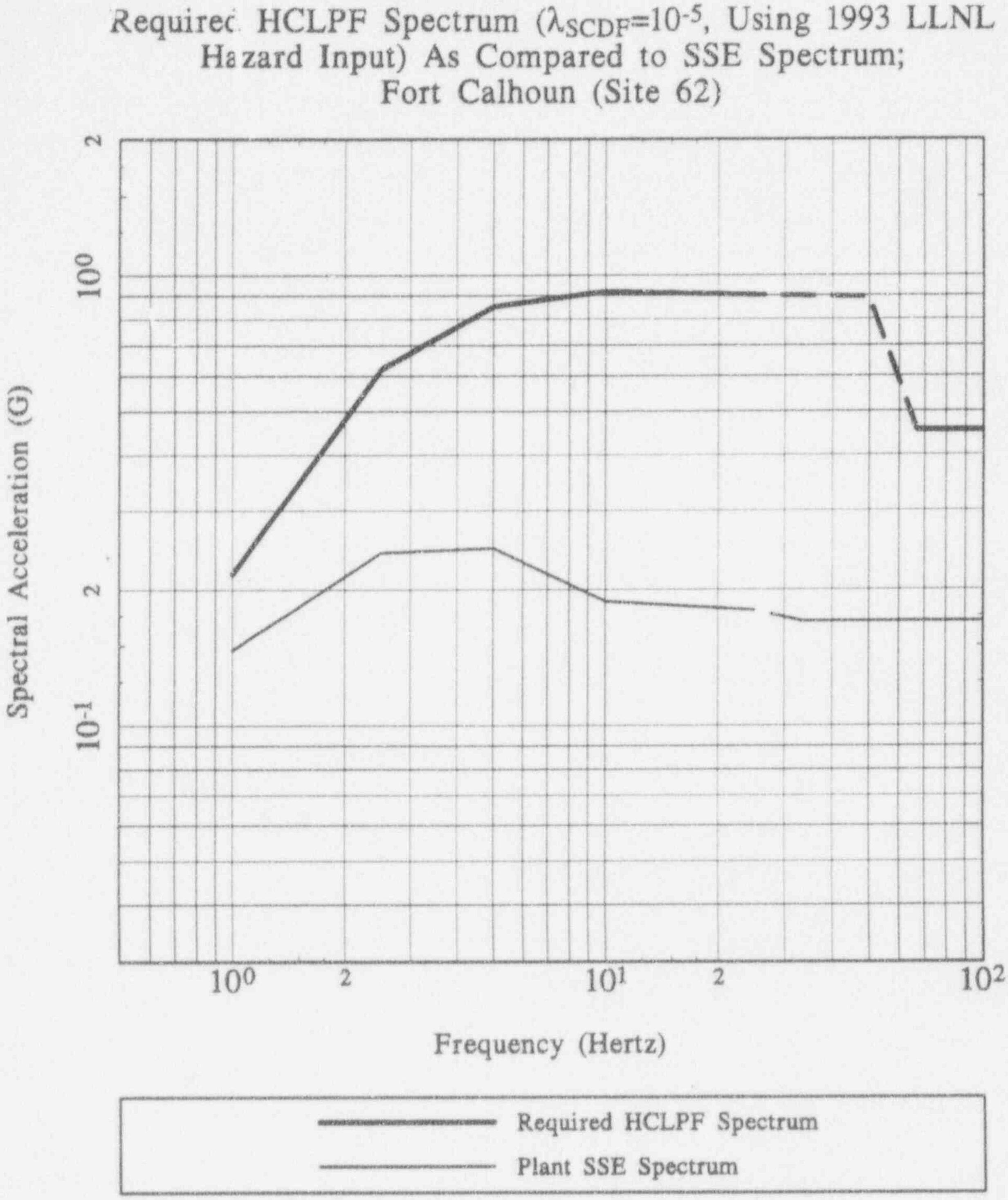


Figure A-18. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of $1x10^{-5}$), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 62, Fort Calhoun.

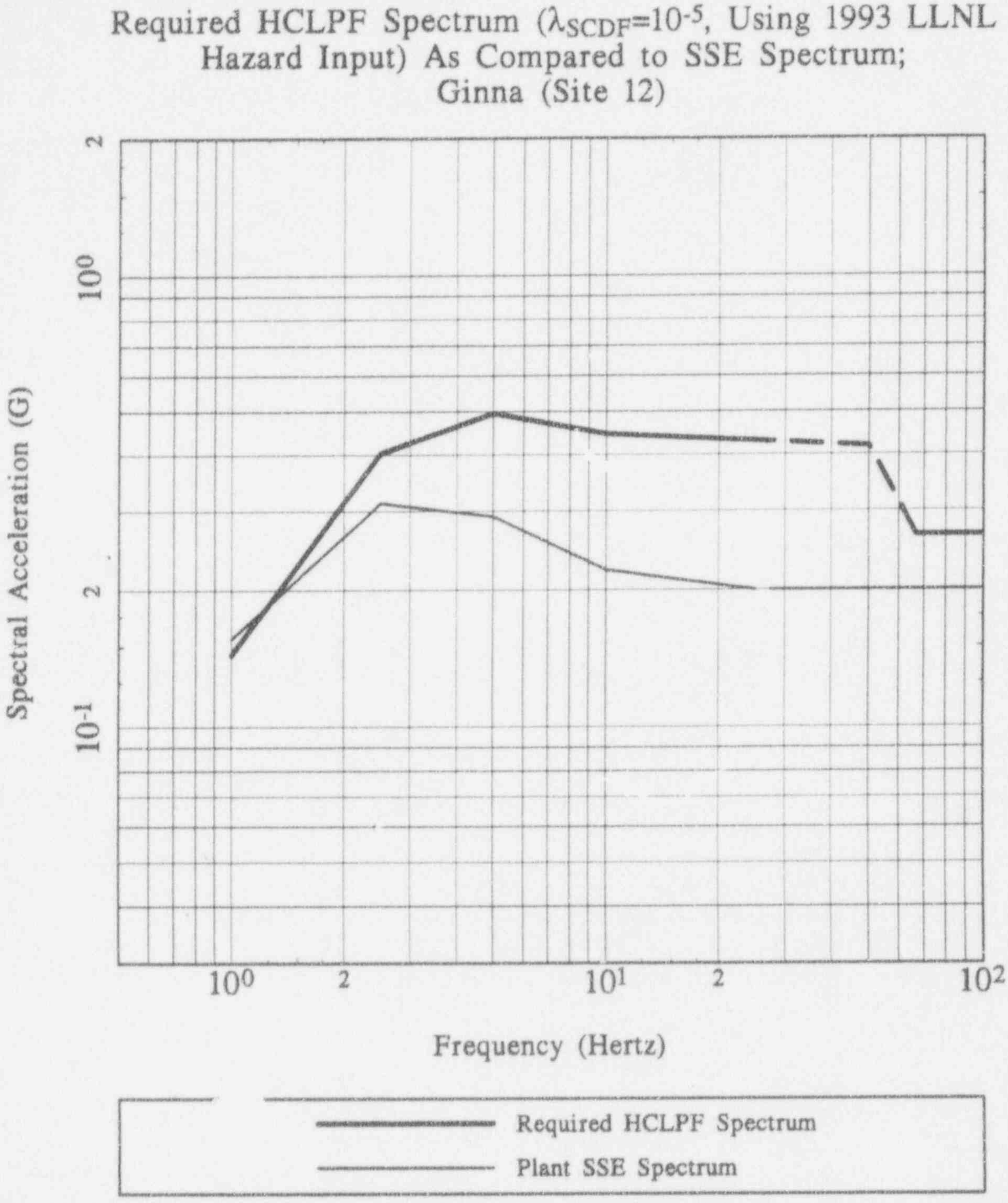


Figure A-19. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 12, Ginna.

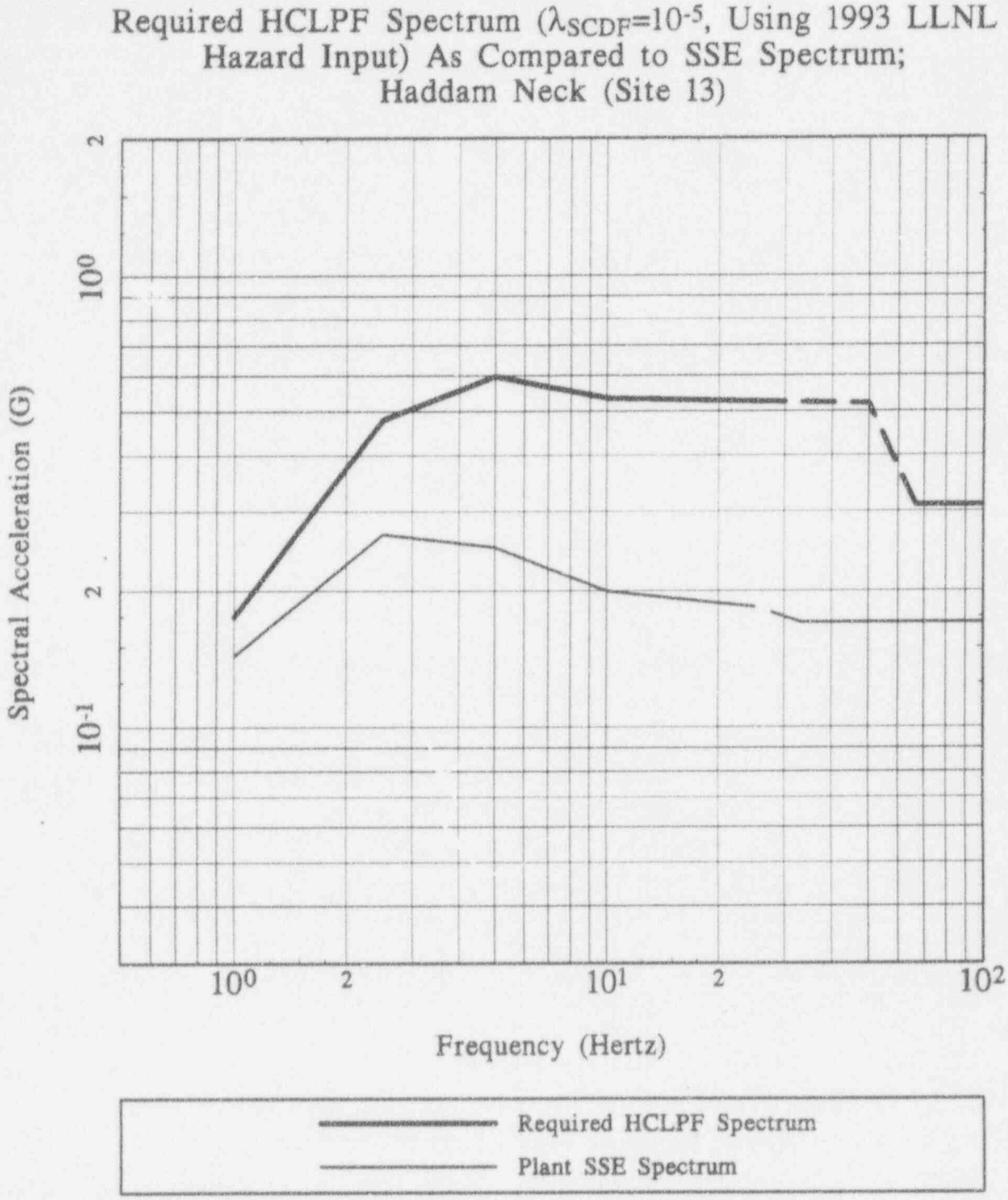


Figure A-20. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 13, Haddam Neck.

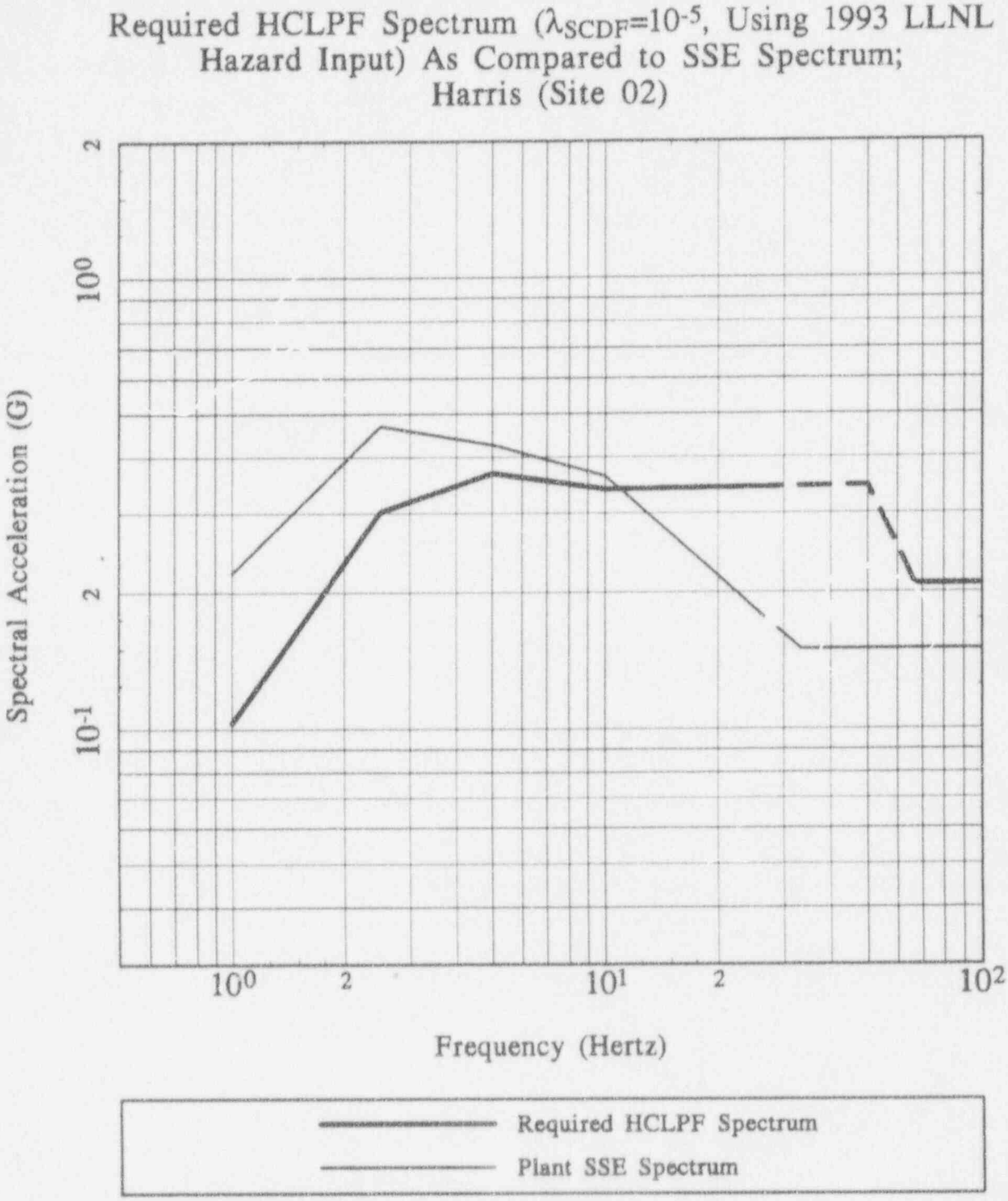


Figure A-21. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 02, Harris.

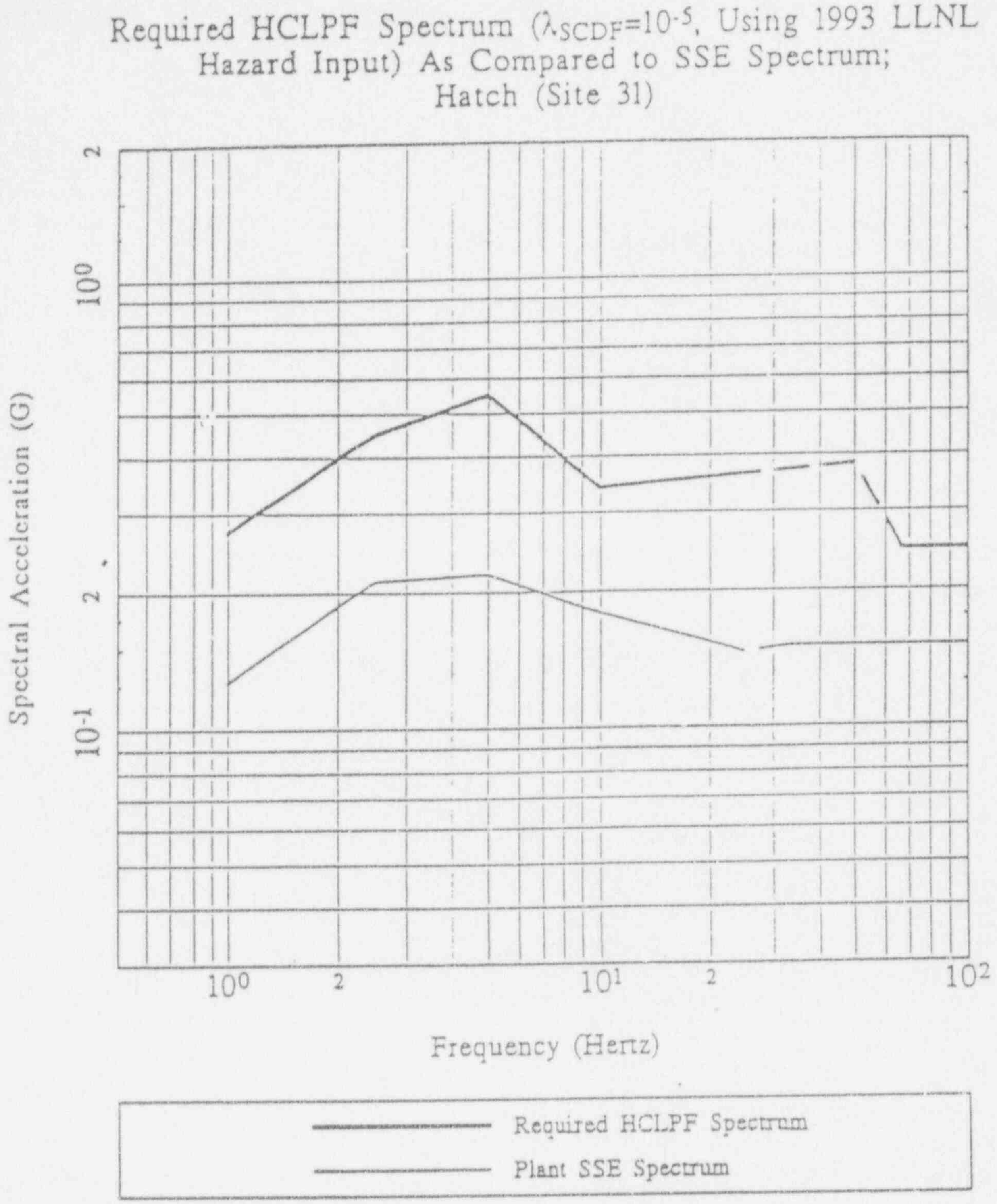


Figure A-22. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 31, Hatch.

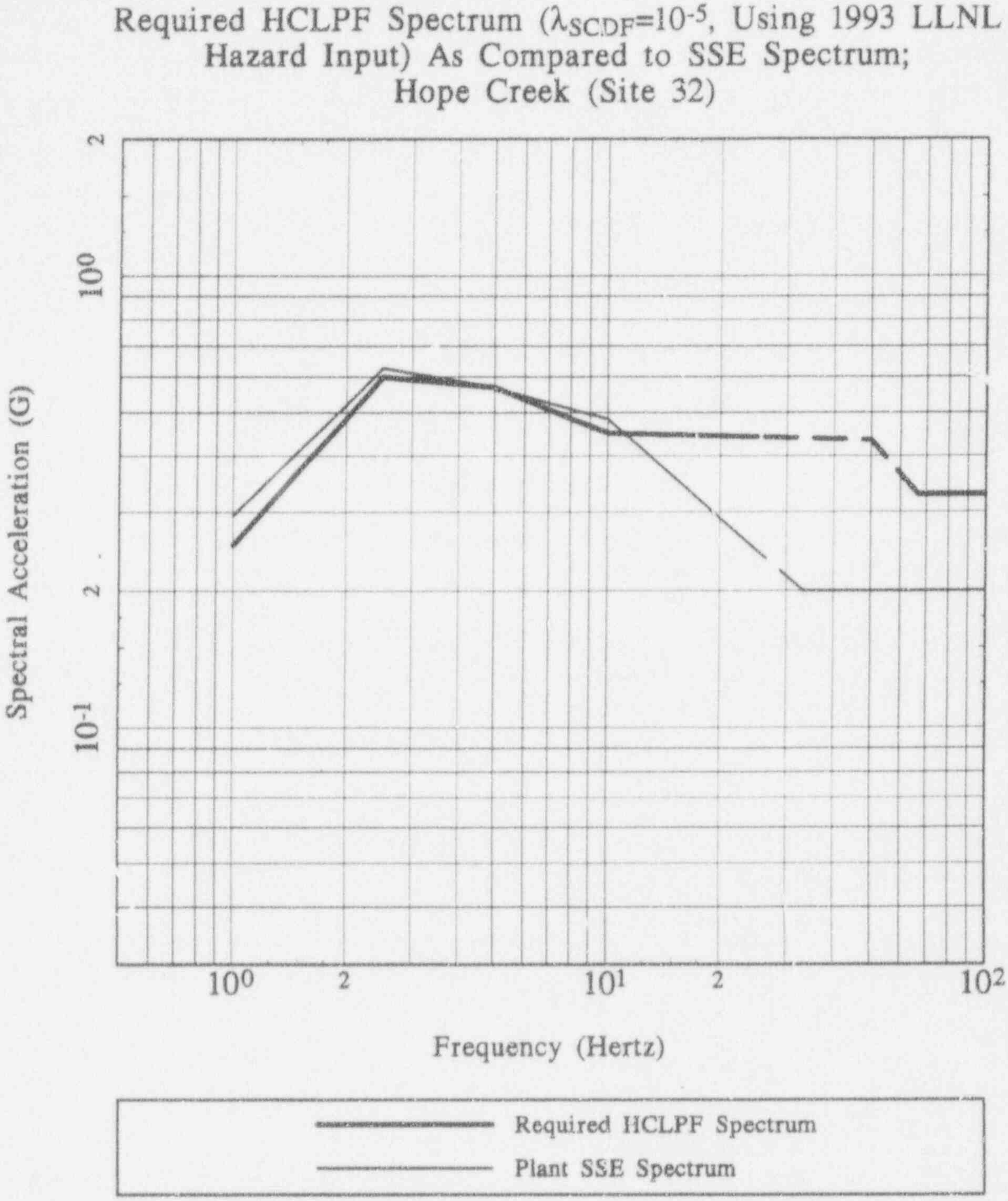


Figure A-23. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 32, Hope Creek.

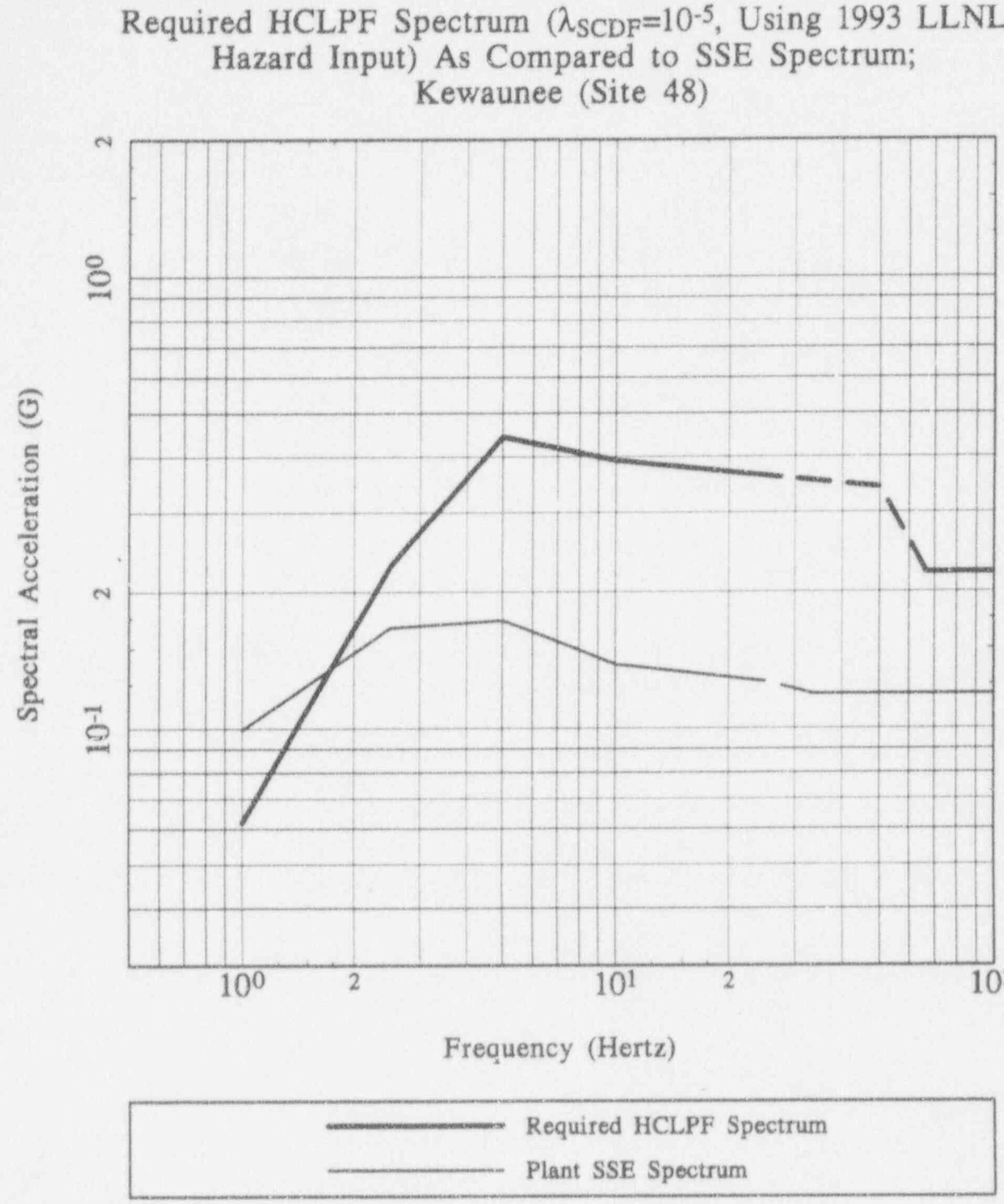


Figure A-24. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 48, Kewaunee.

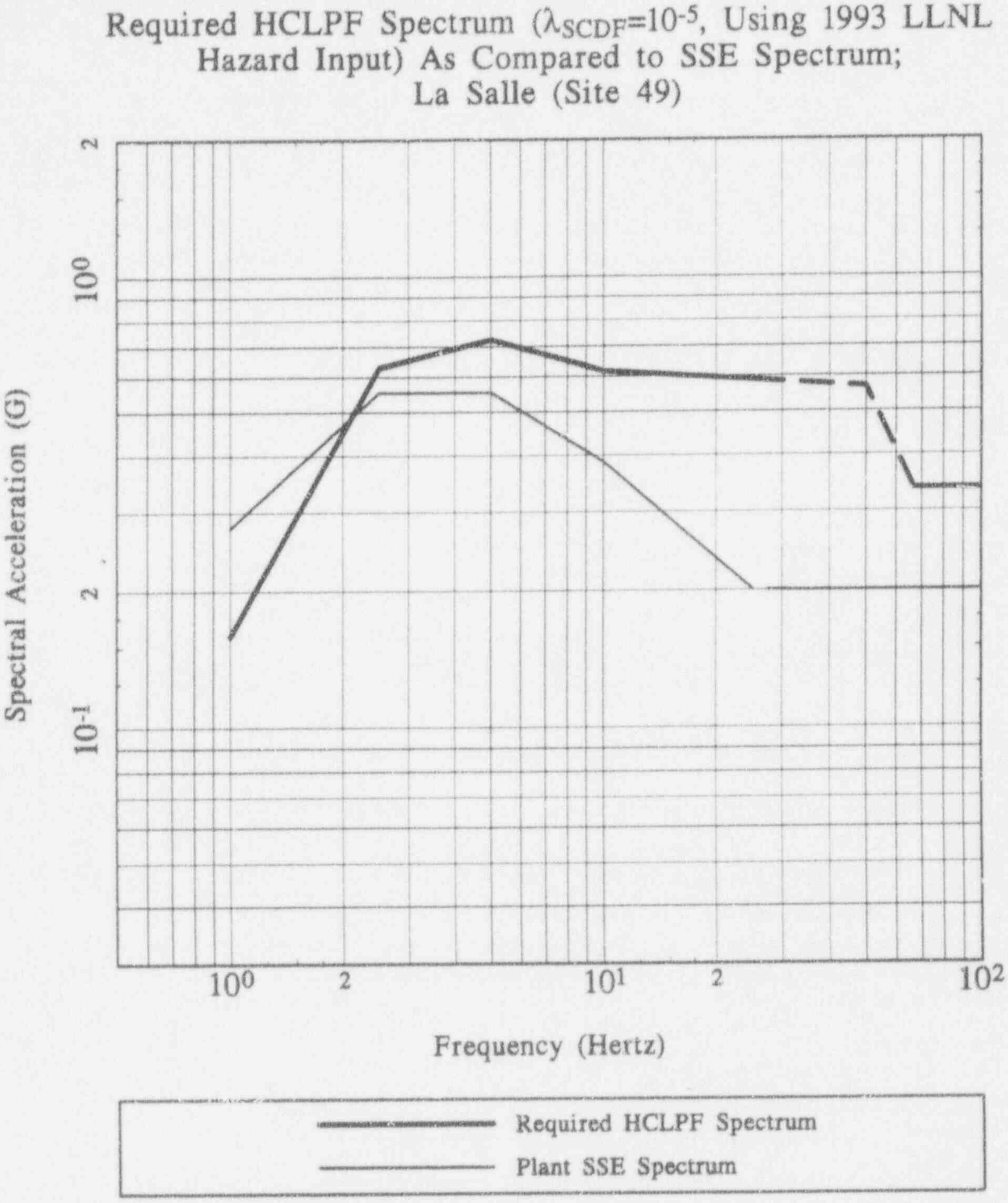
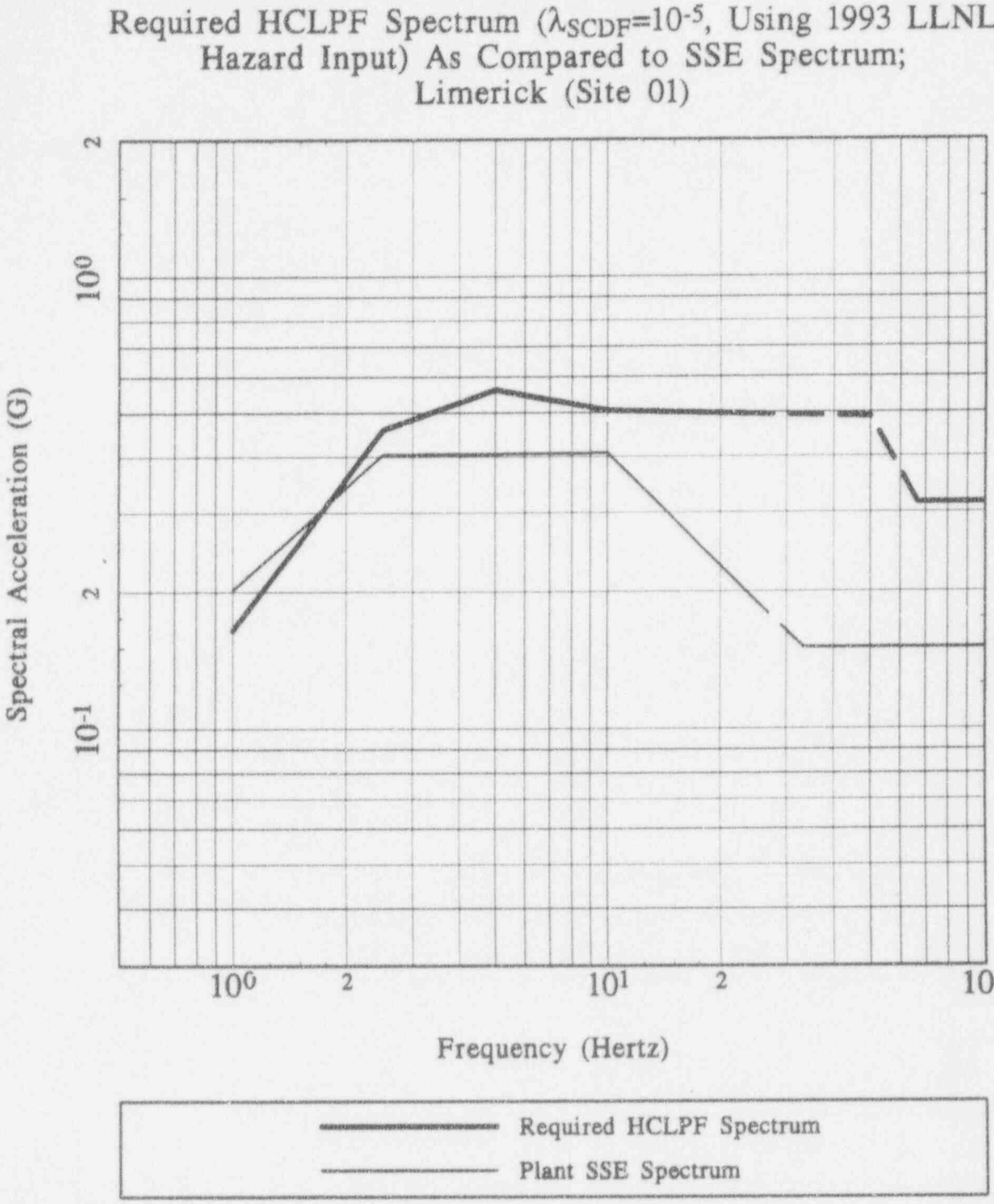


Figure A-25. Required HCLPF spectrum (for a limiting mean seismic core damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 49, La Salle.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Limerick (Site 01)

Figure A-26. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of $1x10^{-5}$), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 01, Limerick.

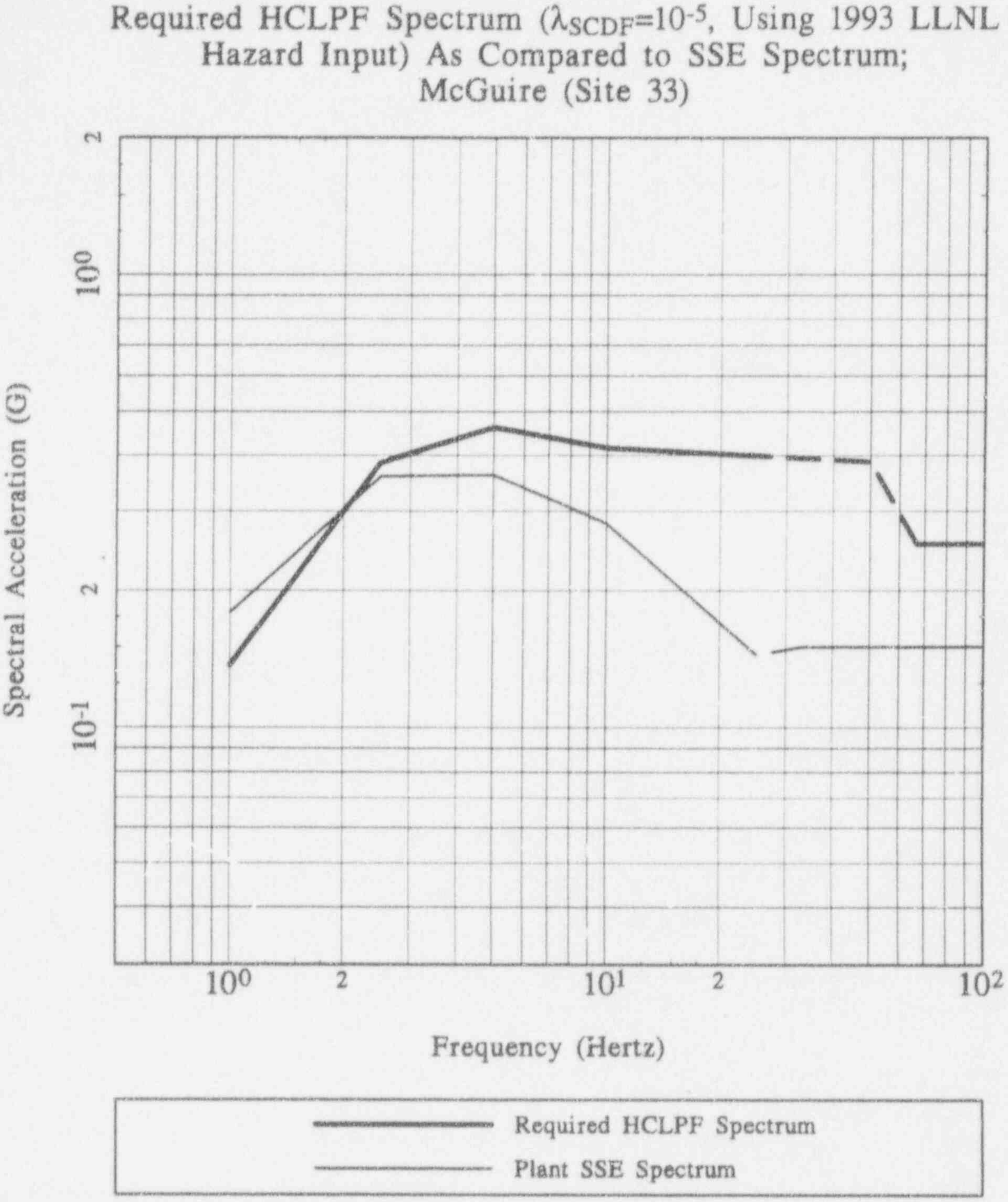


Figure A-27. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 33, McGuire.

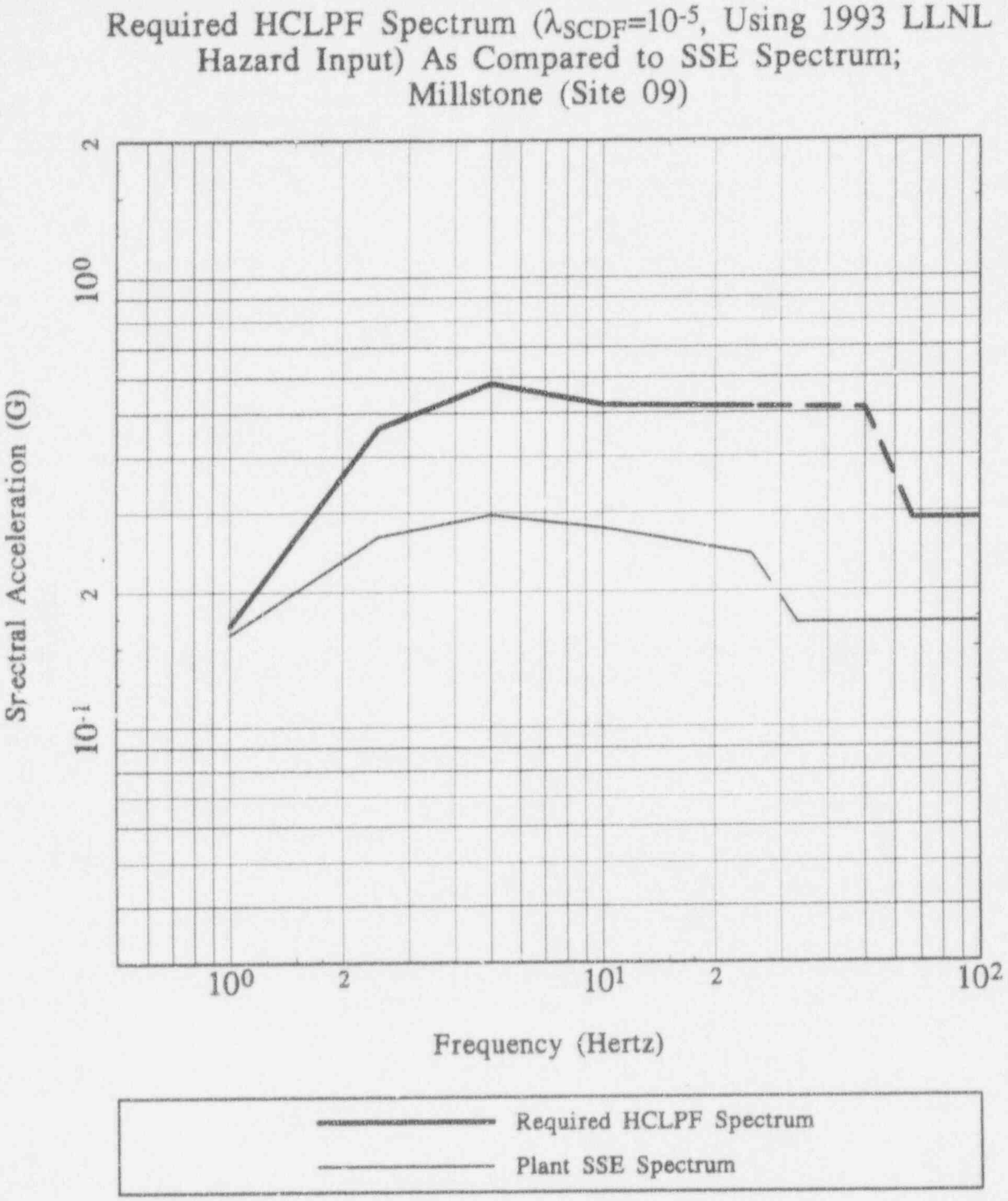


Figure A-28. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 09, Millstone.

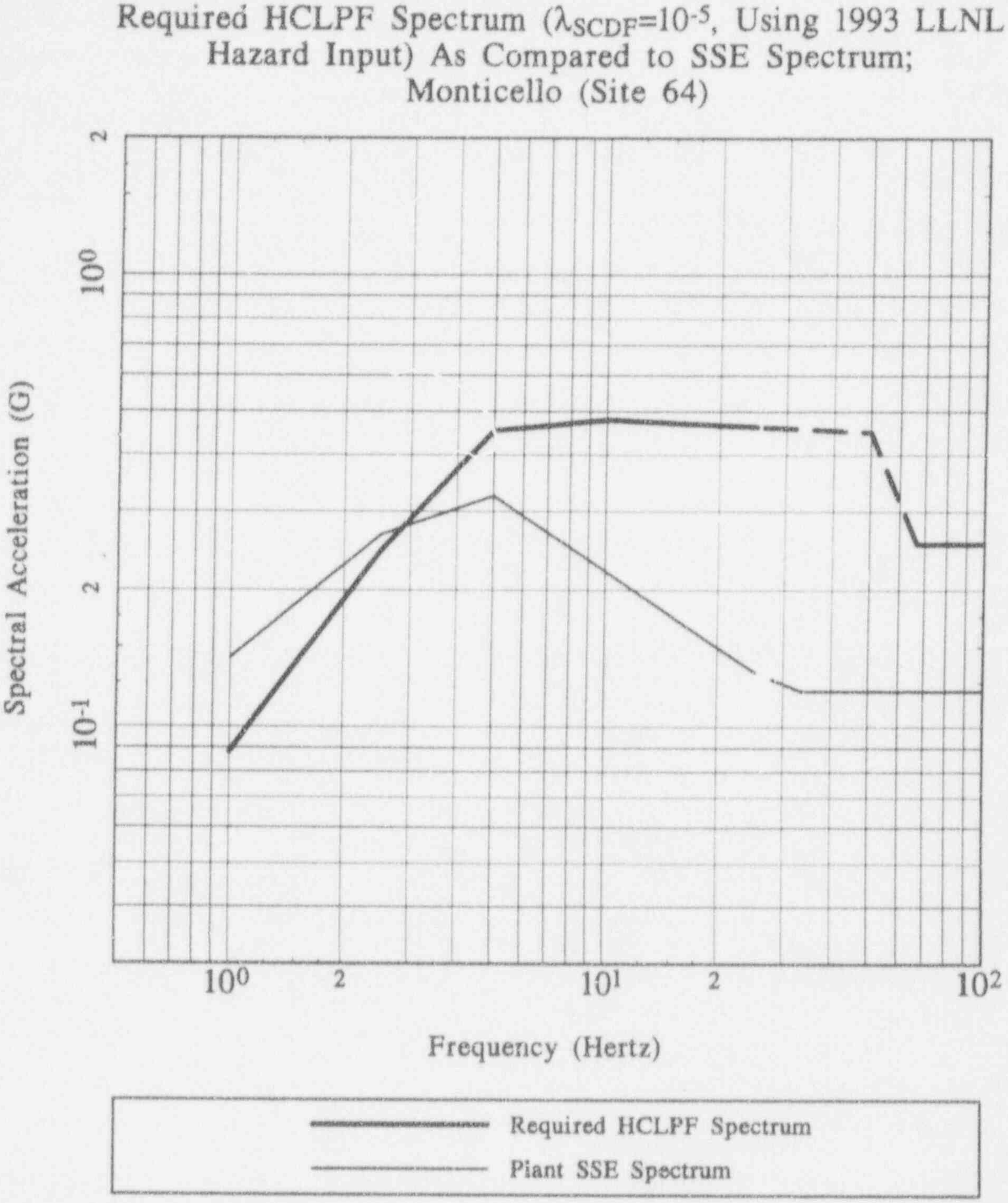


Figure A-29. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 64, Montecillo.

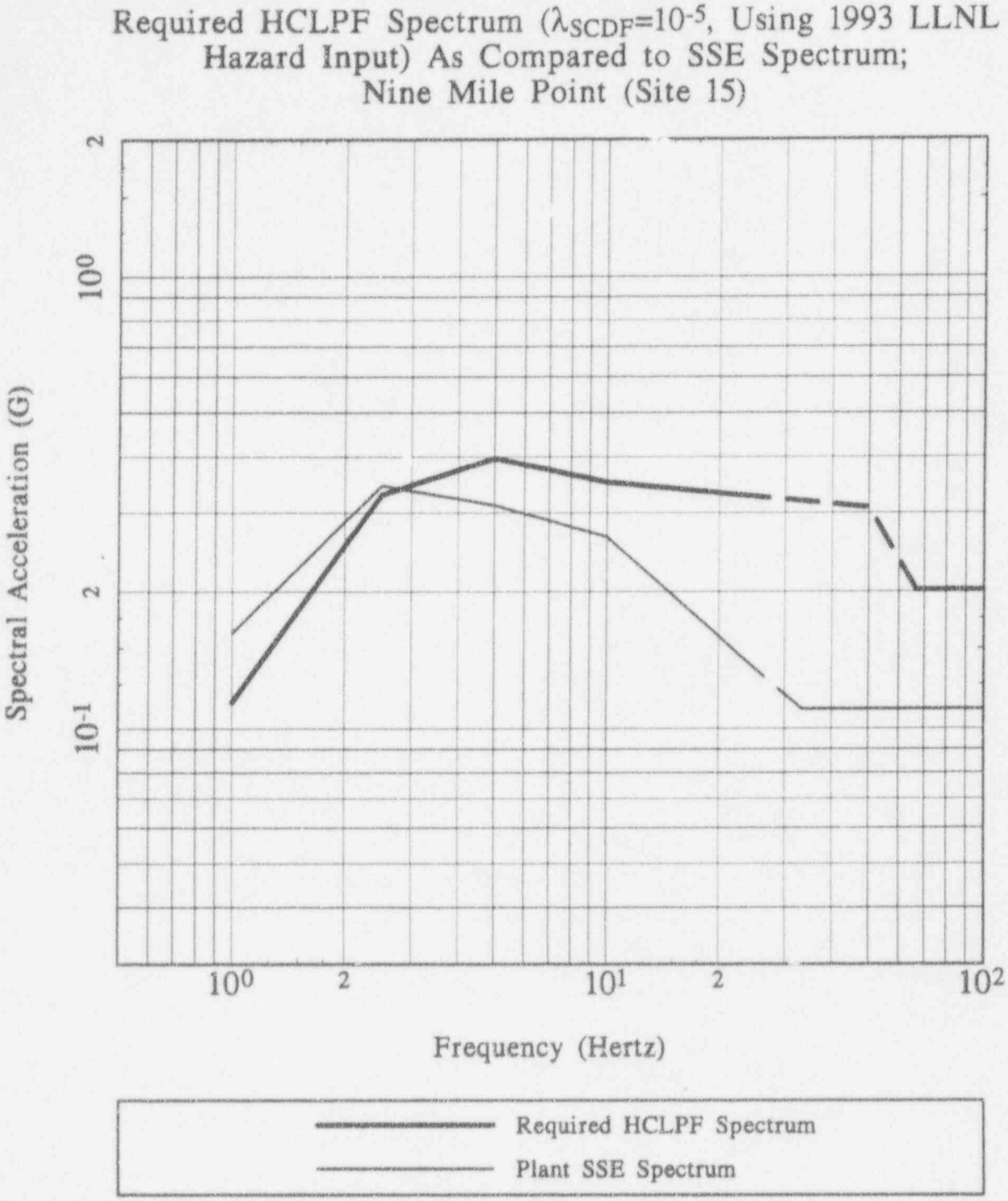


Figure A-30. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 15, Nine Mile Point.

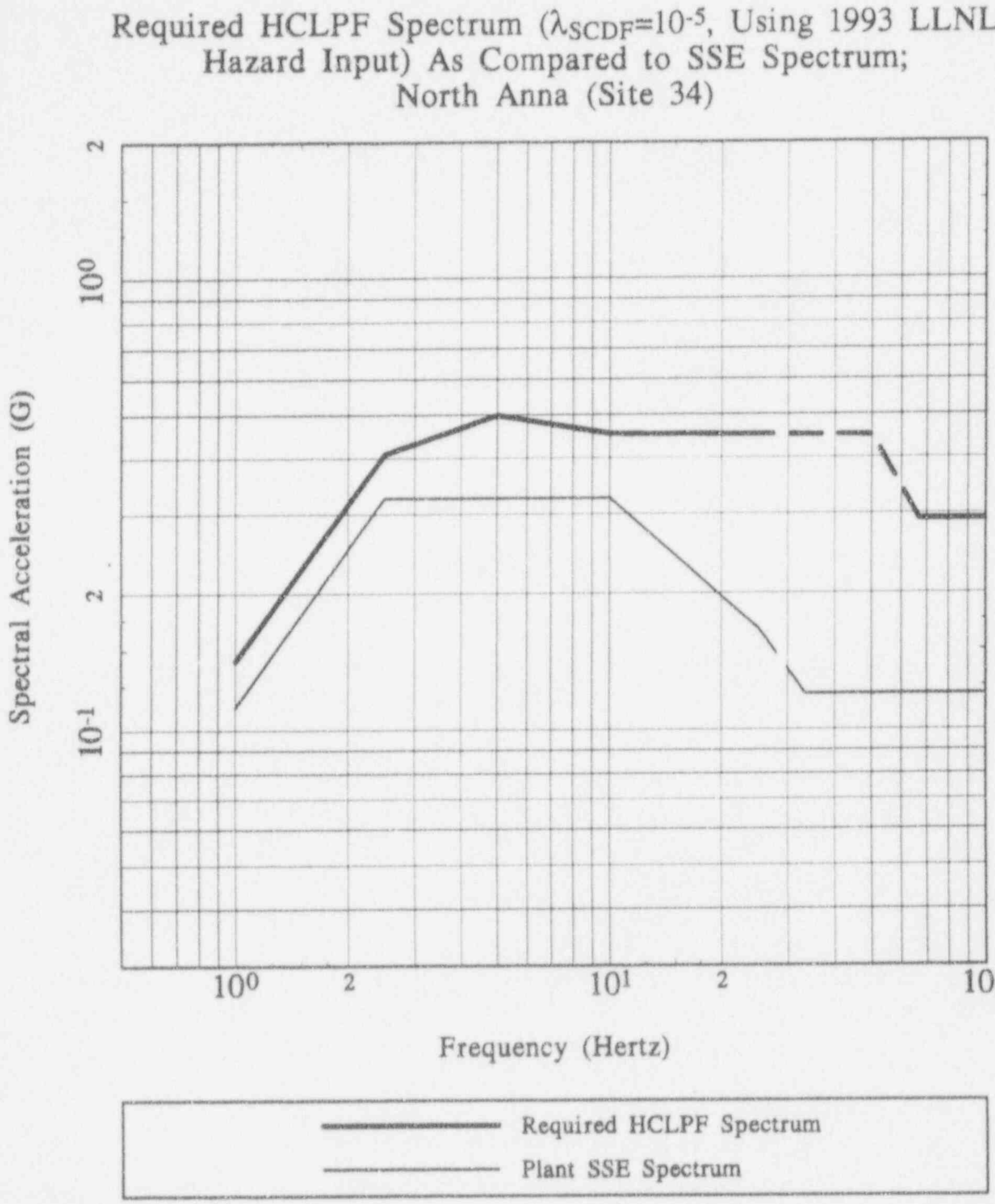


Figure A-31. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 34, North Anna.

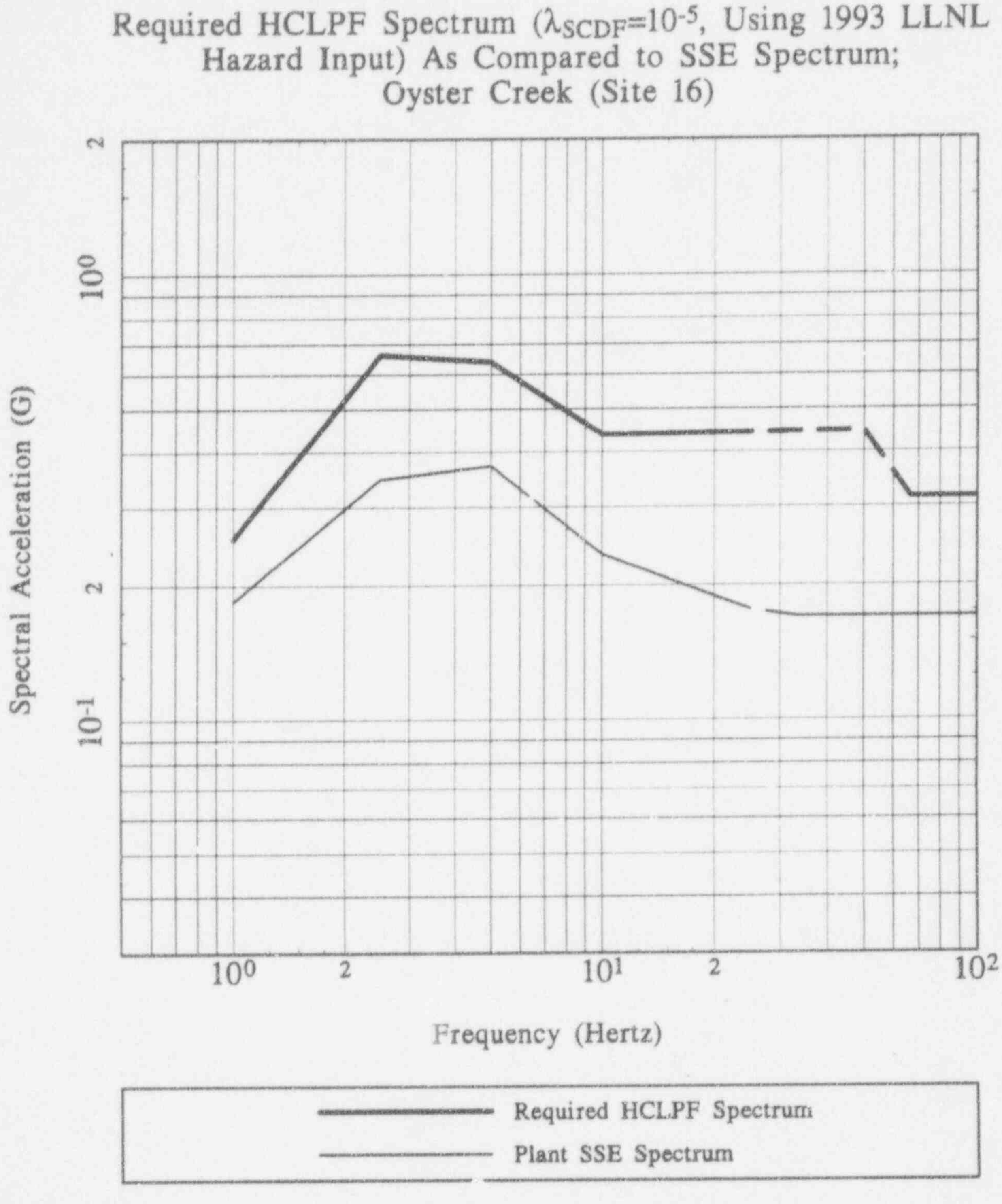
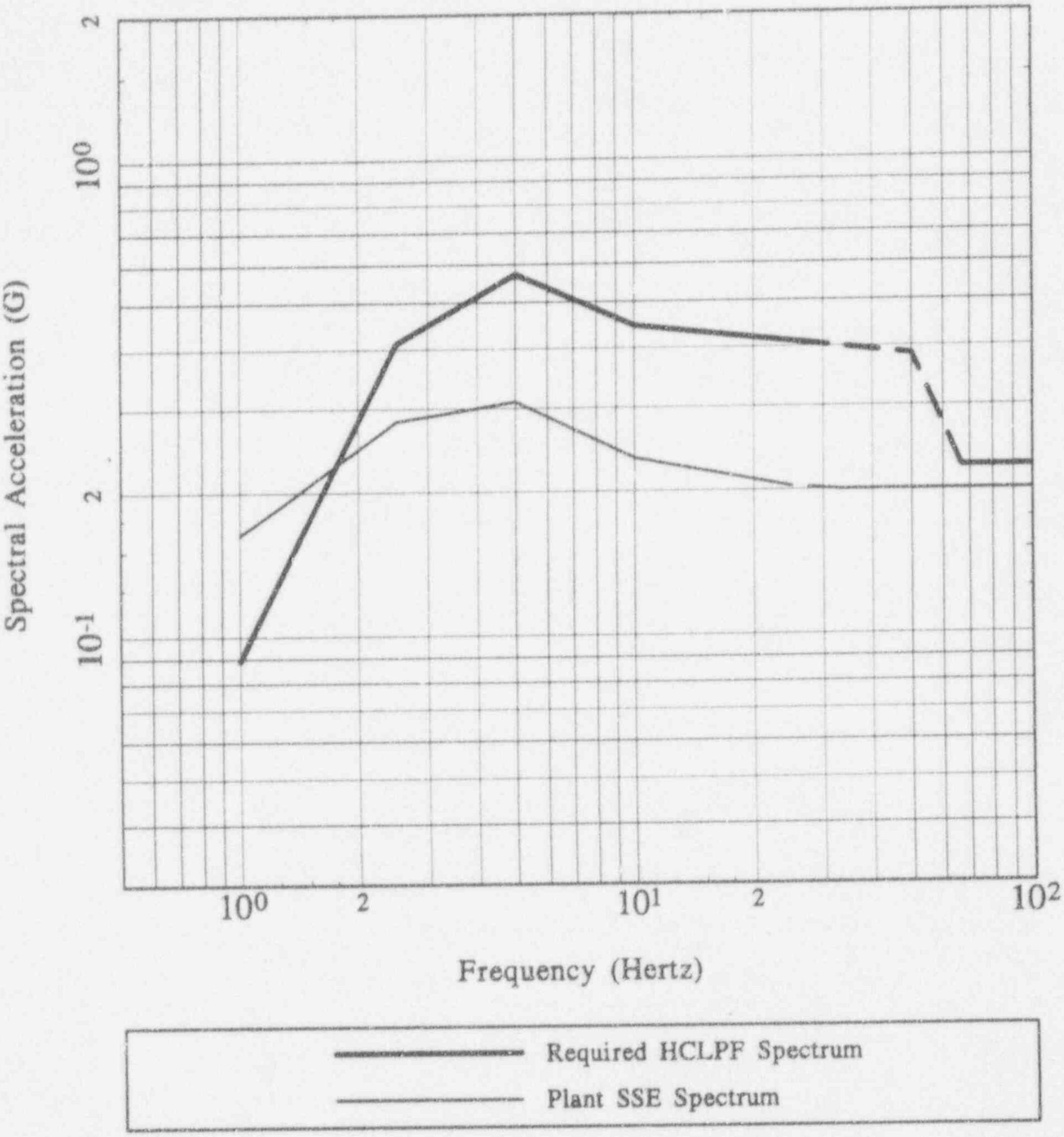
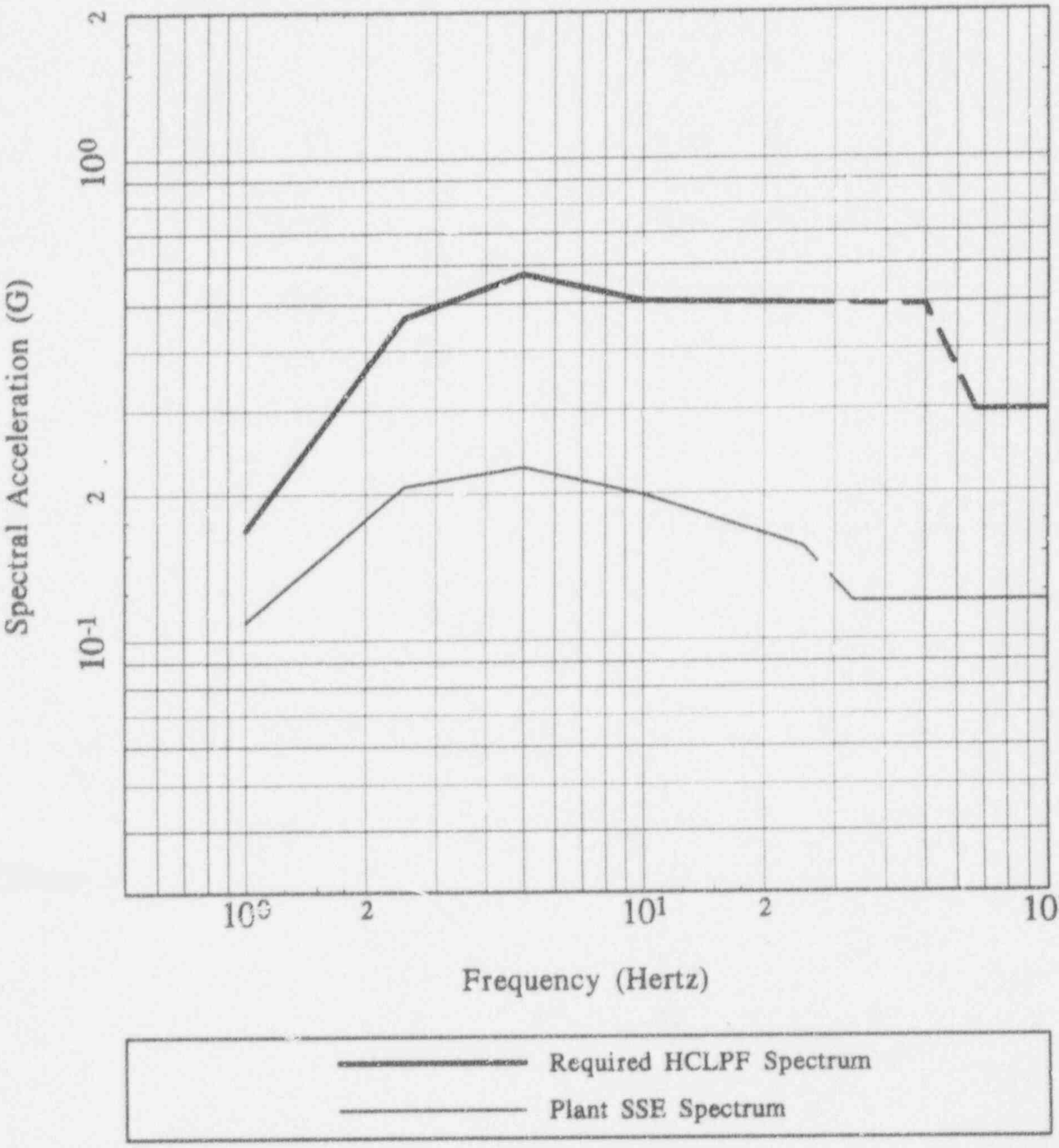

Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Oyster Creek (Site 16)

Figure A-32. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 16, Oyster Creek.



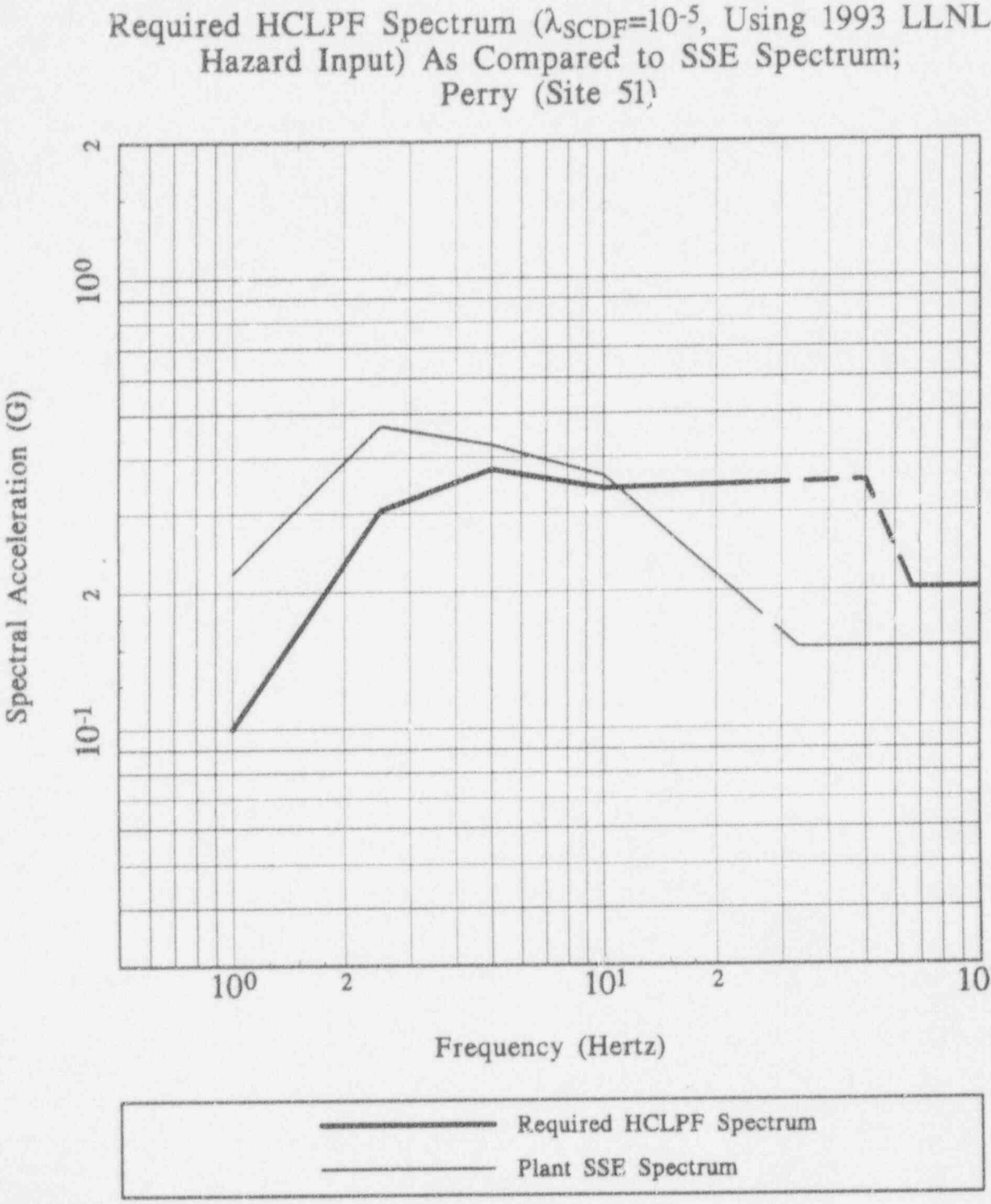
Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Palisades (Site 50)

Figure A-33. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 50, Palisades.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Peach Bottom (Site 17)

Figure A-34. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 17, Peach Bottom.



Required HCLPF Spectrum (λ_{SCDF}=10^{-5}, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Perry (Site 51)

Figure A-35. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 51, Perry.

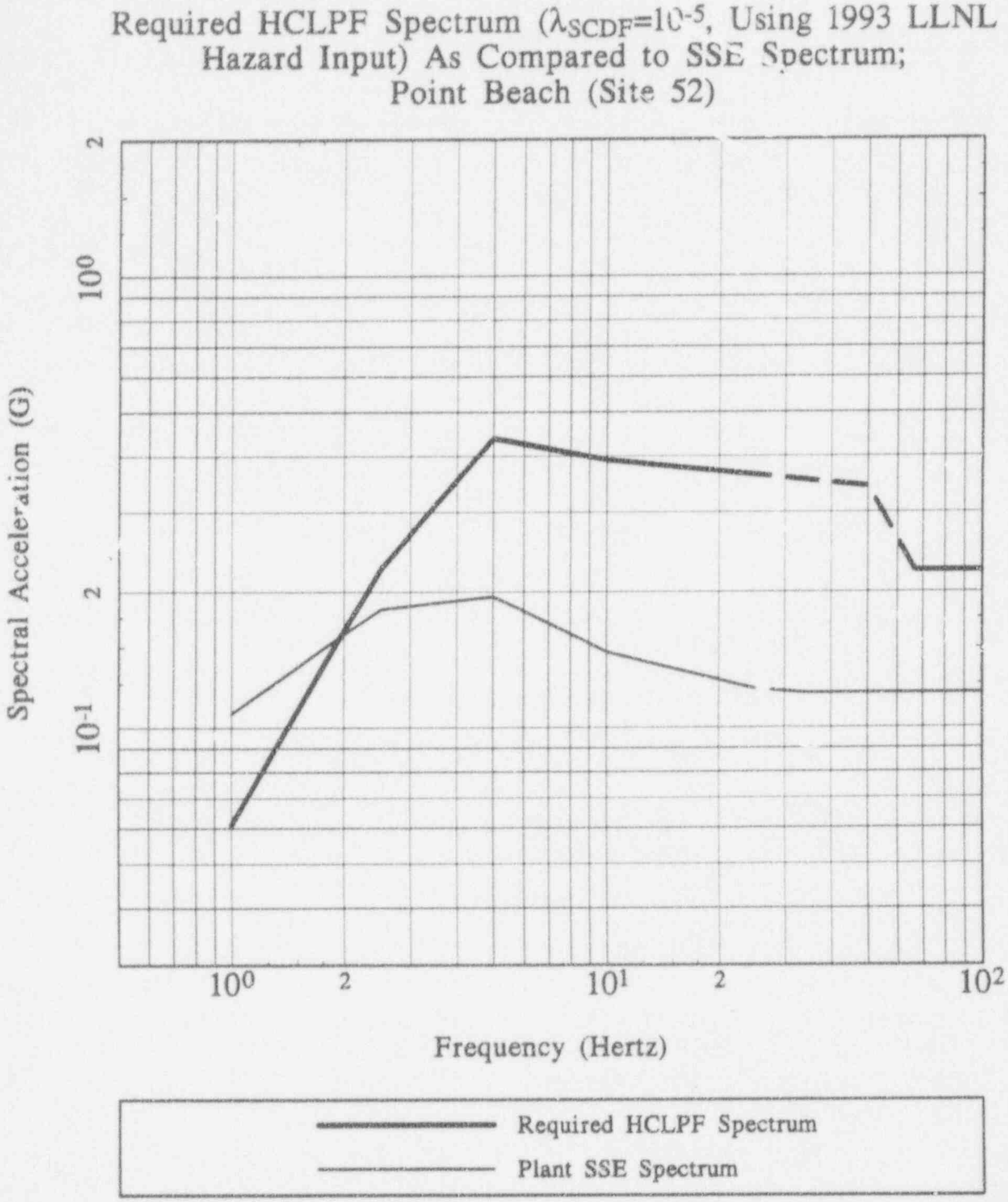


Figure A-36. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 52, Point Beach.

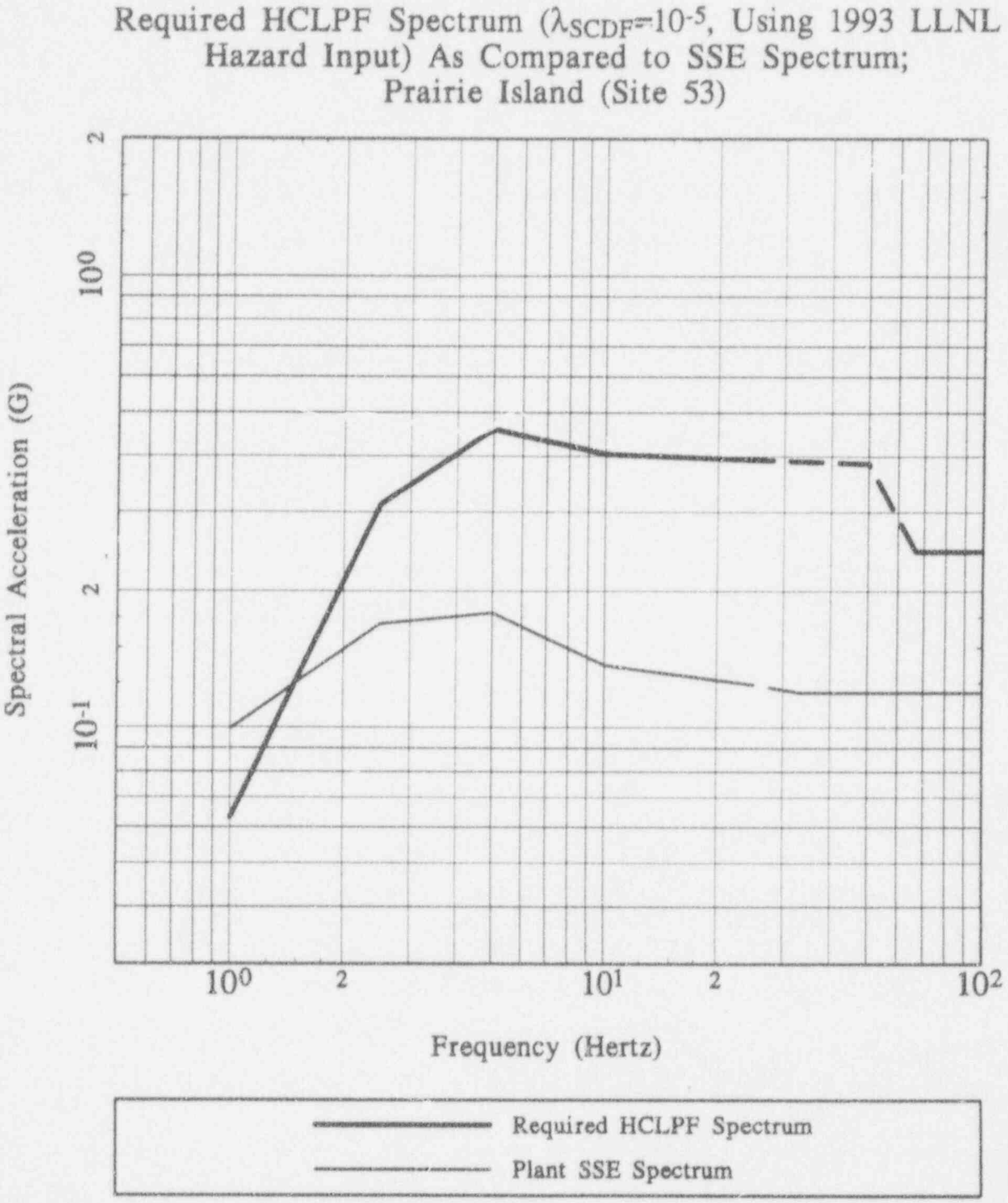


Figure A-37. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of $1x10^{-5}$), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 53, Prairie Island.

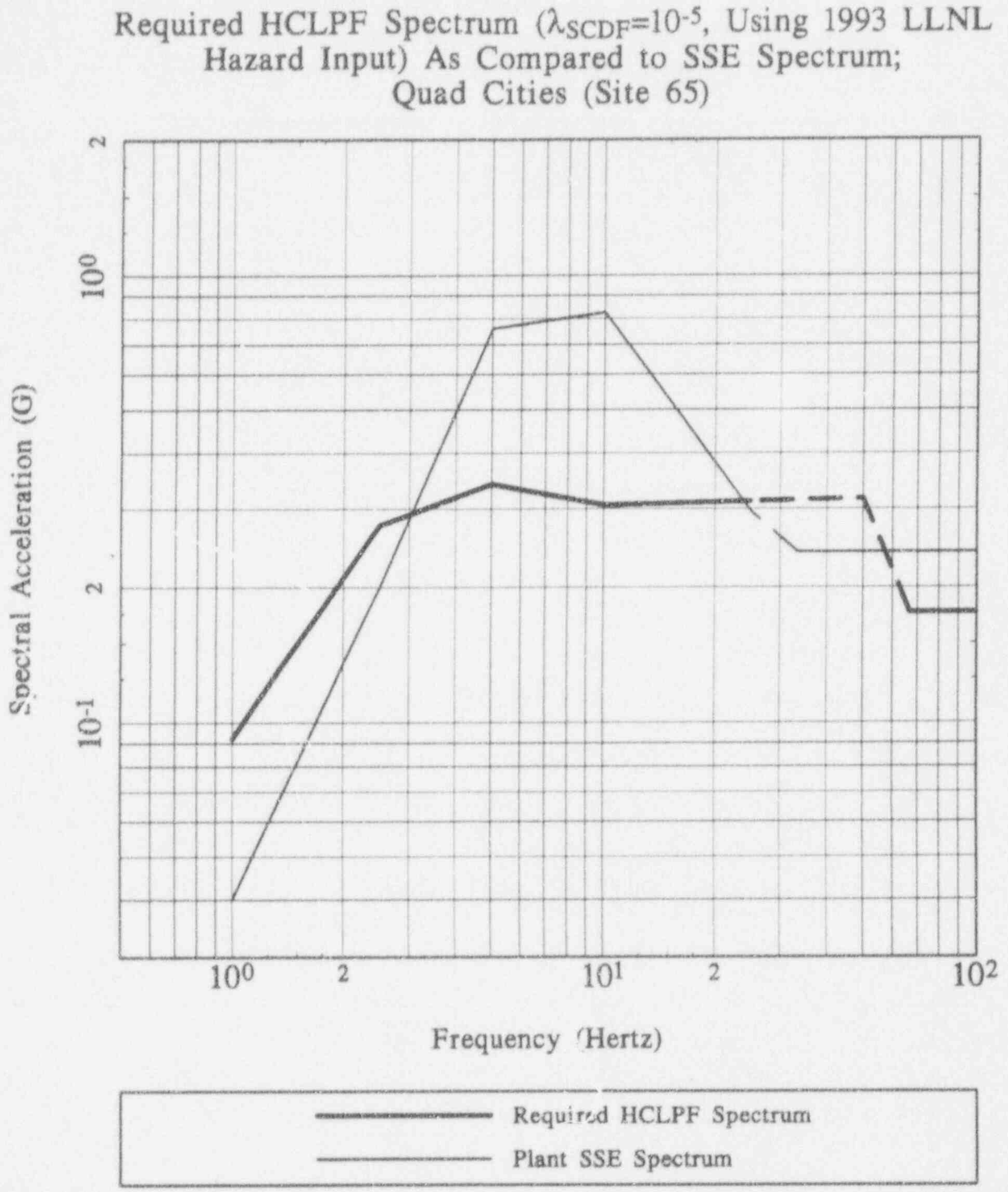
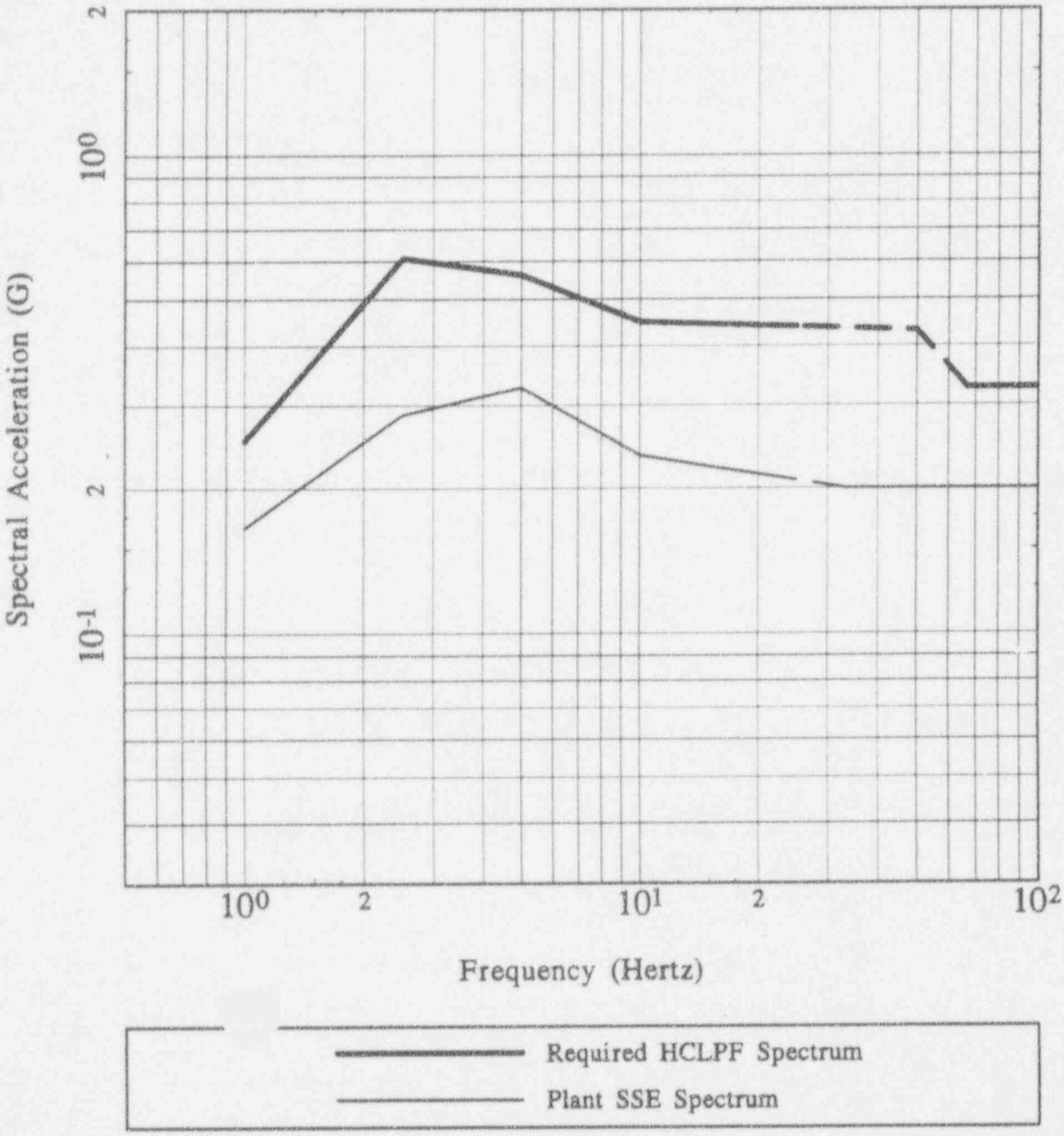
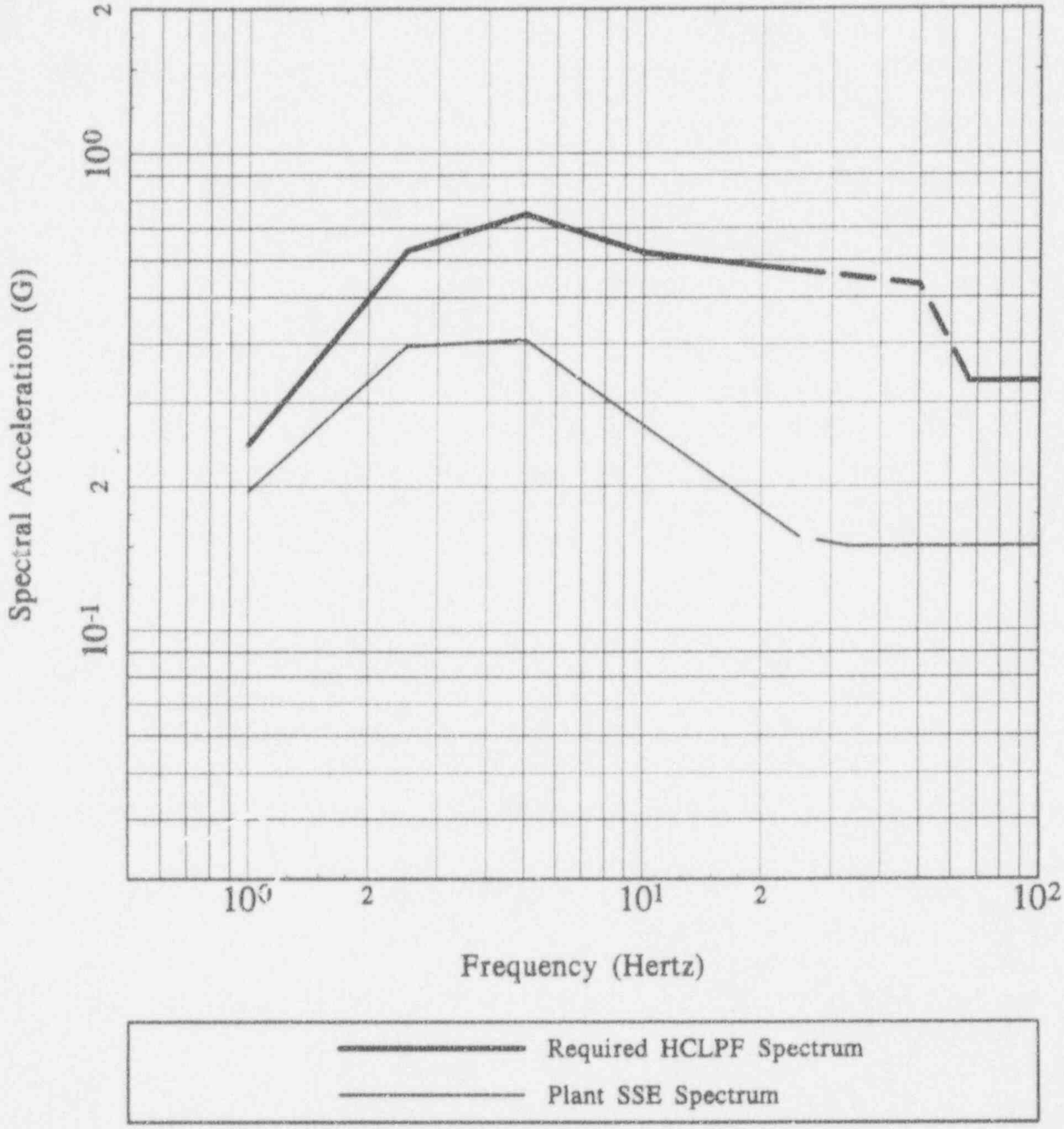


Figure A-38. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 65, Quad Cities.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Salem (Site 19)

Figure A-39. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 19, Salem.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Summer (Site 38)

Figure A-40. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 38, Summer.

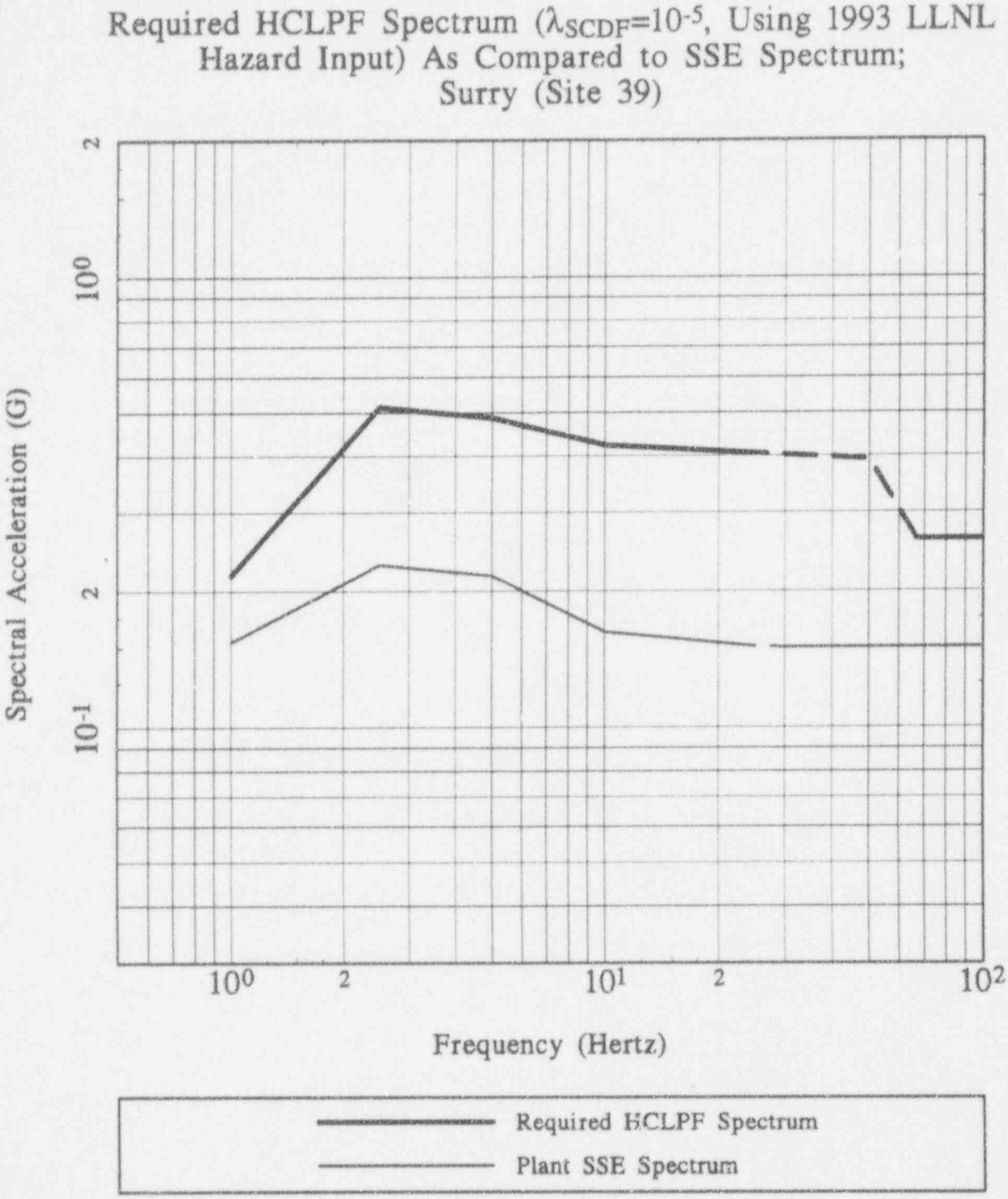


Figure A-41. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 39, Surry.

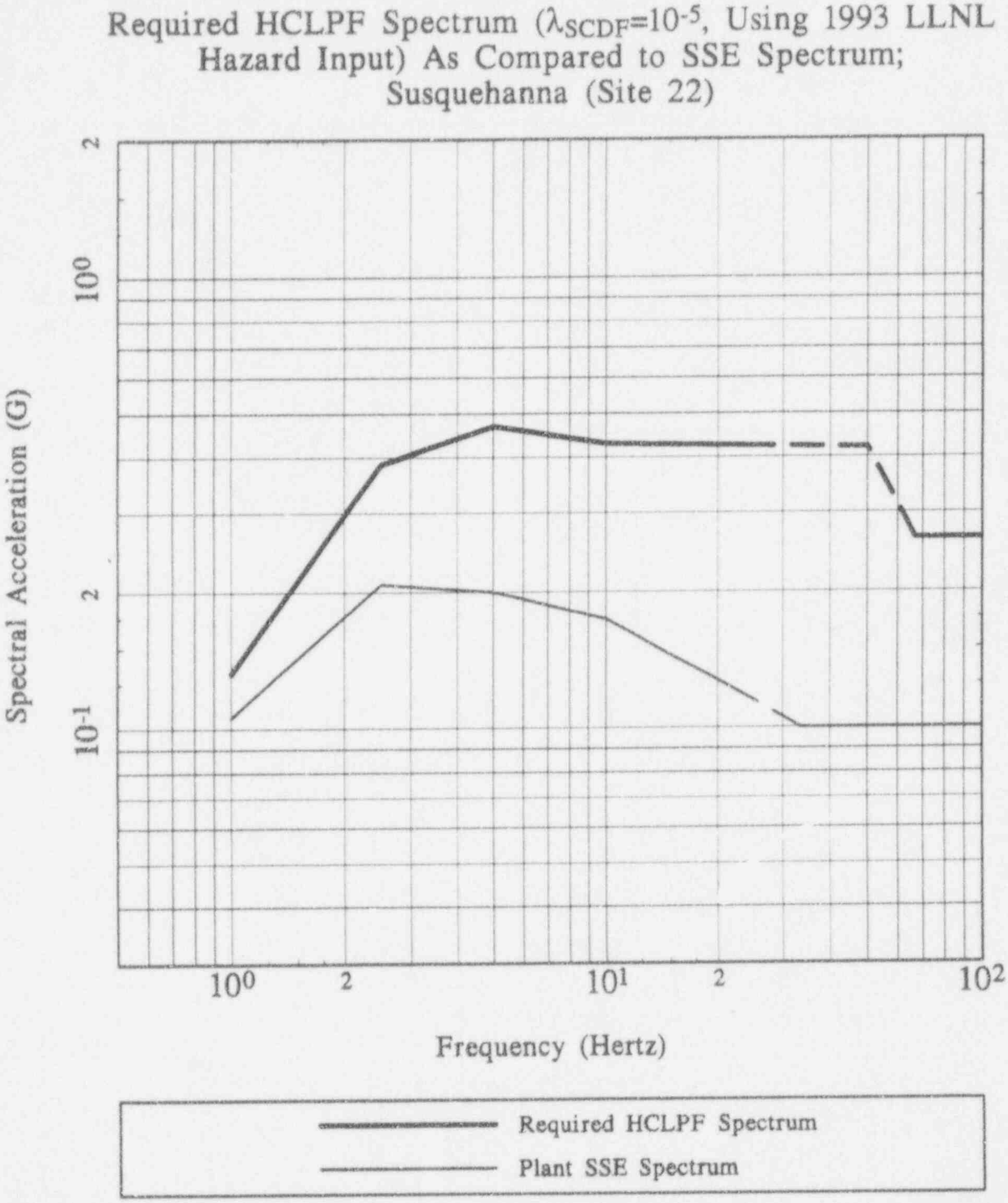


Figure A-42. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 22, Susquehanna.

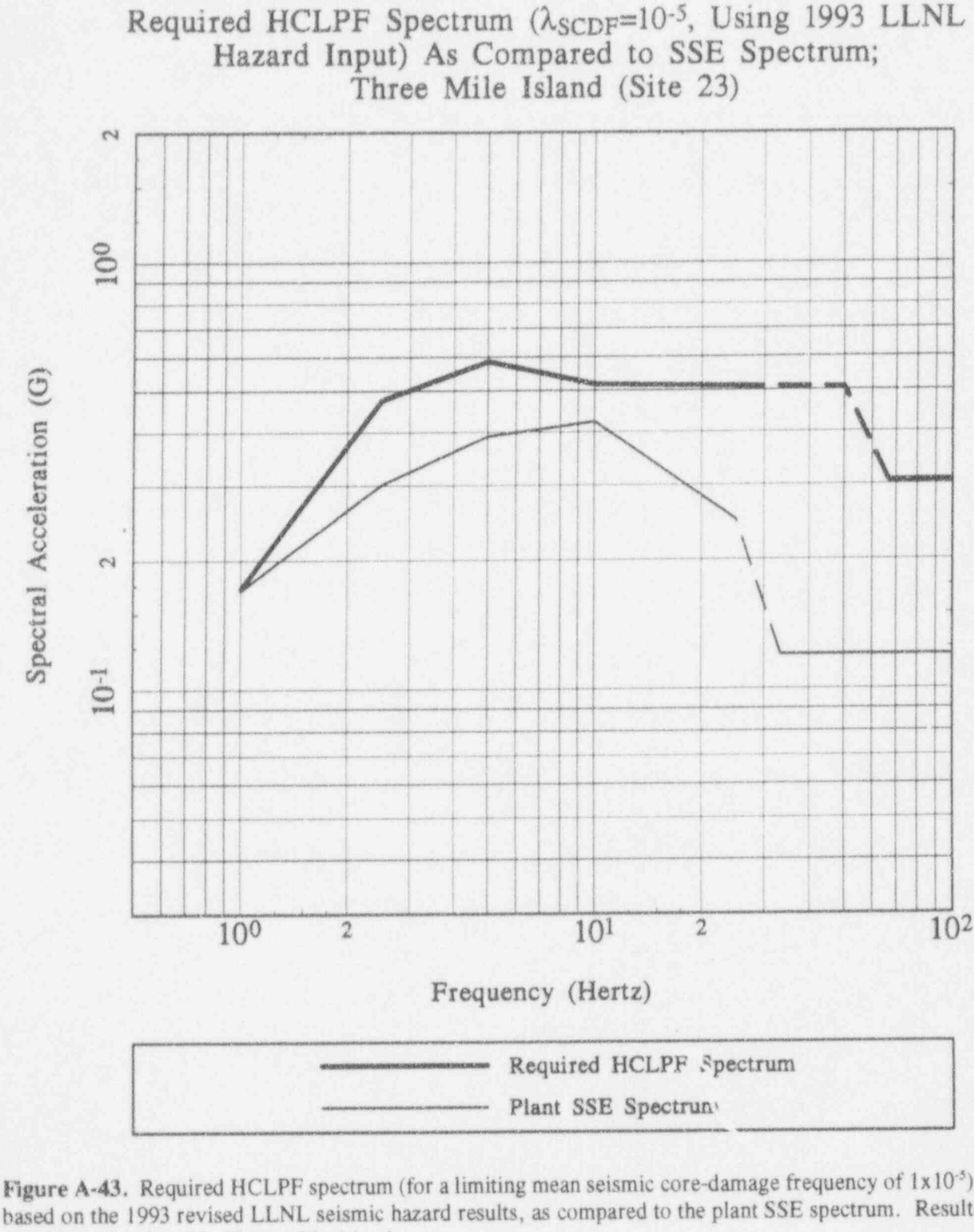


Figure A-43. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 23, Three Mile Island.

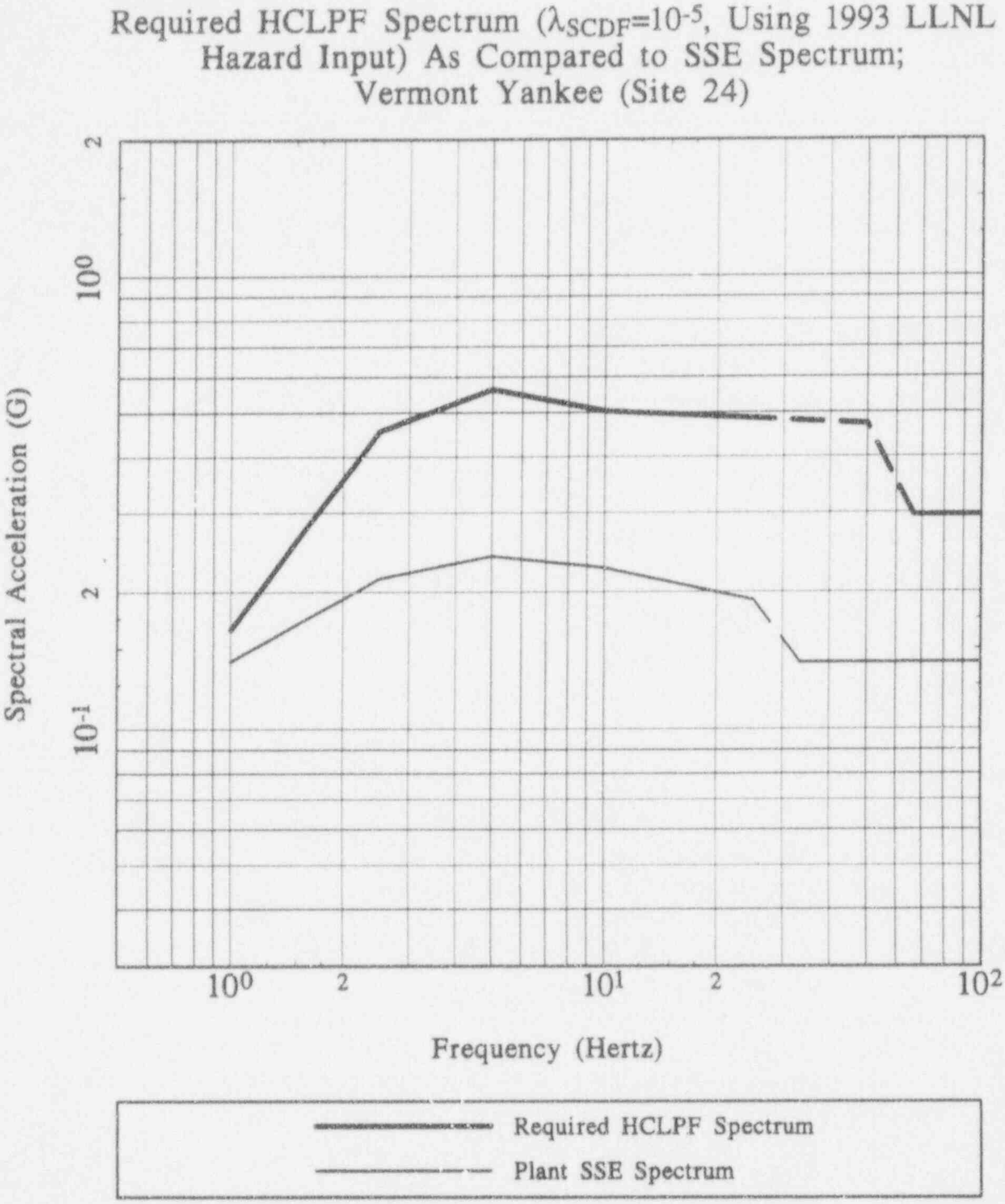
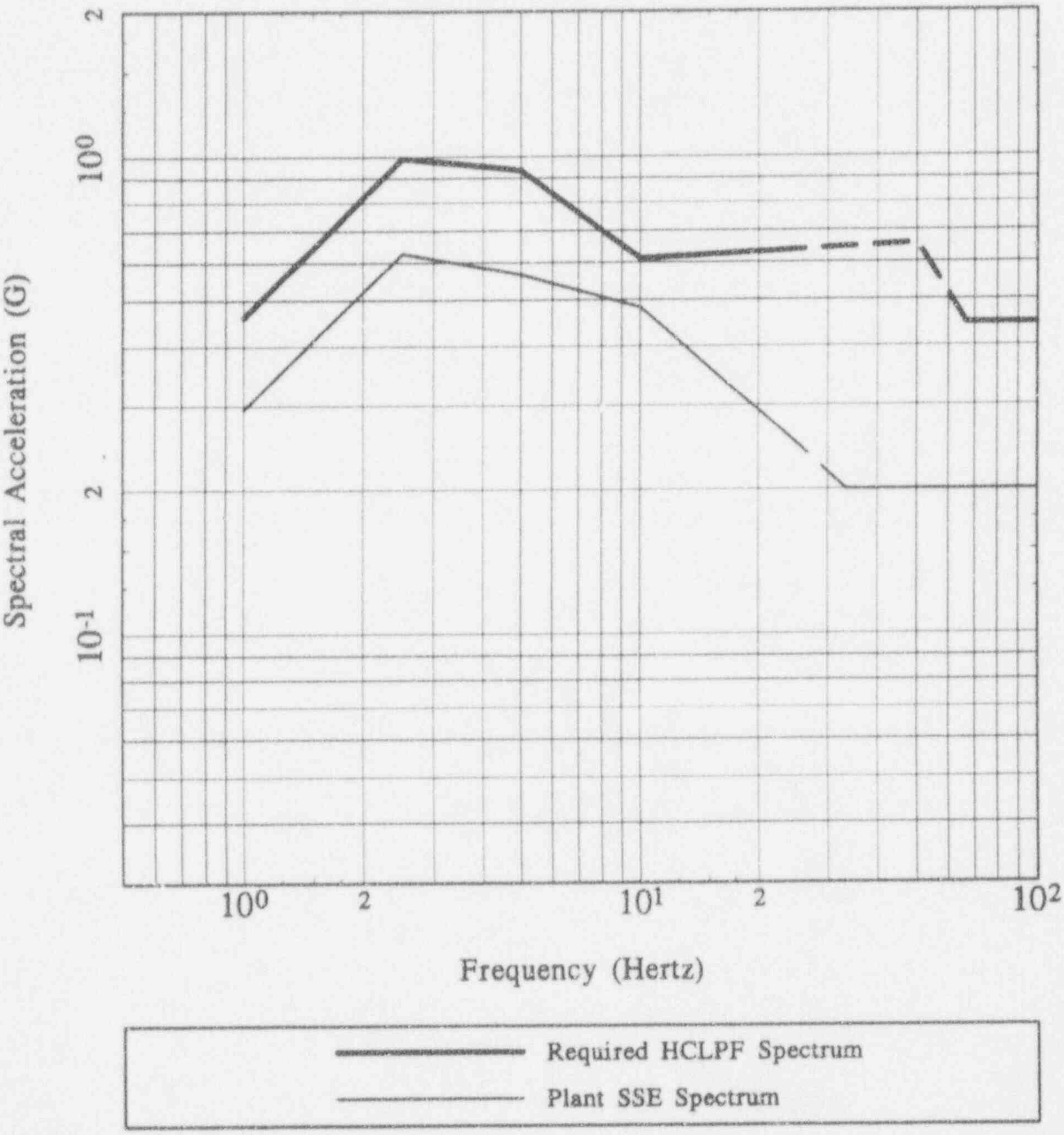


Figure A-44. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 24, Vermont Yankee.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Vogtle (Site 08)

Figure A-45. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 08, Vogtle.

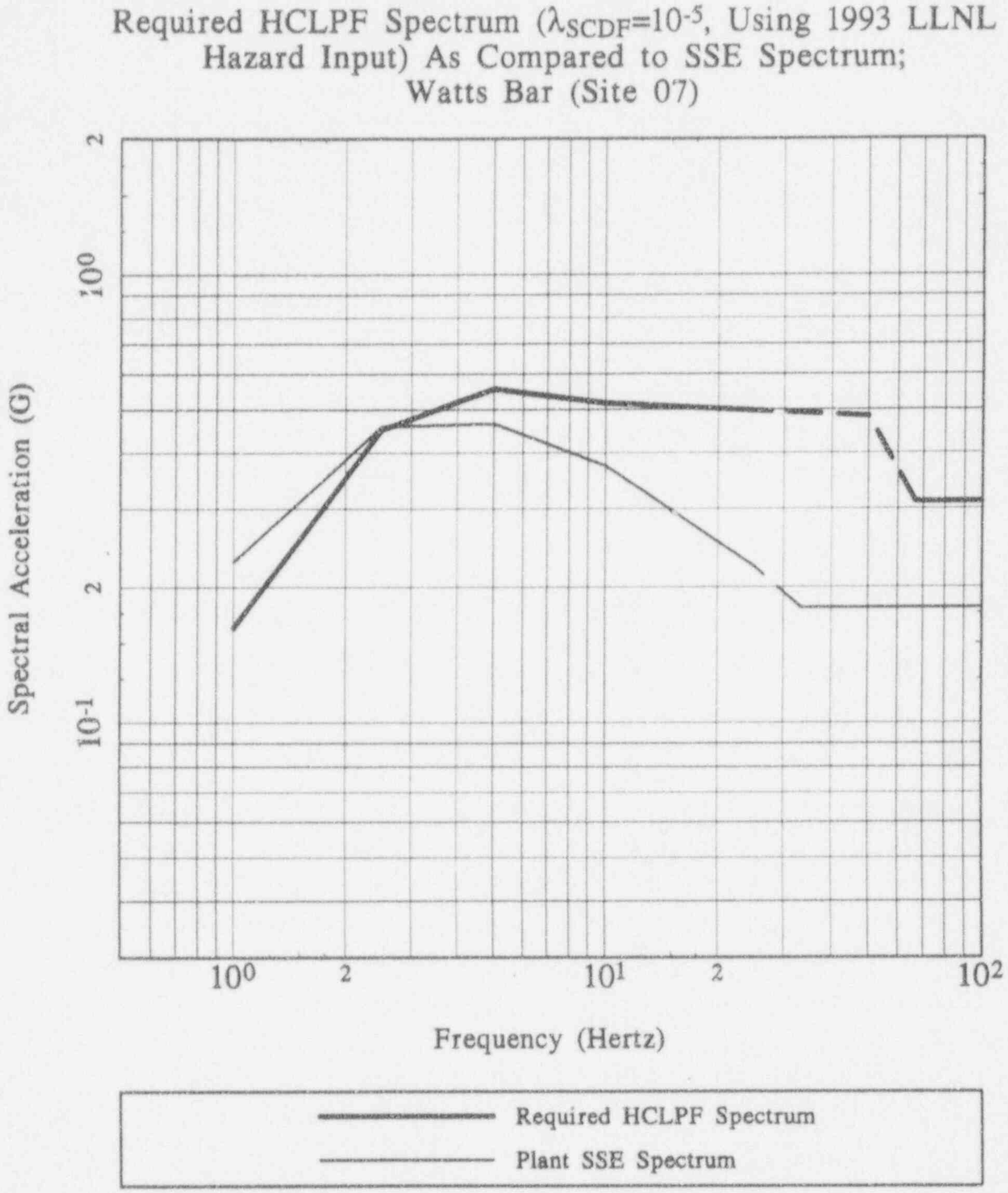


Figure A-46. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 07, Watts Bar.

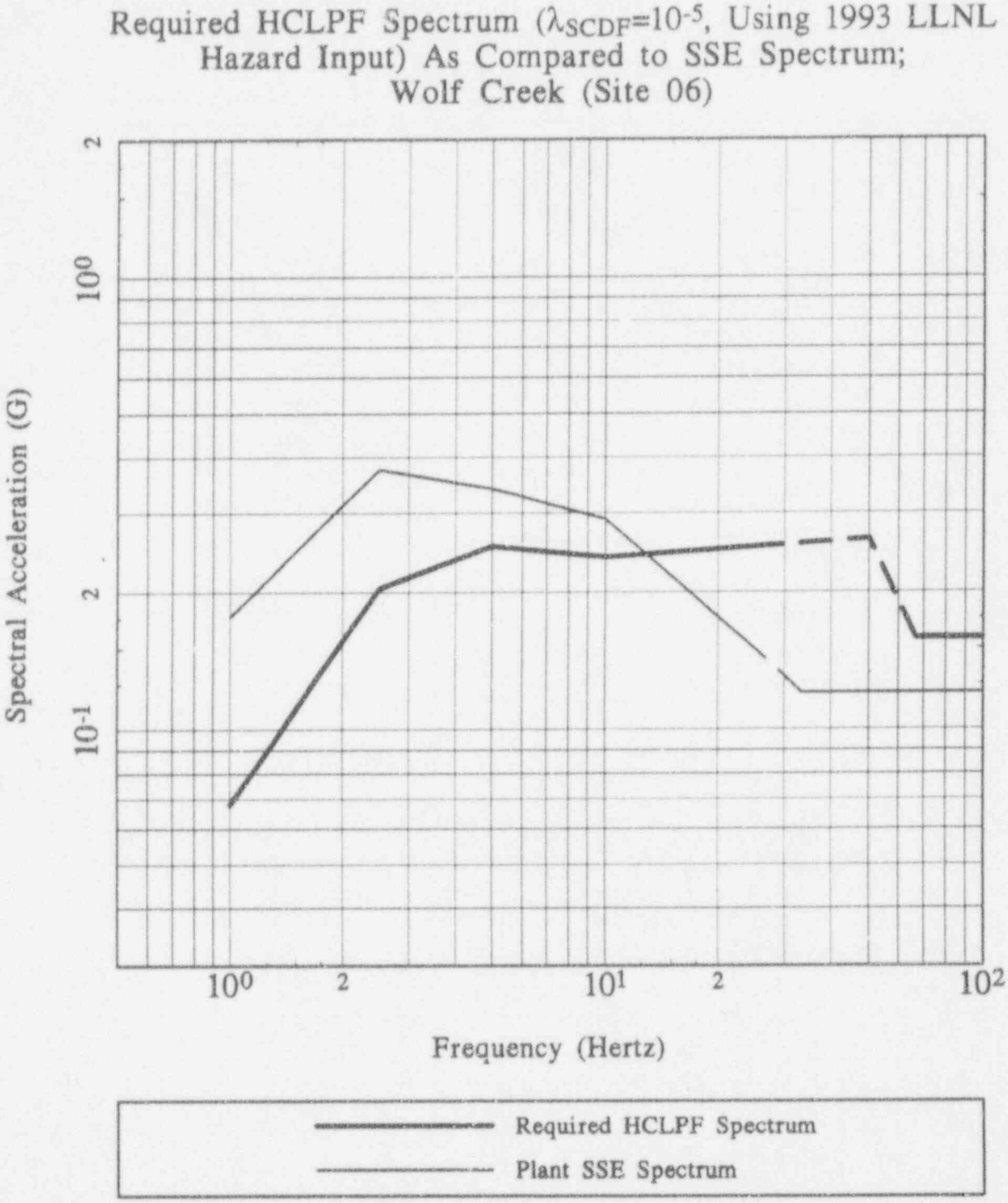
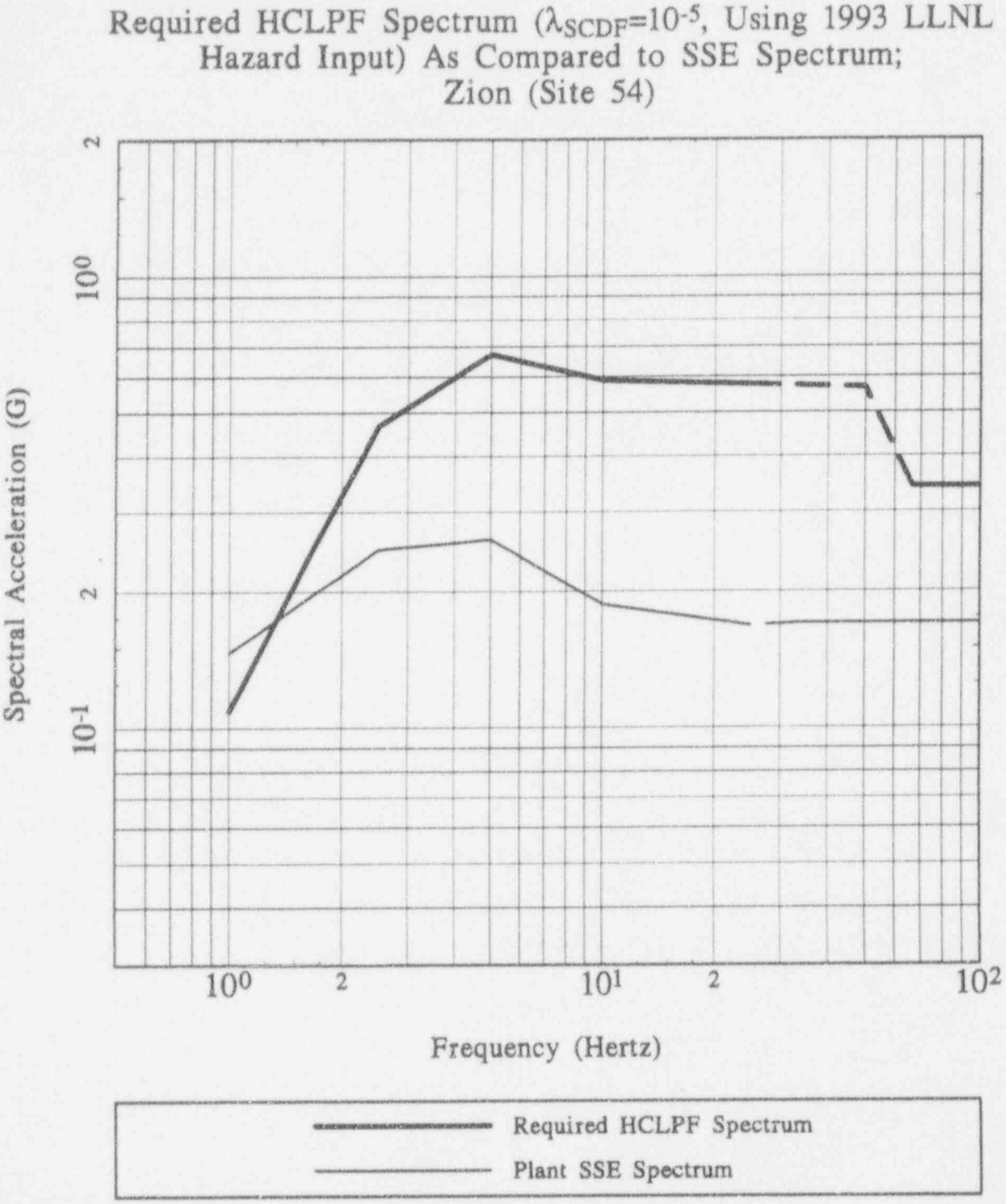


Figure A-47. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 06, Wolf Creek.



Required HCLPF Spectrum ($\lambda_{SCDF}=10^{-5}$, Using 1993 LLNL Hazard Input) As Compared to SSE Spectrum; Zion (Site 54)

Figure A-48. Required HCLPF spectrum (for a limiting mean seismic core-damage frequency of 1×10^{-5}), based on the 1993 revised LLNL seismic hazard results, as compared to the plant SSE spectrum. Results are shown for Site 54, Zion.