US NRC Generic Issue (GI-199) and its Impact on Analysis/Design of Independent Spent Fuel Storage Installation (ISFSI) in CEUS

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Keywords: Spent Nuclear Fuel Storage, ISFSI Analysis/Design, Increase in Seismic Demand, CEUS.

ABSTRACT:

The U. S. Nuclear Regulatory Commission (NRC) Generic Issues Program (GIP) evaluates technical issues that apply to two or more facilities and that may not be covered by existing regulatory processes or criteria. Issues are evaluated for their effect on safety, security, and/or the environment. The GIP is a program by which these issues can be formally assessed to see if they can be dis-positioned by existing regulatory processes or if not, to determine their safety and/or risk significance and how best to treat them.

NRC issued Information Notice (IN) 2010-018 [1] in September, 2010 to all current holders of a license to operate a Nuclear Power Plant, addressing the Generic Issue 199 (GI-199) [2], "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants." In the continental USA, geographic areas located east of the Rocky Mountain Front (East of approximately 104° west longitude) are generally known as the Central and Eastern United States (CEUS). GI-199 investigates the safety and risk implications of updated earthquake-related data and models that suggested that the probability for earthquake ground shaking above the seismic design basis for some nuclear power plants in the CEUS is still low, but larger than previous estimates.

Spent Nuclear Fuel storage, using an NRC approved Dry Cask Storage System (DCSS) is an acceptable means of spent fuel management. The Independent Spent Fuel Storage Installations (ISFSIs) are required to satisfy the safety objectives of Title 10 of the Code of Federal Regulations (10 CFR) Part 72 [3]. Regulatory Guides (RGs), NUREGs, Standard Review Plans (SRPs) and other guidance documents are available to assist an applicant in complying with the regulations.

Although not specifically evaluated as part of GI-199 a preliminary screening review was performed by the NRC Office of Nuclear Material Safety and Safeguards (NMSS). Design Earthquakes (DE), and the Safe Shutdown Earthquake (SSE) used for the cask designs at the existing ISFSI locations in the CEUS were compared. This review indicated that the safety margin defined for ISFSIs as: the ratio of DE/SSE was adequate and, these ISFSIs can continue to operate safely while the licensees investigate the issue using their site specific detailed information. Even so, holders of an operating license for ISFSIs were included among addressees in the IN 2010-018. Currently there are 48 operating ISFSIs in the CEUS. Except for a wet storage facility at G. E. Morris located in Illinois, these ISFSIs are co-located at operating reactor sites, and a few at permanently shutdown reactor sites. The IN includes ISFSIs that are co-located at the reactor sites, which use the plant SSE as their design/licensing basis, as well as ISFSIs located away from the reactor site, which have their own location-specific licensing/design-basis earthquake. The NRC expects that recipients of the IN will review the information, when available, related to potential increase in seismic demand for applicability to their facilities and consider actions, as appropriate. This paper will provide an overview of some of these issues that NRC licensed facilities will address in the near future to establish adequacies of these ISFSI facilities within the framework of existing 10 CFR Part 72 regulations.

BACKGROUND:

The NRC Generic Issues Program (GIP) evaluates technical issues that apply to two or more facilities and that may not be covered by existing regulatory processes or criteria. Issues are evaluated for their effect on safety, security, and/or the environment. The GIP is a program by which these issues can be formally assessed to see if they can be dispositioned by existing regulatory processes or if not, to determine their safety and/or risk significance and how best to treat them. Information on the program is available on the public NRC GIP website (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html).

This issue was proposed as a Generic Issue (GI) in May 2005 after NRC staff's review of updates to the seismic source and ground motion models provided by applicants in support of early site permits for new reactors. The updated seismic information included new Electric Power Research Institute (EPRI) models to estimate earthquake ground motion and updated models for earthquake sources in seismic regions such as

eastern Tennessee, and around both Charleston, South Carolina and New Madrid, Missouri. In the continental USA, geographic areas located east of the Rocky Mountain Front (east of approximately 104° west longitude) are generally known as CEUS.

The new data and models resulted in increased estimates of the seismic hazards for some plants in the CEUS. The staff evaluated this new information along with preliminary results from a 2004 U.S. Geological Survey (USGS) letter report regarding seismic hazard estimates. From this review the staff concluded that the likelihood of exceeding the seismic hazard values, used in plant design and in previous evaluations (such as the Individual Plant Examination of External Events (IPEEE) Program) [4], may be higher than previously understood for some currently operating CEUS sites.

The licensing basis for currently operating plants is based on deterministic analysis of design basis loads from the maximum earthquake level determined from historical data. The licensing basis does not include a probabilistic assessment of seismic hazards or probabilistic assessment of their potential impact on plant structures, systems, and components.

SCOPE:

The scope of the GI-199 Safety/Risk Assessment is limited to all plants in the CEUS. Although plants at the Columbia, Diablo Canyon, Palo Verde, and San Onofre sites are not included in the GI-199 Safety/Risk Assessment, the Information Notice on GI-199 is addressed to all operating power plants in the U.S. (as well as all independent spent fuel storage installation licensees). The staff will also consider inclusion of operating reactors in the Western U.S. in its future generic communication information requests.

While the GI-199 Safety/Risk Assessment focused solely on operating power reactors in the CEUS, spent fuel storage has also been considered by NRC. The NRC Office of NMSS was informed of GI-199 and a preliminary screening review was performed in November, 2008 by the NMSS Division of Spent Fuel Storage and Transportation (DSFST). There are 48 operating independent spent fuel storage installations (ISFSIs) in the CEUS (see Table 1). Except for a wet storage facility at G. E. Morris located in Illinois, the ISFSIs are collocated at the operating and permanently shutdown reactor sites. A review of design earthquakes (DE) used at the existing ISFSI locations in the CEUS indicated that the safety margin for the cask designs (defined as the ratio of DE/SSE, where SSE is the *safe shutdown earthquake*) were in the range of 1.20 ~ 3.90. Therefore, NMSS/DSFST considers that there is adequate margin built into the existing designs and has reasonable assurance that the ISFSIs can continue to operate safely while the licensees investigate this issue using their site specific information to verify their adequacy. Even so, holders of an operating license for ISFSIs are included among addressees in the Information Notice on GI-199.

While the GI-199 Safety/Risk Assessment focused solely on operating power reactors in the CEUS, fuel cycle facilities have also been considered by NRC. Based on preliminary reviews of the updated seismic hazard estimates, NRC staff in the Office of NMSS Fuel Cycle Safety and Safeguards (FCSS) concluded that, for the fuel cycle facilities within the CEUS, there is no immediate safety concern and FCSS will issue a separate IN for their licensees.

METHODOLOGY:

The NRC staff collected and analyzed seismic hazard information from the USGS and from other sources, and seismic risk information from IPEEE [4] analyses. EPRI reported that they calculated mean seismic hazard results for all nuclear power plant sites in the CEUS and used these results to perform an independent evaluation of the implications of changes in seismic hazard estimates. The staff completed the review and analysis of seismic data in support of the Safety/Risk Assessment in June 2009.

The effect of a single earthquake is small on the estimated *seismic hazard* at any location, and as a result overall impact on GI-199 is also small, unless the seismic event occurs in an area not previously recognized as being capable of producing earthquakes, or the area is larger than previously believed possible in a region. In a seismic hazard study, the seismic source zones are specifically delineated to include a sufficient number of earthquakes to provide a stable estimate of the seismicity rate and are thus relatively insensitive to the addition of a single earthquake. If an earthquake does occur in an area not previously recognized as being capable of producing earthquakes or if an earthquake occurs that is larger than previously believed possible in a region, changes to the seismic hazard model used to develop seismic hazard estimates would be required.

Note: The magnitude 5.2 earthquake that occurred on April 18, 2008 in southeastern Illinois provides a good example of the potential impact of a single earthquake. This earthquake occurred in an area recognized as being capable of producing significant earthquakes (the Wabash Valley seismic source zone) and was smaller than the maximum magnitude event defined for the zone based on geologic investigations (maximum magnitude of 7-7.5). The addition of a single event of this magnitude to the earthquake database for this area would likely change the activity rate by less than a few percent and thus have a very small impact on the estimated seismic hazard at any of the nuclear facilities in the area.

DEFINITIONS:

- ***Annual exceedance frequency (AEF)*** – Number of times per year that a site's ground motion is expected to exceed a specified acceleration.

- ***Core damage frequency (CDF)*** – Expected number of core damage events per unit of time. *Core damage* refers to the uncovering and heat-up of the reactor core, to the point that prolonged oxidation and severe fuel damage is not only anticipated but also involves enough of the core to result in off-site public health effects if released. *Seismic core damage frequency* refers to the component of total CDF that is due to seismic events.

- ***Design basis earthquake* or *safe shutdown earthquake (SSE)*** – A *design basis earthquake* is a commonly employed term for the *safe shutdown earthquake* (*SSE)*; the SSE is the earthquake ground shaking for which certain structures, systems, and components are designed to remain functional. In the past, the SSE has been commonly characterized by a standardized spectral shape associated with a peak *ground acceleration* value.

- ***Ground acceleration*** – Acceleration produced at the ground surface by seismic waves, typically expressed in units of *g*, the acceleration of gravity at the earth's surface.

- ***High confidence of low probability of failure (HCLPF) capacity*** – A measure of *seismic margin*. In *seismic risk* assessment, *HCLPF capacity* is defined as the earthquake motion level, at which there is high confidence (95%) of a low probability (at most 5%) of failure of a structure, system, or component.

- ***Large early release frequency (LERF)*** – The expected number of large early releases per unit of time. A *large early release* is the rapid, unmitigated release of airborne fission products from the containment building to the environment, occurring before the effective implementation of off-site emergency response and protective actions, such that there is a potential for early health effects. *Seismic large early release frequency* refers to the component of total LERF that is due to seismic events.

- ***Seismic hazard*** – Any physical phenomenon, such as ground motion or ground failure, that is associated with an earthquake and may produce adverse effects on human activities (such as posing a risk to a nuclear facility).

- ***Peak ground acceleration (PGA)*** – Peak ground acceleration is a measure of earthquake intensity. Unlike the Richter magnitude scale, it is not a measure of the total size of the earthquake, but rather how hard the earth shakes in a given location. Unlike the Mercalli scale, it is measured by instruments, not from personal reports. Peak ground acceleration can be measured in *g* (the acceleration due to gravity) or m/s².

- ***Seismic risk*** – The risk (frequency of occurrence multiplied by its consequence) of severe earthquake-initiated accidents at a nuclear power plant. A severe accident is an accident that causes core damage, and, possibly, a subsequent release of radioactive materials into the environment. Several risk metrics may be used to express *seismic risk*, such as seismic *core damage frequency* and seismic *large early release frequency*.

  For the representative plant in the chart below, the *annual exceedance frequency* for a 0.7*g* acceleration (e.g., for a large, but highly improbable earthquake) has increased from approximately one in 250,000 years (for IPEEE-era curves) to approximately one in 60,000 years (for recent *seismic hazard* curves). (In other words, the annual exceedance frequency for 0.7*g* acceleration has increased from about 4×10^{-6} (0.000004) per year for IPEEE-era curves to about 1.8×10^{-5} (0.000018) per year for recent seismic hazard curves.) Note that the curves in this example are virtually indistinguishable at the SSE (design basis) level, but this is not always the case. *Ultimately, GI-199 is about understanding the impact of these seismic hazard changes on reactor risk.*

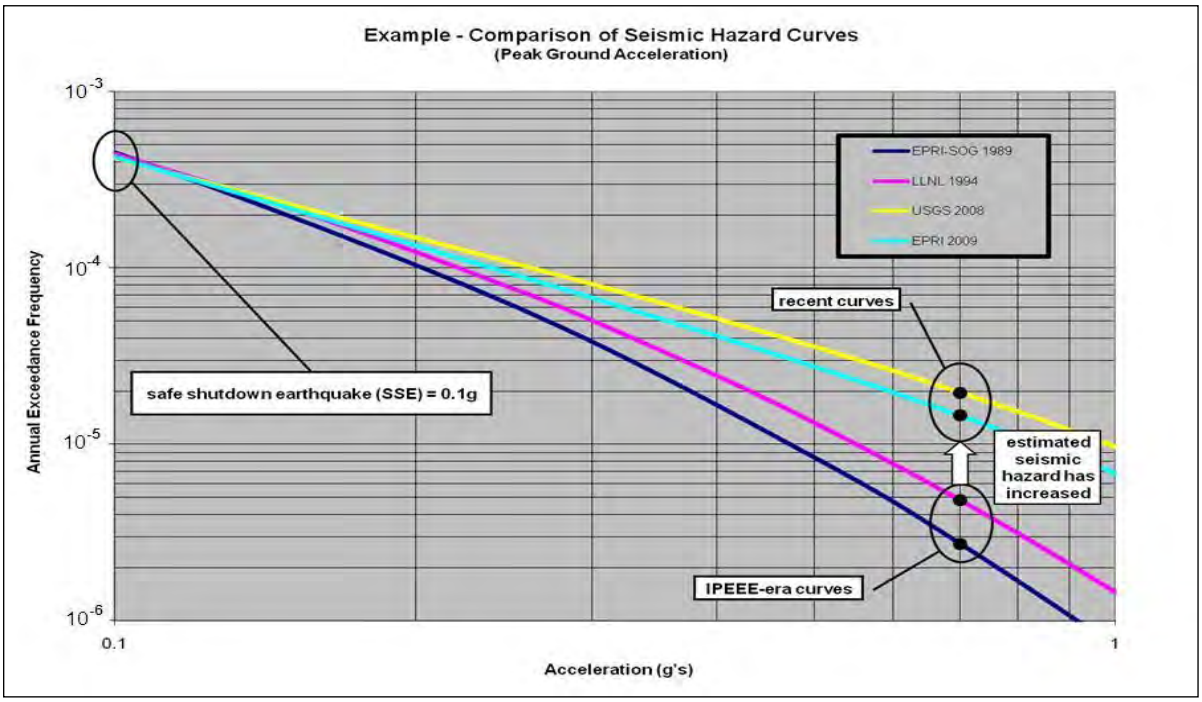

Figure -1 Comparison of Seismic Hazard Curves PGA

- ***Seismic margin*** – The difference between a plant's *HCLPF* capacity and its seismic design basis (*safe shutdown earthquake, SSE*), as shown in the figure below. (Note that the "plant capacity" label in this figure is the acceleration expected to result in core damage half of the time.)

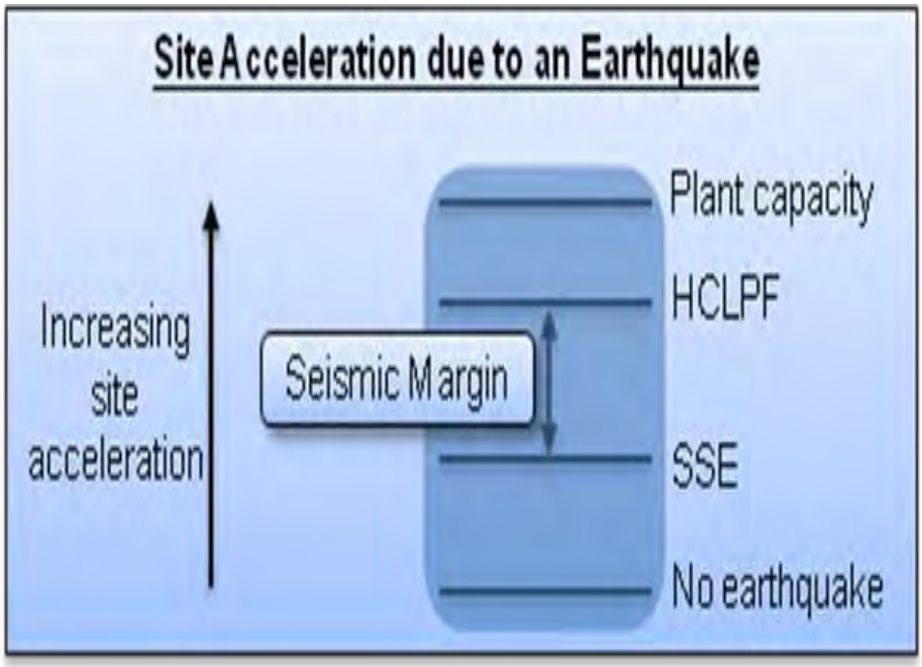

Figure – 2 Seismic Margin

INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS:

Spent Nuclear Fuel storage, using an NRC approved DCSS is an acceptable and safe means of spent fuel management. The ISFSIs are required to satisfy the safety objectives of Title 10 of the Code of Federal Regulations (10 CFR) Part 72 [3]. Regulatory Guides (RGs), NUREGs, Standard Review Plans (SRPs) and other guidance documents are available to assist an applicant in complying with the regulations.

Seismic hazard (earthquake hazard) represents the chance (or probability) that a specific level of ground shaking could be observed or exceeded at a given location. Seismic community's estimates of seismic hazard at some CEUS locations have changed based on results from recent research, indicating that earthquakes occurred more often in some locations than previously estimated. The estimates of seismic hazard have also changed because the models used to predict the level of ground shaking, as caused by a specific magnitude earthquake at a certain distance from a site, changed.

This is a complicated issue involving the intersection of the probabilistic risk analysis and seismic disciplines. Obtaining data, developing methods, and performing analyses are all required to address the issue. Analyzing a few representative plants for this issue (as is normally done in the GIP) is inappropriate because the *seismic hazard* and associated impact to the power plant are very site-specific; so analysis for 96 separate plants is required. GI-199 has also been a communication-intensive generic issue because it affects many parts of the NRC and industry, and because it is important to NRC and all stakeholders that the Safety/Risk Assessment results are properly conveyed. No immediate action is needed because:

(1) Existing plants were designed to withstand anticipated earthquakes with substantial design margins, as confirmed by the results of the Individual Plant Examination of External Events;

(2) The probability of exceeding the *safe shutdown earthquake* ground motion may have increased at some sites, but only by a relatively small amount;

(3) The increased probability is primarily in the high structural response frequencies, so buildings and equipment should not be affected (seismic amplitudes at lower frequencies are the primary contributors to building and equipment damage).

Regarding seismic requirements for dry cask storage systems and independent spent fuel storage installations (ISFSIs), the NRC staffs also expects that licensees will use the most recent seismic hazard information available for risk-informed regulatory applications.

For the analyses and design of ISFSI the applicable regulations are: Title 10 of Code of Federal Regulations (CFR) Part 72 [3].

The Section 72.102 of 10 CFR Part 72 [3] specifies the requirements for those *ISFSI applications before October 16, 2003*. In the CEUS, the Design Earthquake (DE) response spectrum anchored at 0.20g shall be used. Except in regions around Charleston, SC and new Madrid, MO, the DE response spectrum anchored at 0.25g shall be used. *For sites that have been evaluated under the criteria of Appendix-A of 10 CFR Part 100 [5], the DE must be equivalent to the safe shutdown earthquake (SSE) for the Nuclear Power Plant (NPP), but in no case less than 0.10g.*

The Section 72.103, "Geological and Seismological Characteristics for Applications for Dry modes of Storage on or *after* October 16, 2003", Paragraph (a)(2) requires, for CEUS, that a standardized DE described by an appropriate response spectrum anchored at 0.25g shall be used. Alternatively, a site-specific DE may be determined by using the criteria and level of investigations required by Paragraph (f) of section 72.103. For sites collocated with a Nuclear Power Plant (NPP) the existing geological and seismological criteria may be used. Paragraph (f)(1) requires that the geological, seismological, and engineering characteristics of a site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site.

10 CFR 72.103, Paragraph (f)(2) requires that the geologic and seismic siting factors considered for design include a determination of the DE for the site, the potential for surface tectonic and non-tectonic deformations, the design bases for seismically induced floods and water waves, and other design conditions. In 10 CFR 72.103, Paragraph (f)(2)(i) requires that uncertainties inherent in estimates of the DE be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis (PSHA) or suitable sensitivity analyses.

The NRC issued in October 2003, a Regulatory Guide (RG) 3.73 [6]. This guide was developed to provide general guidance and procedures acceptable to the NRC staff to determine that the *DE used for applications after October 16, 2003,* satisfy the requirements of Part 72. The regulatory position 3.4 of RG 3.73 permits, for CEUS sites, to perform a probabilistic seismic hazard analysis using the reference probability of 5E-4/yr. *(This equates to an earthquake with a return period of only 2000 years, as opposed to an earthquake with a return period of 10,000 years, which was typically used to determine the SSE for the NPP).* The procedure for determining the DE is described in regulatory position 4.0 of RG 3.73 [6].

As a condition for utilizing their general license to operate an ISFSI, 10 CFR Part 72.212 requires a licensee to perform written evaluations that establish that, for their site-specific conditions, the conditions set forth in the Certificate of Compliance (CoC) have been met and that cask storage pads and areas have been designed to adequately support the static and dynamic loads of the stored casks, considering potential amplification of earthquakes through soil-structure interaction, and soil liquefaction potential or other soil instability due to vibratory ground motion. *Note that the reinforced concrete pad supporting the dry casks for an ISFSI has been classified as a structure important to safety (ITS) Category C per NUREG 6407 [7]. However, staff noted that it has been classified as non-safety-related and non-seismic category 1 structure by some licensees.* NRC regulations (in 10 CFR Part 72) require licensees to perform written evaluations to establish that, for their site-specific conditions, the conditions set forth in the Certificate of Compliance (CoC) have been met. They must also perform evaluations showing that cask storage pads and areas have been designed to adequately support the static and dynamic loads of the stored casks, considering potential amplification of earthquakes through soil-structure interaction as well as soil liquefaction potential or other soil instability due to vibratory ground motion.

Information Notice IN 2010-18 [1] was issued on September 2, 2010. References to NMSS/SFST ISFSI facilities were included in that IN. A public meeting was held on May 18, 2011 to discuss NRC (Nuclear Reactor Regulation (NRR) potential Generic Letter (GL) on the information collection needs to enable the staff to complete the Regulatory Assessment of impact from increased seismic hazard estimates at some operating reactor sites. SFST will continue to be a part of the revised and updated information regarding GI-199 and IN 2010-18 in future as needed,

As of this writing, the DSFST staff awaits any pertinent and final information from NRR staff regarding those CEUS sites that may be affected due to issues described in GI-199. The ISFSI operating licensees were informed by the IN 2010-18 to review implications if any of that new information (when available) and its effects on CEUS/ISFSI seismic design *for casks, as well as supporting pads.*

Attached herewith is Table 1, "List of Operating ISFSIs in the CEUS". Based on the available licensing basis DE and SSE information, DSFST staff performed a preliminary screening analyses that indicated that the DE used for the existing ***storage casks*** for ISFSIs located in the CEUS provides reasonably adequate safety margin (defined as a ratio of DE/SSE), and are in compliance with the current Part 72 requirements. Adequacies of these *storage casks and their pad support* will have to be revalidated for any potential increase in seismic demand at those sites that may show slight increase in the seismic demands.

CONCLUSIONS:

The CEUS is generally an area of low to moderate earthquake hazard with few active Faults in contrast to the western United States. Even so, in 1811–1812, three major earthquakes (Magnitude 7 to 7.7 on the commonly used Richter scale) shook much of the CEUS. These earthquakes occurred near the town of New Madrid, MO. In 1886, a large earthquake (Richter scale magnitude of about 7) occurred near Charleston, SC. This earthquake caused extensive damage and was felt in most of the eastern United States. Geologists are aware of these historic occurrences, and knowledge of such earthquakes was taken into account in plant design and analysis.

The NRC regularly reviews new information on earthquake source and ground motion models. For example, the NRC reviewed updated earthquake information provided by applicants in support of Early Site Permits for new reactors. This additional information included new models to estimate earthquake ground motion and updated models for earthquake sources in seismic regions such as eastern Tennessee and around both Charleston and New Madrid.

As of this writing, NRC is developing a Generic Letter (GL) to request information from all U.S. nuclear plants. The GL was issued in draft form to support a public meeting in late spring 2011. NRC expects to issue the final GL by the end of summer of 2011, near the time when new seismic models are expected to become available. These new seismic models are being developed by NRC, the U.S. Department of Energy, and the Electric Power Research Institute and will be reviewed by the USGS. The NRC expects to receive information from the GL in 2012 and will review it to determine whether any plant improvements are needed.

Similarly, based on the magnitude of potential increase in seismic demand, NRC will establish if there is a need to collect information regarding operating ISFSIs analyses and design. The current operating licensees of ISFSIs, licensed under 10 CFR Part 72 are fully aware of the details of GI-199, and appropriate actions are expected to be taken to revalidate the adequacy of DCSS and the ISFSI pads at these sites.

The author of this paper is solely responsible for the opinions, conclusions, recommendations, and overall contents herein and does not necessarily reflect the views of the U. S. Nuclear Regulatory Commission.

Table -1 LIST OF OPERATING ISFSIs in the CEUS

NRC Region	Site	Type of License	Remarks
I	Calvert Cliffs	Specific	Collocated w/ Reactor
"	Fitzpatrick	General	"
"	Ginna	"	"
"	Indian Point	"	"
"	Limerick	"	"
"	Millstone	"	"
"	Oyster Creek	"	"
"	Peach Bottom	"	"
"	Hope Creek	"	"
"	Salem	"	"
"	Seabrook	"	"
"	Susquehanna	"	"
"	Vermont Yankee	"	"
"	Maine Yankee	"	Stand Alone
"	Connecticut Yankee	"	"
"	Yankee Rowe	"	"
II	Browns Ferry	"	Collocated w/Reactor
"	Brunswick	"	"
"	Catawba	"	"
"	Farley	"	"
"	Hatch	"	"
"	McGuire	"	"
"	North Anna	General & Specific	"
"	Oconee	"	"
"	Robinson	"	"
"	Sequoyah	General	"
"	St. Lucie	"	"
"	Surry	General & Specific	"
III	Big Rock Point	General	Stand alone
"	Byron	"	Collocated w/Reactor
"	Davis-Besse	"	"
"	Dresden	"	"
"	Duane Arnold	"	"
"	Fermi	"	"
"	G.E. Morris	Specific	Wet Storage - Stand Alone
"	Kewaunee	General	Collocated w/Reactor
"	LaSalle	"	"
"	Monticello	"	"
"	Palisades	"	"
"	Perry	"	"
"	Point Beach	"	"
"	Prairie Island	Specific	"
"	Quad Cities	General	
IV	ANO	General	Collocated w/Reactor
"	Cooper	"	"
"	Fort Calhoun	"	"
"	Grand Gulf	"	"
"	River Bend	"	"

Notes: **1) Currently Operating ISFSIs in CEUS = 48**
2) Twenty Six (26) States in CEUS have at least one ISFSI

REFERENCES:

[1] Information Notice IN 2020-018, "Generic Issue 199, "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants", September 2010.

[2] Generic Issue, GI-199, "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants", September, 2010.

[3] Title 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste of the *Code of Federal Regulations* (Latest Revision).

[4] IPEEE, "Generic Letter 88-20, "Individual Plant Examination (IPEEE) for Severe Accident Vulnerabilities" November 23, 1988.

[5] Title 10 CFR Part 100, "Reactor Site Criteria" of the *Code of Federal Regulations* (Latest Revision).

[6] US NRC RG 3.73, Regulatory Guide, "Site Evaluations and Design Earthquake Ground Motions for Dry Cask Independent Spent Fuel Storage and Monitored Retrievable Storage Installations", October 2003.

[7] NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety", January 1996.