PMSTPCOL PEmails

From: STPCOL
Sent: Thursday, October 18, 2012 3:02 PM
To: PMSTPCOL PEmails
Subject: FW:
Attachments: RAI 01.05-1 Corrected.pdf

From: Foster, Rocky
Sent: Monday, October 01, 2012 8:44 AM
To: STPCOL
Subject: FW:

From: Scheide, Richard [mailto:rhscheide@STPEGS.COM]
Sent: Tuesday, September 25, 2012 9:41 AM
To: Foster, Rocky
Cc: Mookhoek, William; Head, Scott; Thomas, Steven; Rejcek, Milton
Subject:

Rocky,

The following overview was prepared by Engineering:

We have prepared a detailed response to RAI 01.05-1, which requests evaluation of any impacts of the recently released seismic source characterization for the central and eastern U.S (CEUS-SSC) on the seismic design of Units 3 & 4. In short, we have found that the seismic design basis for Units 3&4 is not measurably impacted by CEUS-SSC. This email provides an executive summary of that work, whereas the details can be found in the attached RAI response.

Units 3&4 seismic design was based on earthquake source characterization (i.e., source catalog, recurrence rates and maximum magnitudes) derived from the available EPRI source model updated with most recent seismic source characterization. These modifications are described in the STP 3&4 FSAR and the resulting seismic characterization is referred to herein as the FSAR-SSC. Since then, the CEUS-SSC project has redefined the seismic source characterization for regions and discrete sources that contribute to the hazard at the Unit 3&4 site. RAI 01.01-1 requests that differences between the STP FSAR-SSC and the new CEUS-SSC be evaluated. (Both the FSAR and RAI 01.01-1 utilize the same EPRI ground motion prediction equations, and so any differences in the site hazard would be due entirely to the source characterizations.)

Fortunately, evaluating the impacts of CEUS-SSC for the STP site does not require that the entire probabilistic seismic hazard assessment be repeated using CEUS-SSC in place of FSAR-SSC. This is because the CEUS-SSC report includes seismic hazard curves for Houston, Texas as one of the eight sites at which the new CEUS model was demonstrated. Houston serves as a good surrogate for the STP site because it is less than 80 miles away, and because neither the geology nor the seismicity change quickly in this seismically quiescent region. In fact, comparison of recurrence rates for Houston and the STP site suggest that the seismic hazard at the STP site might be marginally lower.

In addition to its proximity to the site, the notion that Houston can be a good surrogate for the STP site is demonstrated in two ways. First, the 2008 USGS seismic hazard curves calculated for each site are very similar (STP slightly less hazardous). Second, the STP FSAR-SSC hazard is shown to be very similar to the corresponding CEUS-SSC Houston hazard, despite the fact they use different source characterization.

Given that the rock hazards are very similar, the corresponding site-specific free surface and foundation input ground motions must also be very similar because they would be based on the same soil amplifications. This is demonstrated in Figure 6 of our RAI response, which compares the GMRS from the FSAR to associated GMRS points calculated from the CEUS-SSC Houston hazard curves. The GMRS based on the CEUS-SSC is enveloped by the SSE, and therefore no modifications to the GMRS or FIRS are required.

In addition to the rock hazard, the CEUS-SSC report also provides Houston hazard curves for a generic deep soil, but this soil differs from the STP site and is not used for comparison. Also, the CEUS-SSC report provides rock hazard curves based on modifications to the EPRI SSC that appear in other COLA's, but this "COLA" curve is unrelated to the STP 3&4 COLA. Herein only the CEUS-SSC Houston rock hazards are used as surrogate curves for STP site rock hazards.

In summary, Houston provides a good surrogate for the STP site because it is nearby with respect to regional geology and seismicity. Horizontal ground motions calculated using CEUS-SSC Houston rock hazard and STP site-specific soils are very close to the GMRS provided in the FSAR, and are enveloped by SSE spectrum. We conclude that the new CEUS-SSC has no impact on the design of STP 3&4, and that there is no reason to revise the site-specific GMRS or FIRS as they appear in the current FSAR.

Dick Scheide
Office: 361-972-7336
Cell: 479-970-9026

Hearing Identifier: SouthTexas34Public_EX
Email Number: 3481

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RAI 01.05-1, Revision 1

QUESTION:

This request for additional information (RAI) specifically addresses Recommendation 2.1, of the Fukushima Near-Term Task Force recommendations contained in SECY-12-0025 as it pertains to the seismic hazard evaluation. This recommendation specifies the use of NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," (CEUS-SSC) in a site probabilistic seismic hazard analysis (PSHA). Consistent with Recommendation 2.1, as well as the need to consider the latest available information in the (PSHA) for South Texas Project Units 3 and 4 planned reactor site, the NRC staff requests that STP:

a) Evaluate the potential impacts of the newly released CEUS-SSC model, with potential local and regional refinements as identified in the CEUS-SSC model, on the seismic hazard curves and the site-specific ground motion response spectra (GMRS)/foundation input response spectra (FIRS). For re-calculation of the PSHA, please follow either the cumulative absolute velocity (CAV) filter or minimum magnitude specifications outlined in Attachment 1 to Seismic Enclosure 1 of the March 12, 2012 letter " Request for information pursuant to Title 10 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1.2.3, and 9.3, of the near-term task force review of insights from the Fukushima Dai-Ichi accident." (ML12053A340).
b) Modify the site-specific GMRS and FIRS if you determine changes are necessary given the evaluation performed in part a) above.

In order to minimize delays to the current licensing schedule, the staff requests that you respond within 60-days of receipt of this RAI or provide a schedule for your response within 30-days.

RESPONSE:

a) An evaluation of the potential impact of the newly released CEUS SSC model (NUREG-2115, NRC, 2012a) on the characterization of seismic hazard curves and the site-specific ground motion response spectra (GMRS) shows that hazard curves and spectra developed from the CEUS SSC model are not significantly different from the hazard curves and spectra developed for STP 3 & 4 Combined License Application (COLA) (Part 2, Tier 2, FSAR Figure 2.5S.2-52) and confirms the original information in the STP 3 & 4 COLA.

   The basis for this conclusion is a comparison of the STP 3 & 4 site GMRS with spectral accelerations developed from the Houston, Texas, demonstration site analysis provided in NUREG-2115, Chapter Eight.

   For this comparison, values for the STP 3 & 4 site GMRS are taken directly from FSAR Table 2.5S.2-21 of the STP 3 & 4 COLA for 38 frequencies ranging from 100 Hz to 0.1 Hz. These values include site-specific amplification factors going from rock to free ground surface soil responses at the GMRS horizon.

   Values for CEUS SSC rock spectral accelerations at 10^{-4} and 10^{-5} mean annual frequencies of exceedance (MAFEs) for the Houston demonstration site can be measured from the curves shown in

NUREG-2115 (NRC, 2012a) Figures 8.2-3d, 8.2-3e, and 8.2-3f for 10 Hz, 1 Hz and PGA (taken as equivalent to 100 Hz response motions) spectral accelerations, respectively. These values can also be interpolated from a suite of mean spectral accelerations given in Table 8.2.3-1, again for 10 Hz, 1 Hz and PGA.

One additional CEUS SSC-based pair of 10^{-4} and 10^{-5} MAFE Houston rock values at 30 Hz was estimated by using the ratio of 100 Hz to 30 Hz rock motions from the STP 3 & 4 FSAR and applying this ratio to the CEUS SSC PGA value. The bases for the assumption that the ratio of 100 Hz to 30 Hz spectral acceleration developed for the STP site would be closely approximated for the Houston demonstration site is that this ratio is stable for a wide range of critical magnitudes and distances (McGuire et al., 2001), that both the CEUS SSC and STP 3 & 4 COLA models use the same ground motion prediction equations (GMPEs), that the rock probabilistic seismic hazard analysis (PSHA) curves for the three frequencies for which comparison is directly comparable are very similar, and that the hazard in the Houston-STP region varies slowly with exact location (e.g., Petersen et al., 2008).

There are several reasons to believe that earthquake hazard in the Houston-STP region varies slowly. First, the historical seismicity pattern on which recurrence parameters are based is similar for both the CEUS SSC and STP 3 & 4 COLA studies. Figures 1a and 1b show regional earthquakes as cataloged for these two studies. Differences in detail exist due to the slightly different periods of coverage and the different magnitude scales used in the two studies (body-wave magnitude, m_b, for EPRI-SOG and moment magnitude, M_w, for CEUS SSC), but the general pattern and, in particular, the general quiescence of the region surrounding both the Houston and STP sites (shown in the figures) are clear.

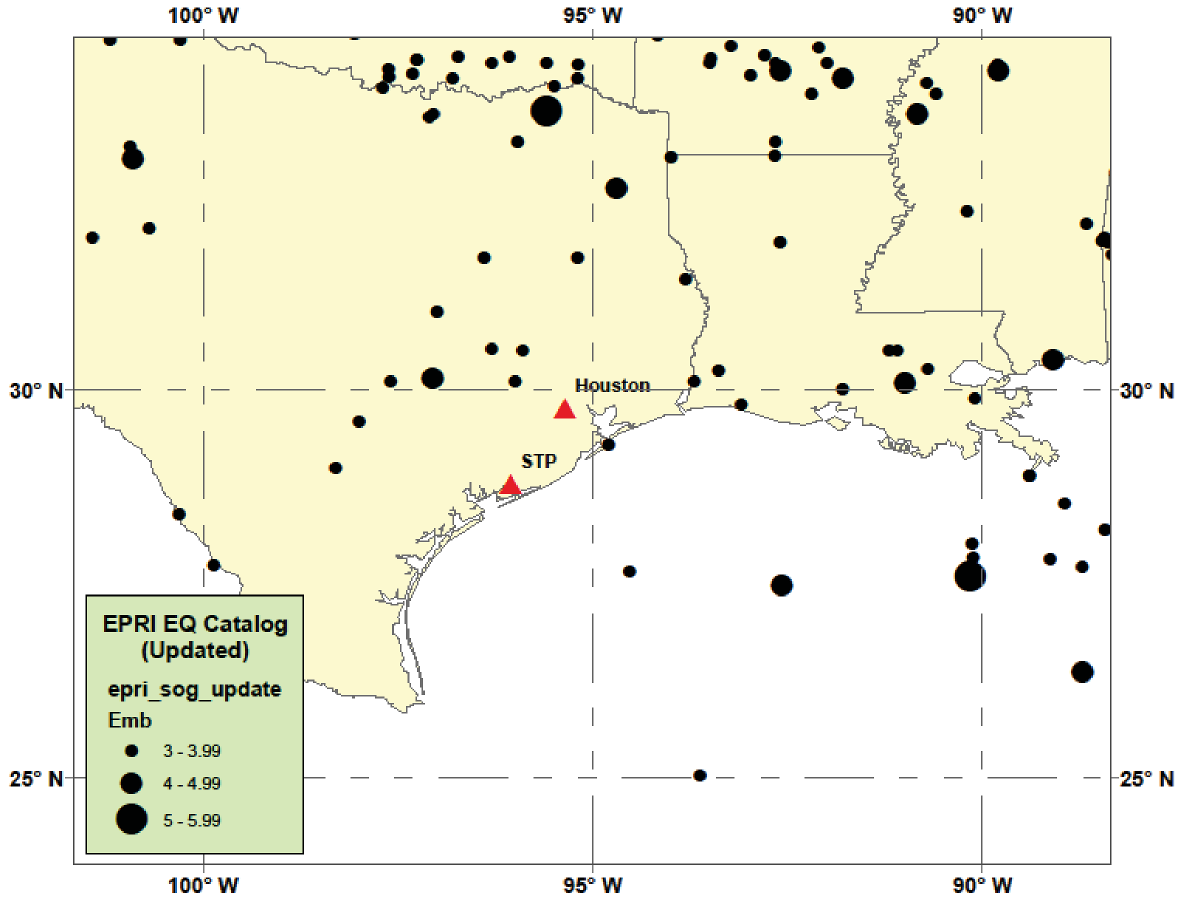

Figure 1a. STP-updated EPRI-SOG regional mainshock [independent] seismicity from the STP 3 & 4 FSAR. Magnitudes shown use the body-wave magnitude [m_b] scale.

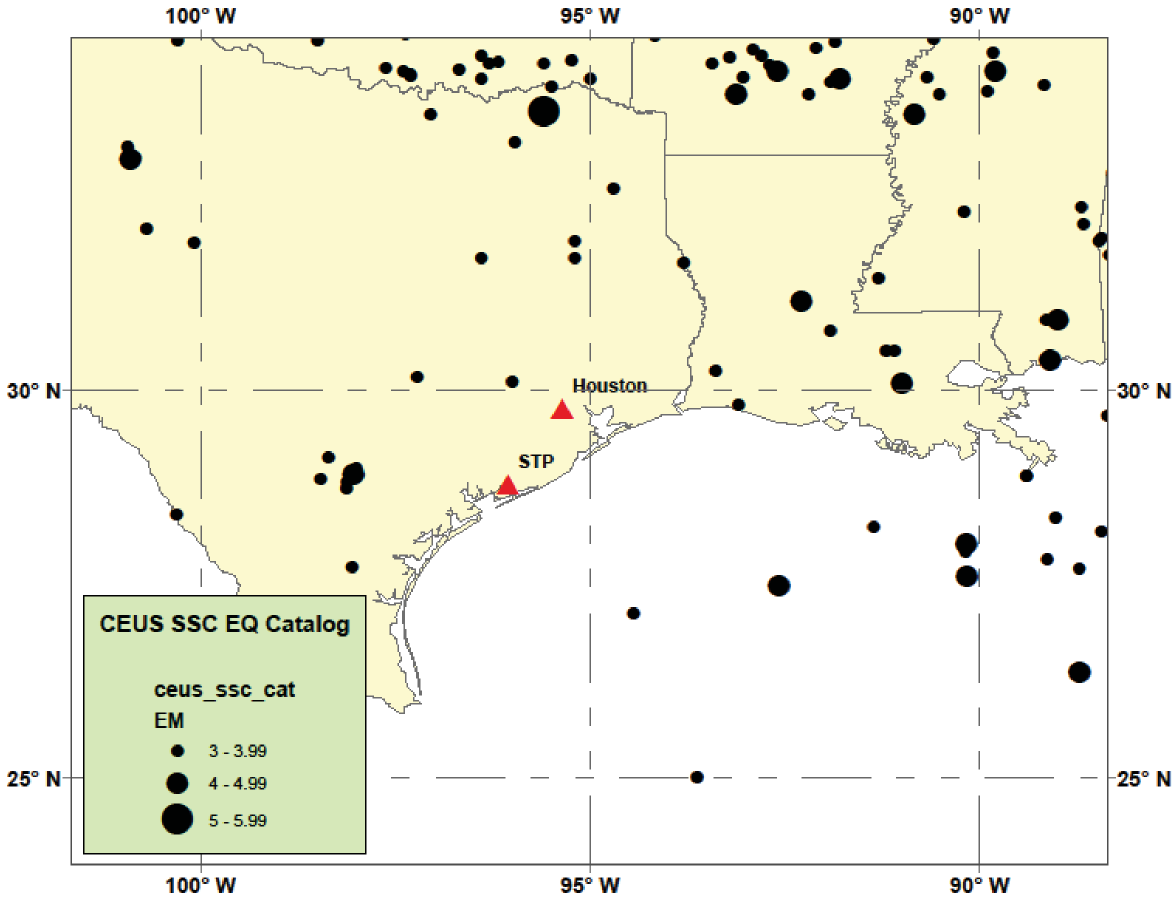

Figure 1b. Map of regional mainshock [independent] seismicity from the CEUS SSC seismicity catalog [NRC, 2012a]. Magnitudes shown use the moment magnitude [M_w] scale.

Second, the STP site and Houston also share similar geologic and tectonic settings. This is reflected in the characterization of regional seismic source zones in both the STP 3 & 4 Combined License Application (COLA) (see Figure 2.5S.2-8) and the CEUS SSC report (e.g., see Figures Figure 6.2-2 and 7.1-1 of the final CEUS SSC report).

Third, the earthquake activity parameter, "a", of the usual Gutenberg-Richter (1956) recurrence relation, $\log_{10}N = a - bM$, (where N is the cumulative number of earthquakes in a given time, M is magnitude, and a and b are curve fitting parameters) especially when smoothed over local or regional areas, would not be expected to show sharp geographical differences in an area of widely scattered small to moderate earthquakes and similar geologic and tectonic settings. Indeed this is borne out by the $\log_{10}N_5$ values - where N_5 is the averaged smooth annual cumulative rate of earthquakes for magnitude 5 and greater per equatorial degree - used to develop rock 10^{-4} and 10^{-5} mean annual frequency of exceedance (MAFE) results in the CEUS SSC and STP 3 & 4 COLA studies. This is shown in Figures 2a and 2b.

Both figures again show the Houston and STP locations and the $\log_{10}$ of interpolated N_5 values at these two sites using inverse-square weighting of the values at the four closest grid points. As with the seismicity maps there are differences in detail, mostly attributable to the different magnitude scales used for the two characterizations, but the geographic variation in $\log_{10}N_5$ is slow and the implied regional earthquake activity suggests that the activity around the STP site is slightly lower (that is, of a slightly larger negative value) or very similar to that around the Houston site.

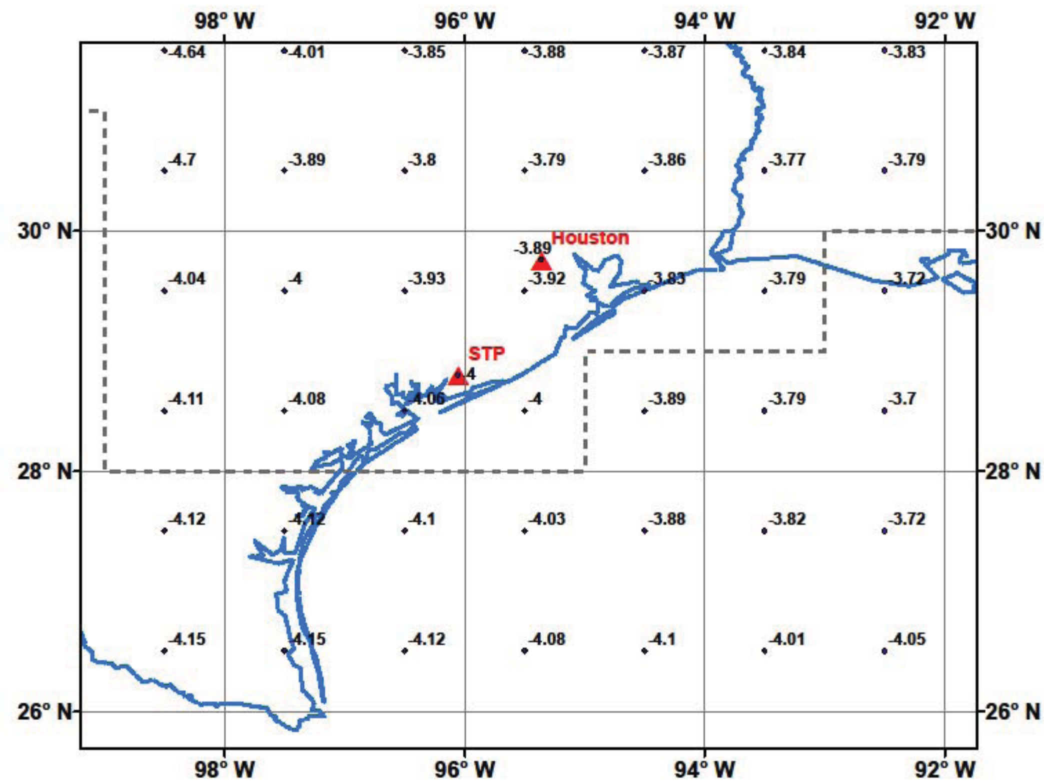

Figure 2a. Activity rates for the average of the STP-updated EPRI-SOG ESTs (Earth Science Teams), presented here by $\log_{10}N_5$, where N_5 is the averaged smooth cumulative rate of earthquakes for magnitude m_b 5 and greater per equatorial degree. Grid point spacing is 1.0 degree. The dashed line shows the southern boundary of the EPRI incompleteness regions.

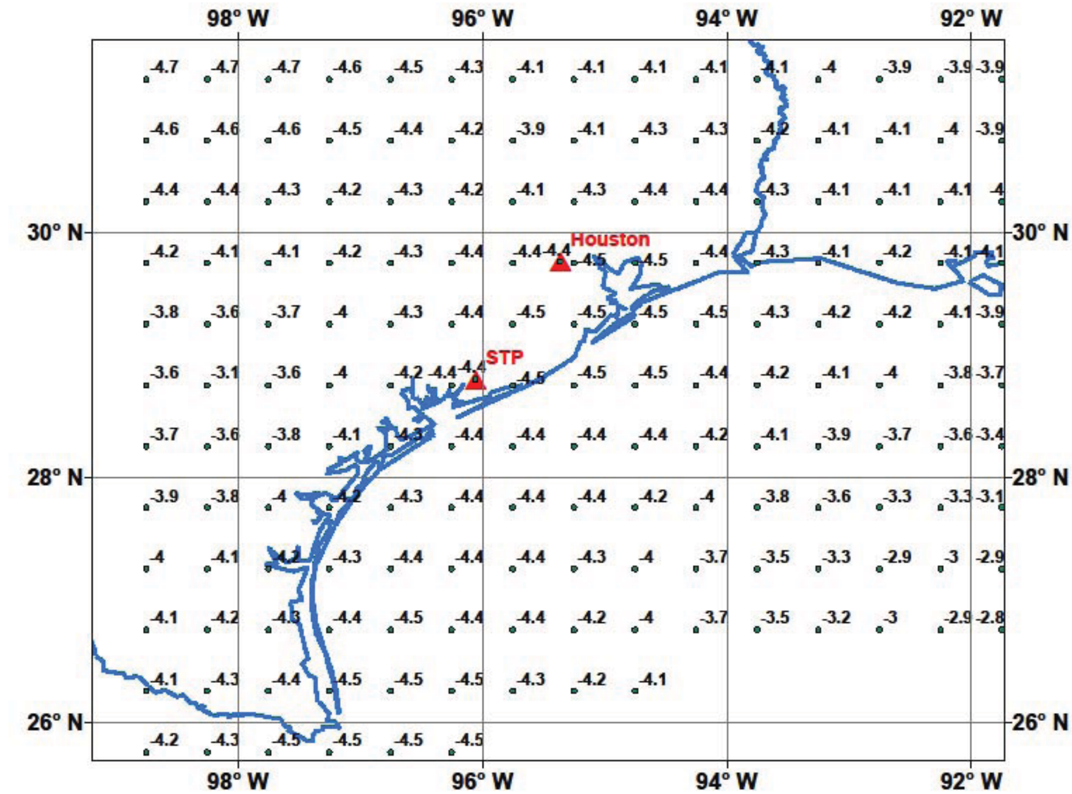

Figure 2b. Activity rates for the CEUS SSC presented here by $\log_{10}N_5$, where N_5 is the averaged smooth cumualative rate of earthquakes for magnitude M_w 5 and greater per equatorial degree. Grid point spacing is 0.5 degrees.

To emphasize this last point the numbers in Figures 2a and 2b have been normalized in Figures 3a and 3b by the Houston N_5 value. These numbers in these figures imply that N_5 varies from 22% less at STP than Houston (the STP COLA Units 3 & 4 seismic source model) to 8% higher at STP than Houston (the CEUS SSC seismic source model).

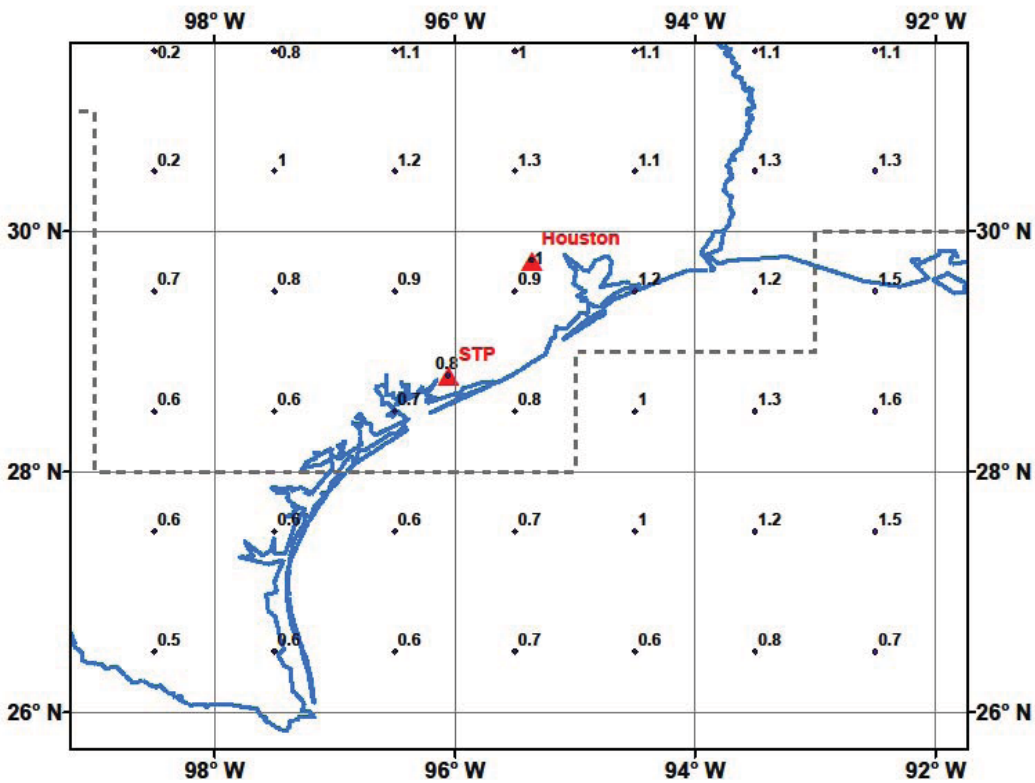

Figure 3a. Relative values of activity rates, $N_5/N_{5,Houston}$, for the STP-updated EPRI-SOG ESTs. The dashed line shows the southern boundary of the EPRI incompleteness regions.

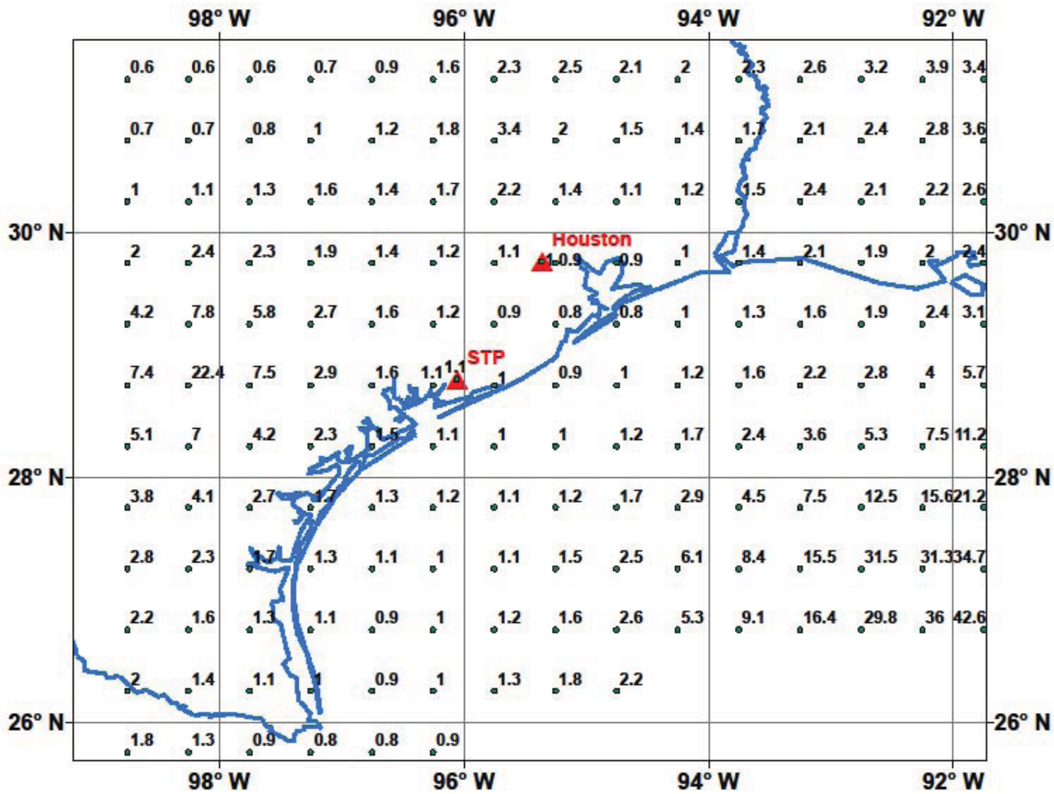

Figure 3b. Relative values of activity rates, $N_5/N_{5,Houston}$, for the CEUS SSC study.

Against this background several comparisons of earthquake hazard at the STP site and Houston may be made. These are shown in Figures 4a through 4c.

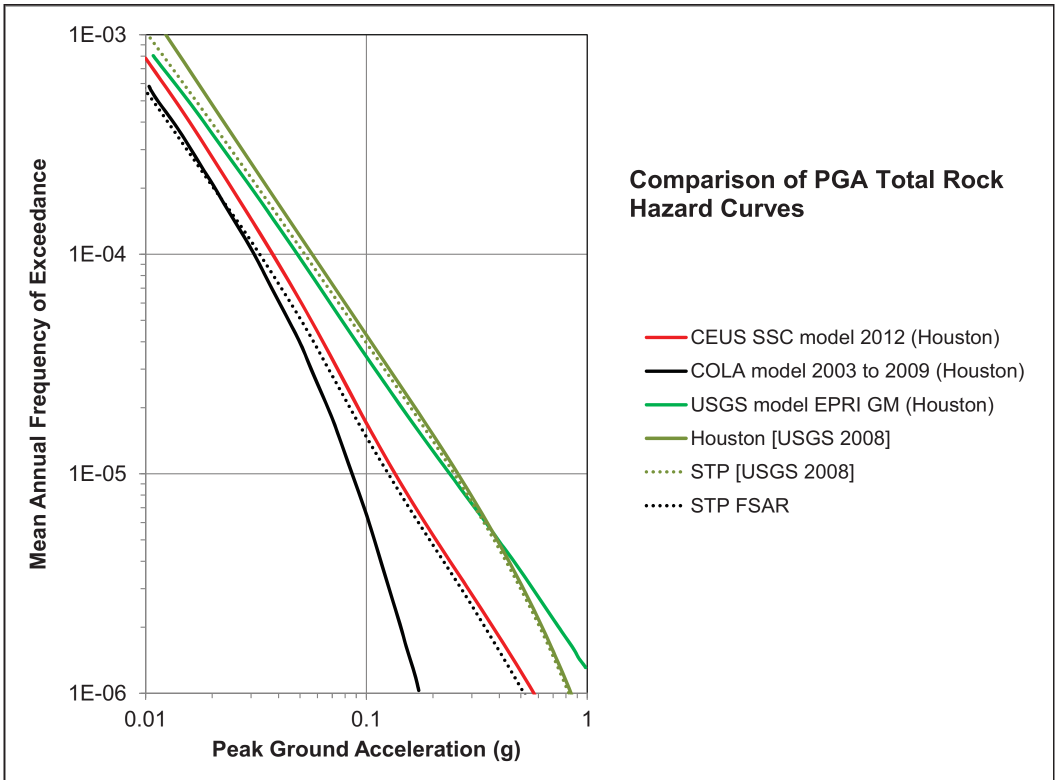

Figure 4a. PGA total rock hazard curves from CEUS SSC (Figure 8.2-3l) the STP 3 & 4 COLA, and the USGS (2008). See text for description.

Three of the PGA total rock hazard curves that are shown in Figure 4a are taken directly from the CEUS SSC report. These are all for the Houston demonstration site but using three different seismic source models. The hazard curve for Houston using the full CEUS SSC model is shown as a solid red line. This is the curve that is believed to be a good approximation of what the implementation of the full CEUS SSC model would give at the STP site. Other hazard curves from the CEUS SSC report for Houston are called “USGS Model EPRI GM” (solid green line) and the “COLA model 2003 to 2009,” (solid black line).

The basis for the USGS curve appears unambiguous. It marries the geographic and magnitude distributions of earthquakes from Petersen et al. (2008) with the ground motion prediction equations (GMPE) and updated equation uncertainties from the Electric Power Research Institute (EPRI, 2004 and 2006, respectively). The basis for the “COLA model 2003 to 2009” model is only very briefly described in the CEUS SSC report and is less unambiguous. This is discussed further below.

The remaining three hazard curves of Figure 4a are two curves developed from the 2008 USGS National Hazard Map Gridded data (Petersen et al., 2008, with digital earthquake recurrence parameter values associated with the implementation of this model cited throughout as USGS (2008) (downloaded from http://earthquake.usgs.gov/hazards/products/conterminous/2008)) for Houston (solid olive green line) and the STP site (dotted olive green line) and the hazard curve directly from the STP Units 3&4 COLA (see Figure 2.5S.2-18) (dotted black line).

A number of implications can be drawn from comparisons of these six hazard curves. First, the only intra-model [seismic source and GMPE] comparison – that of the USGS (2008) hazard curves for Houston and the STP site, shows that these curves are very close to one another, the STP curve falling slightly below the Houston curve for all PGAs. This agrees with arguments made above that hazard varies only very slowly between Houston and the STP site and that the hazard at STP would be expected to be slightly lower than at Houston given the slight decrease in a broadly smoothed regional activity rate tied to historical earthquakes (see Figures 2 and 3).

Differences between the solid green "USGS Model EPRI GM" and solid olive green USGS Houston curves reflect the effect of the different GMPEs used. Although larger than differences arising from the locations of Houston and STP these differences are still much less than the differences among the three CEUS SSC report curves. Since each of these three CEUS SSC report curves use the same GMPE characterization (and the same as is used for the STP Unit 3 & 4 COLA) their differences must arise from a combination of differences in their Gutenberg-Richter recurrence parameters and/or maximum magnitude distribution of contributing seismic sources.

The comparison of these same six curves for spectral frequencies of 10 Hz and 1 Hz are shown in Figures 4b and 4c, respectively.

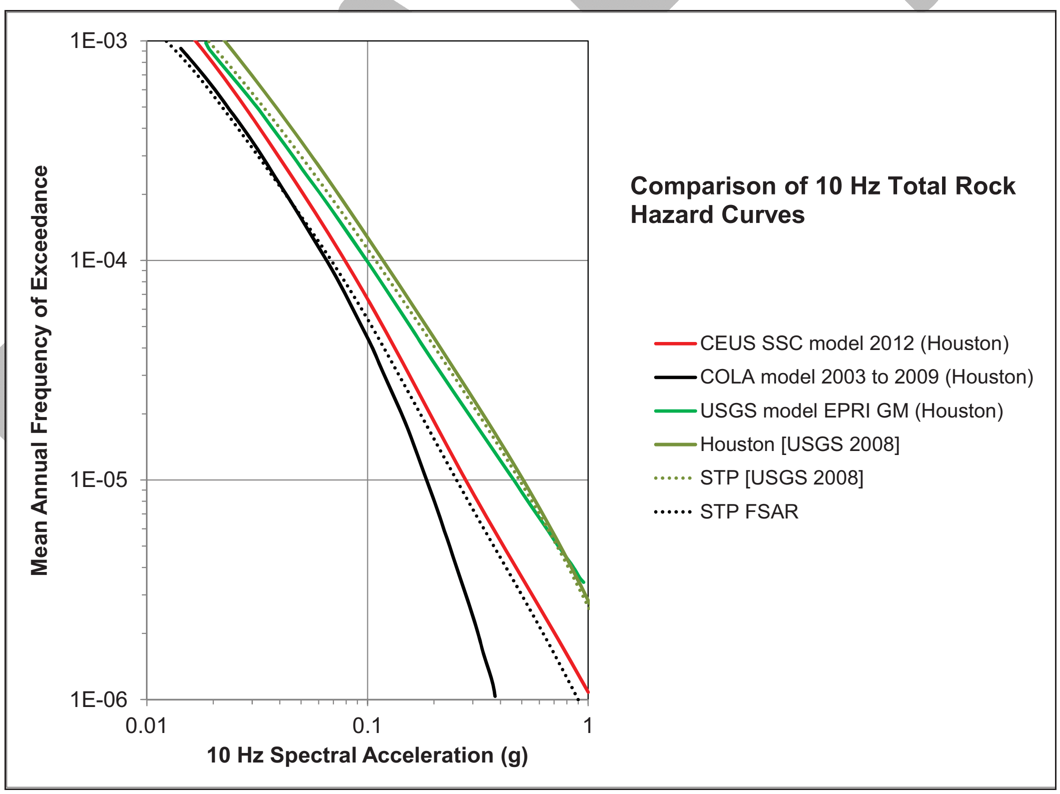

Figure 4b. 10 Hz spectral acceleration total rock hazard curves from CEUS SSC (Figure 8.2-3j) the STP 3 & 4 COLA, and the USGS (2008).

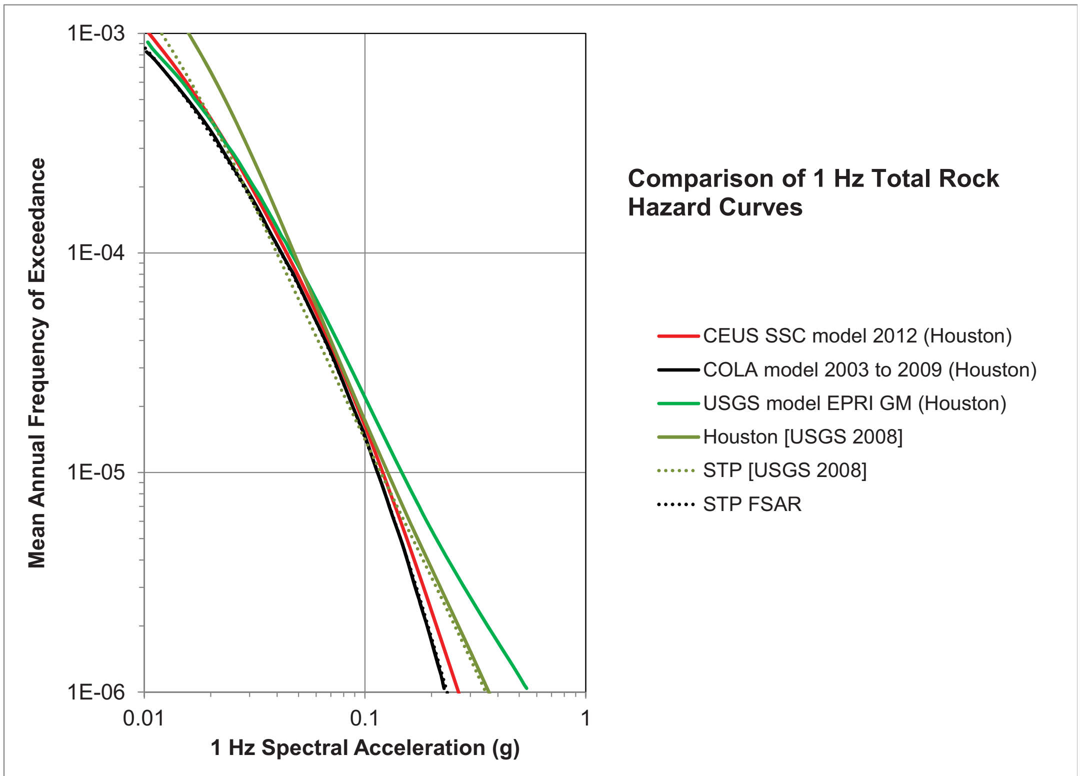

Figure 4c. 1 Hz spectral acceleration total rock hazard curves from CEUS SSC (Figure 8.2-3k) the STP 3 & 4 COLA, and the USGS (2008).

The STP Units 3 & 4 rock hazard curves [dotted black] match the shape and have lower amplitudes than the Houston demonstration site rock hazard curves using the CEUS SSC model [solid red] over the three frequencies for which a direct comparison is available and for the entire range of ground motion accelerations investigated. All curves appear to match each other better as the ground motion frequency decreases, especially in the 10^{-4} and 10^{-5} MAFE range of greatest interest for GMRS development.

Both the slow variation of earthquake recurrence parameters with location within the Houston-STP 3 & 4 region (as shown above for both the STP COLA and CEUS SSC plots of gridded $\log_{10}N_5$ or $N_5/N_{5,Houston}$ values) and the detailed STP region-specific evaluation of potential earthquake sources indicate that there are no identified potential local and regional refinements needed to the CEUS SSC model in the Houston-STP 3 & 4 region. That is, earthquake hazard would be expected to vary more slowly with specific location within this region than in a region divided by identified tectonic boundaries in the seismic source model.

Given the above observations, given that there is very little difference between Houston and STP site results in the only case where an intra-model comparison is available (the USGS, 2008 results), and given that the comparison between CEUS SSC Houston and STP Units 3 & 4 COLA results show similar ground motion hazard values for the STP Units 3 & 4 site as would be implied by the N_5 value distribution, we conclude that the CEUS SSC Houston demonstration site results provides a reasonable estimate for CEUS SSC model rock results at the STP site within the uncertainty in seismic source characterization among the several models examined.

A question remains if, in comparing the CEUS SSC "COLA model 2003 to 2009" hazard curves at Houston it is assumed that these hazards should match the hazard curves that would be generated at Houston from the seismic source model used for the STP Units 3 & 4 COLA.

As mentioned above there is very little description of the "COLA model 2003 to 2009" model in the CEUS SSC report. The report says only (NUREG-2115, 2012a, p 8.2):

> "*Figures j-l:* Comparison of mean rock hazard from three source models for 10 Hz SA, 1 Hz SA, and PGA. This comparison shows total hazard for the current CEUS SSC source model and for two other source models, all using the EPRI (2004, 2006) ground motion model. One source model is the USGS model developed for the National Seismic Hazard Mapping Project (Petersen et al., 2008). The other is the "COLA" model that has been used for nuclear power plant licensing applications since 2003. This is the EPRI-SOG (EPRI, 1988) model updated with more recent characterizations of several seismic sources. The updated New Madrid fault source (NMFS) is based on the Clinton and Bellefonte applications, and the updated Charleston seismic zone is based on the Vogtle application. Also, maximum magnitude (M_{max}) values for some seismic sources near the Gulf of Mexico coastline were updated to reflect recent seismicity. Calculations of hazard for all three models use the EPRI (2004, 2006) ground-motion equations, so the differences in hazard presented here between the three models is attributable to differences in the source models themselves."

While the "updated EPRI-SOG" model used to calculate the rock "COLA model 2003 to 2009" hazard curves is similar to the EPRI-SOG update used for the STP Units 3 & 4 COLA (both use the same updated New Madrid source characterization noted and the update of Gulf of Mexico maximum magnitudes) there is one important difference. That is, the spatial distribution of "a" and "b" values of the original EPRI-SOG model was apparently not updated to recognize that in the original EPRI-SOG model local seismicity near STP and within the Gulf of Mexico had been under-represented or simply omitted as too near or south of the boundary of the EPRI-SOG incompleteness regions, needed to specify the "a" and "b" values – see Figure 5. These issues were treated extensively in the STP Units 3 & 4 COLA and remedied – see FSAR Sections 2.5S.2.1.5 and 2.5S.2.4.2.2.

A critical comparison of the seismic activity rates of the original EPRI-SOG (Figure 5) with those of the STP-updated activity rates (Figure 2a) shows for the original EPRI-SOG not only the obvious empty grid points of seismic activity values in the near offshore of the Gulf of Mexico, but in the immediate vicinity of both Houston and STP the $\log_{10}N_5$ values are slightly higher [less negative] for the updated EPRI-SOG characterization in Figure 2a. Therefore, for the updated EPRI-SOG model of the Gulf of Mexico seismic sources, not only were empty grid points of seismic activity filled in, but following re-evaluation of the smoothed activity rates, the grid points of activity rate for the updated EPRI-SOG model used at STP show slightly greater activity rates than in the original EPRI-SOG model.

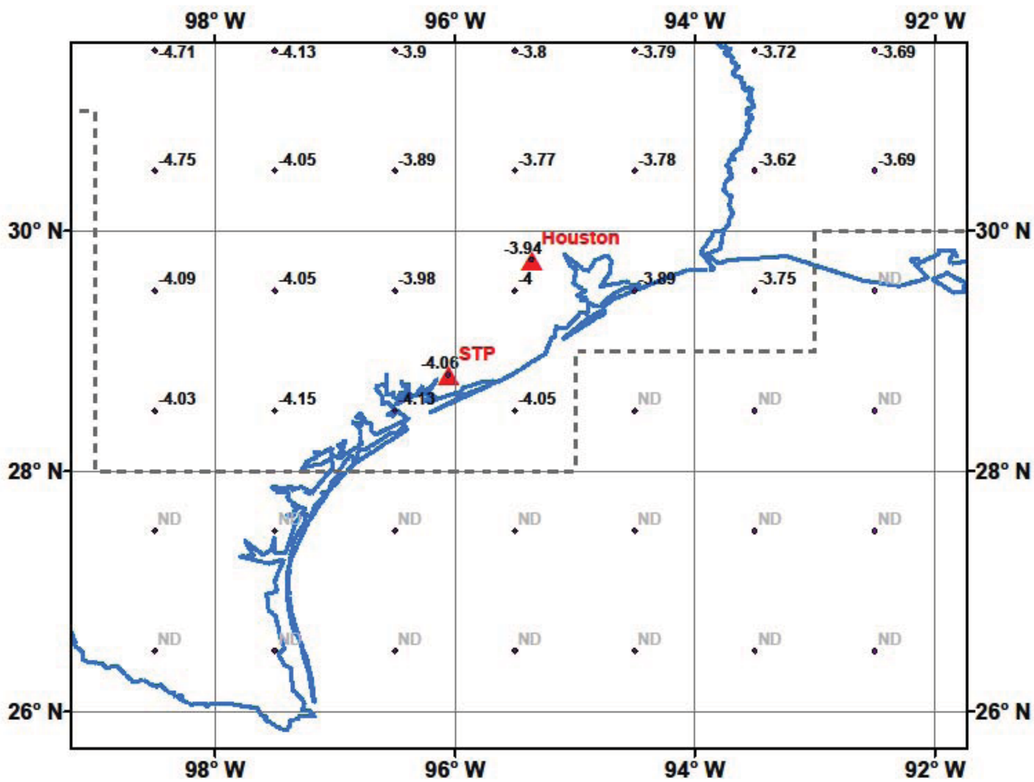

Figure 5. Activity rates for the average of the original EPRI-SOG ESTs, presented here by $\log_{10}N_5$, where N_5 is the averaged smooth cumulative rate of earthquake for magnitude m_b 5 and greater per equatorial degree. Grid point spacing is 1.0 degree. “ND” indicates no data at that grid point. The dashed line shows the southern boundary of the EPRI incompleteness regions.

Therefore, the curves characterized in the CEUS SSC report as “COLA model 2003 to 2009” hazard curves for Houston are not updated to the degree of the updated EPRI-SOG model used for the STP Units 3 &4 COLA. This difference would be expected to, and apparently does, affect high frequencies (that are contributed by moderate nearby earthquakes in the model) much more than lower spectral frequencies (that are much more dominated by the large magnitude, distant New Madrid source that is the same in both updates).

The CEUS SSC PSHA calculations use a minimum moment magnitude, M_w, of 5.0 for the Houston demonstration site spectral acceleration values satisfying the minimum magnitude specifications outlined in Attachment 1 to Seismic Enclosure 1 of the March 12, 2012 letter, "Request for information pursuant to Title 10 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1, 2.3, and 9.3, of the near-term task force review of insights from the Fukushima Dai-Ichi accident," (NRC 2012b).

Houston rock spectral acceleration values from the CEUS SSC report must be modified to consider subsurface material properties like those found at the STP Units 3 & 4 site in order to make an in-kind comparison of the GMRS. The STP 3 & 4 site is underlain by soils to depths of many thousands of feet and is, therefore, characterized as a deep soil site. The STP 3 & 4 COLA calculates site-specific factors for the amplification of the base hard rock motion by the subsurface soil column. These factors are 1.2 for 10 Hz, 3.0 for 1 Hz, and 1.7 for 100 Hz (PGA). The CEUS SSC study develops site amplification factors for a generic "deep soil" site and so approximately characterizes Houston.

Comparison of the generic deep soil subsurface material properties and amplification factors from the CEUS SSC report with the subsurface material properties and amplification factors from the STP 3 & 4 COLA at frequencies of 10 Hz, 1 Hz, and 100 Hz (PGA) shows that the CEUS SSC amplification factors are somewhat lower (approximately 0.9 for 10 Hz, 2.6 for 1 Hz, and 1.4 for 100 Hz [CEUS SSC report Figure 8.1-5]). Because the hard rock motion amplitudes for Houston and the STP 3 & 4 site are similar, and the STP 3 & 4 COLA amplification factors are site-specific, the STP 3 & 4 COLA amplification factors are used to estimate the CEUS SSC-based site-specific GMRS.

Using the procedure recommended in RG 1.208 (NRC 2007) (as defined in STP 3 & 4 COLA Section 2.5S.2.6) to develop GMRS spectra from 10^{-4} and 10^{-5} MAFE hazard curves, a hard rock "GMRS" was developed from the three CEUS SSC Houston rock curves and the additional 30 Hz point scaled from a STP 3 & 4 COLA hard rock "GMRS" 100 Hz-to-30 Hz ratio. Again, these values were then used as close approximations to (and likely conservative for) a CEUS SSC equivalent rock GMRS at the STP 3 & 4 site.

Next, these four points were scaled by the STP FSAR site-specific amplification factors to get approximate CEUS SSC STP Units 3 & 4 site GMRS points. These points are shown in Figure 6 along with the STP Units 3 & 4 COLA GMRS spectrum. The figure shows that the estimated CEUS SSC STP Units 3 & 4 GMRS points developed in this way are very close to, and not significantly above, the STP 3 & 4 COLA points.

Lastly, also shown in Figure 6 is the STP 3 & 4 site-specific SSE. This design spectrum envelops both of the other spectra.

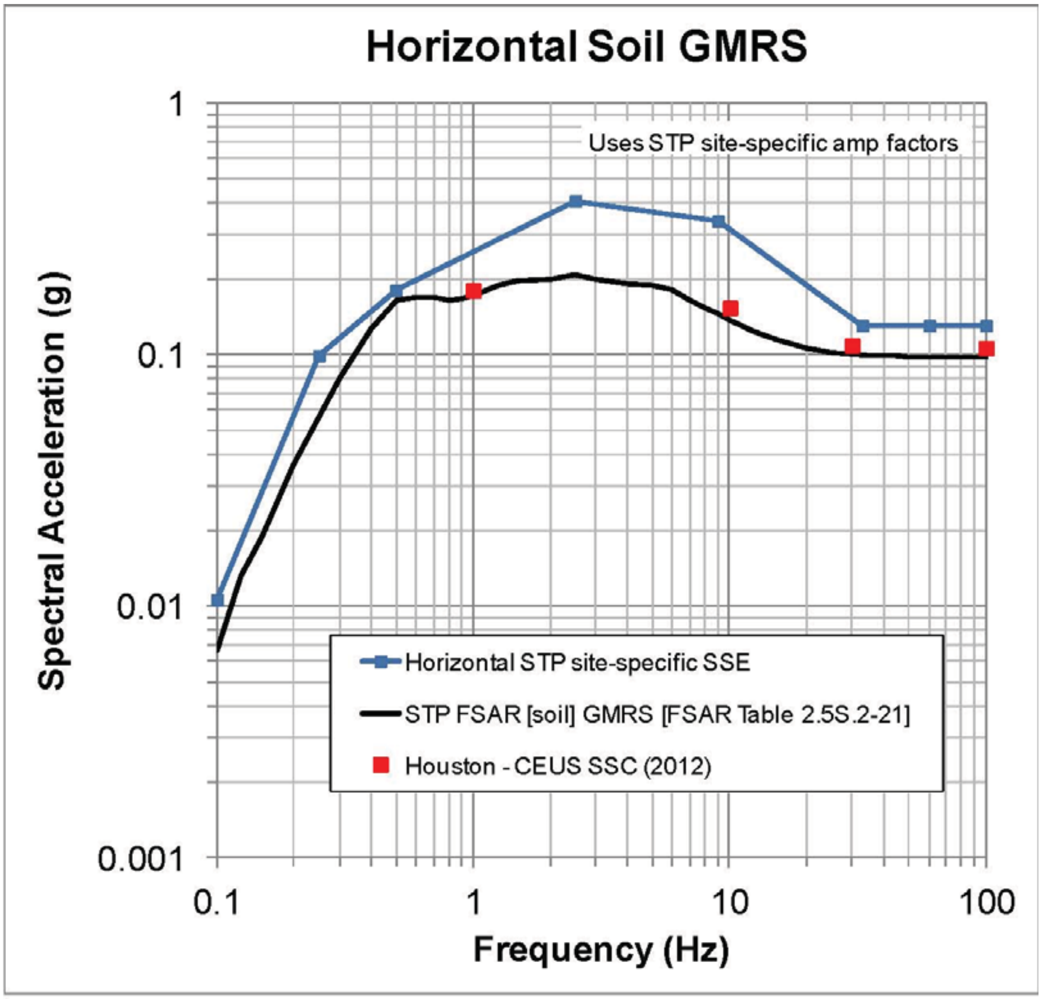

Figure 6. Comparison of the horizontal STP site-specific SSE, the STP 3 & 4 COLA GMRS (from FSAR Table 2.5S.2-21), and the 2012 Houston CEUS SSC GMRS.

Therefore, on the basis of this evaluation, it is concluded that implementation of the CEUS SSC model for the STP 3 & 4 site would be expected to result in similar or slightly higher GMRS motions than predicted in the FSAR, but that this difference is not significant because it is within reasonably expected uncertainty in the characterization of seismic hazard. In addition, and as shown in Figure 6, both the existing STP 3 & 4 COLA results and the estimated CEUS SSC results for the STP sites are enveloped by the SSE design spectrum.

b) Because the STP 3 & 4 COLA results and the estimated CEUS SSC results for the STP site are not significantly different, this investigation found no reason to revise the seismic design basis in the STP 3 & 4 COLA based on an implementation of the CEUS SSC (NUREG-2115) model.

No COLA revision is required as a result of this RAI response.

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