FPL

L-2012-002

10 CFR 52.3

January 10, 2012

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Re: Florida Power & Light Company
Proposed Turkey Point Units 6 and 7
Docket Nos. 52-040 and 52-041
Response to NRC Request for Additional Information Letter No. 037
(eRAI 5896) SRP Section - 02.05.02 Vibratory Ground Motion

Reference:

1. NRC Letter to FPL dated September 29, 2011, Request for Additional Information Letter No.037 Related to SRP Section 02.05.02 - Vibratory Ground Motion for the Turkey Point Nuclear Plant Units 6 and 7 Combined License Application
2. FPL Letter to NRC dated October 31, 2011, Response and Response Schedule to NRC Request for Additional Information Letter No. 037 (eRAI 5896) SRP Section - 02.05.02 Vibratory Ground Motion
3. FPL Letter to NRC dated November 30, 2011, Response and Revised Response Schedule to NRC Request for Additional Information Letter No. 037 (eRAI 5896) SRP Section - 02.05.02 Vibratory Ground Motion

Florida Power & Light Company (FPL) provides, as an attachment to this letter, its response to the Nuclear Regulatory Commission's (NRC) Request for Additional Information (RAI) 02.05.02-4 provided in Reference 1. FPL provided an initial schedule for the response to RAI 02.05.02-4 in Reference 2 and provided a revised schedule for the response to RAI 02.05.02-4 in Reference 3. The attachment identifies changes that will be made in a future revision of the Turkey Point Units 6 and 7 Combined License Application (if applicable).

If you have any questions, or need additional information, please contact me at 561-691-7490.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on January 10, 2012

Sincerely,

William Maher

Senior Licensing Director – New Nuclear Projects

WDM/RFB

D097
NRO

Attachment: FPL Response to NRC RAI No. 02.05.02 -4 (eRAI 5896)

cc:

PTN 6 & 7 Project Manager, AP1000 Projects Branch 1, USNRC DNRL/NRO
Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, Turkey Point Plant 3 & 4

NRC RAI Letter No. PTN-RAI-LTR-037

SRP Section: 02.05.02 - Vibratory Ground Motion

Question for Geosciences and Geotechnical Engineering Branch 1 (RGS1)

NRC RAI Number: 02.05.02-7 (eRAI 5896)

FSAR Subsection 2.5.1.1.1.3.2.4 describes that due to lack of knowledge about individual faults' characteristics, the applicant used an areal source zone to model the seismic hazard from the Cuban seismic sources. In accordance with NUREG-0800, Standard Review Plan, Chapter 2.5.2, "Vibratory Ground Motion," and Regulatory Guide (RG) 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," please provide the following:

a. Rationale for the exclusive use of an areal source rather than multiple areal sources or a combination of fault sources and areal sources. Given the uncertainties, does the use of a single areal source result in a more conservative representation of the hazard from the Cuba seismic sources?

b. Details of the PSHA implementation for the Cuba areal source zone. Specifically, is Cuba seismicity modeled using the EPRI approach, using a uniform source zone, or using some other methodology?

c. A description of how well the seismic source model parameters represent the observed spatial patterns and concentrations of seismicity. Is a uniform seismic source zone justified considering FSAR Figure 2.5.1-267, which shows prominent clusters of seismicity? Discuss evidence, if any, that frequency-magnitude behavior is different for the subset of earthquakes concentrated in western and northern Cuba than for the entire zone.

d. Details on the earthquake catalog completeness, methodology used to compute the *a* and *b* values, the computed *a* and *b* values and rates of earthquakes equal to or greater than moment magnitude 5. If used, please also discuss smoothing operators applied to the a and b values.

e. A detailed description of the PSHA implementation for the Cuba seismicity model. Are large earthquakes modeled as finite faults? If so, can they extend outside the zone boundary, and is there a preferred azimuth? If so, what is their closest distance of approach to the TPNPP site?

FPL RESPONSE:

a) <u>Rationale for the exclusive use of an areal source rather than multiple areal sources or a combination of fault sources and areal sources. Given the uncertainties, does the use of a single areal source result in a more conservative representation of the hazard from the Cuba seismic sources?</u>

The inclusion of individual faults as sources for use in a Probabilistic Seismic Hazard Analysis (PSHA) requires some knowledge of each proposed fault source's activity, geometry, maximum magnitude (Mmax), and earthquake recurrence. The decision to model intraplate Cuba as a single areal source, as opposed to multiple fault sources or a combination of fault and areal sources, is based on the lack of sufficient information for individual faults in Cuba with which to characterize fault source parameters. FPL's response to RAI 02.05.01-21 (FPL Letter No.L-2012-001) provides detailed information regarding the decision to model intraplate Cuba as a single areal source zone.

If fault sources were to be incorporated, significant uncertainties and a lack of constraining data for key seismic source parameters would lead to a very speculative seismic source characterization for intraplate Cuba. The lack of adequate data to evaluate and characterize faults as potential seismic sources within Cuba has motivated modelers of Cuban seismic hazard to remove fault sources in recent PSHA studies Garcia et al. (2008) (FSAR 2.5.2 Reference 255). These concepts are described in FSAR subsection 2.5.2.4.4.3.2.1 and additional details are provided in FPL 's response to RAI 02.05.01-21 (FPL Letter No. L-2012-001).

Without running a significant number of alternative scenarios made up of combinations of areal and fault sources, it would be difficult to confidently assume that the single areal source characterization of Cuba provides a conservative representation of the hazard. However, as part c) of this response illustrates, assuming a higher rate of seismicity for the entire Cuba areal source zone yields insignificant differences in hazard at the site.

b) <u>Details of the PSHA implementation for the Cuba areal source zone. Specifically, is Cuba seismicity modeled using the EPRI approach, using a uniform source zone, or using some other methodology?</u>

Intraplate Cuba was modeled as a single areal source zone with spatially uniform seismicity (total rate (M $\geq$5.0) = 0.0592, β = 1.932). An exponential magnitude model was assumed with a maximum moment magnitude distribution [and weights] of M 7.0 [0.5] and M 7.25 [0.5].

c) <u>A description of how well the seismic source model parameters represent the observed spatial patterns and concentrations of seismicity. Is a uniform seismic source zone justified considering FSAR Figure 2.5.1-267, which shows prominent clusters of seismicity? Discuss evidence, if any, that frequency-magnitude behavior is different for the subset of earthquakes concentrated in western and northern Cuba than for the entire zone.</u>

The Cuba areal seismic source was modeled by assuming a uniform rate for the entire zone. An exponential frequency-magnitude distribution of the Gutenberg-Richter form Log(N) = a – b(M), where N is the number of events greater than or equal to magnitude M, was fit to the observed seismicity using the maximum likelihood technique. The a-value reflects the overall activity rate, and the b-value indicates relative number of small to large magnitudes. This approach produces a uniform rate of seismicity within the areal zone and does not account for local increases in rate associated with areas of more concentrated or "prominent clusters" of seismicity.

However, if the Cuba areal source zone were to be subdivided in an attempt to preserve areas with higher rates of earthquake occurrence, this would also result in areas of lower rates than the average uniform rate applied to the Cuba areal source zone. In particular, the offshore region of the Cuba areal source nearest the Turkey Point Units 6 & 7, which is nearly devoid of seismicity (FSAR Figure 2.5.2-217 and Figure 1), would likely generate little or no hazard. Therefore, this modification may result in a less conservative characterization if the reduction in hazard from the nearest portion of the zone is greater than any increases in hazard from more distant areas of higher seismicity in Cuba. This point is illustrated by inspection of FSAR Figure 2.5.2-227, which shows the M and R deaggregation for 5 and 10 Hz for the 10^{-4} uniform hazard response spectrum (UHRS). The Cuba areal source contribution to the site hazard appears in the M 6.5 to 7.5 range and abruptly begins appearing in the 210 to 240 kilometer (130 to 150 mile) distance bin and beyond. The closest distance from the site to the Cuba areal source is approximately 220 kilometers (140 miles).

The project Phase 2 earthquake catalog exhibits a non-uniform distribution of seismicity across Cuba, with higher concentrations of earthquakes occurring in the western, north-central, and southeastern portions of the island. To address the impact of different rates resulting from alternative zonation schemes within the Cuba areal source, a Northern Subzone zone encompassing the north-central and western seismicity was defined. This area of higher seismicity is used to illustrate the potential impact on hazard if different rates or zonation schemes were used to model the Cuba source. Recurrence statistics were computed for this subzone by calculating the annual rate of M ≥ 3 earthquakes in the zone, and assuming that the previously calculated b-value for the Cuba areal source zone represents the most stable estimate. The annual rates of M 5 to 7.3 earthquakes from the two zones were then compared.

Figure 2 shows seismicity from the project Phase 2 catalog, the boundaries of the Cuba areal source zone, and the Northern Subzone. Before computing recurrence for the Cuba areal source zone, the earthquakes in Figure 2 were filtered to account for the completeness periods published in Garcia et al. (2008) (FSAR 2.5.2 Reference 255). Figure 3 shows the resulting earthquakes after filtering. The number of earthquakes has decreased, but the general pattern of concentrated or "spatially clustered" seismicity remains.

Maximum likelihood recurrence parameters were computed for the Cuba areal source zone, using the Weichert (1980) formulation, and the earthquakes filtered for completeness periods (Figures 1 and 3). The b-value for the Northern Subzone is assumed equivalent to that for the Cuba areal source zone, and the a-value is computed from the annual rate of M ≥ 3 events in the subzone. The a-value, or the rate level parameter, has been normalized to the cumulative value per square kilometer per year, to permit a comparison normalized to a common area.

Table 1 lists the recurrence statistics for the two zonation scenarios. The last column provides the computed rate of M 5 to 7.3 earthquakes on a square kilometer per year basis, which allows for direct comparisons of the rates of earthquakes producing ground motions at the site. The ratio of the Northern Subzone rate to the rate for Cuba areal source zone is shown in parentheses.

Table 1. Cuba Areal Zone and Northern Subzone recurrence parameters

Zone	Zone area (km^2)	a-value	b-value	# Events M ≥ 3 per year	# Events M ≥ 3 per year per km^2	Rate* of M 5 – 7.3 events per year per km^2
Cuba	250,286	2.967	0.839	2.820	1.127×10^{-5}	2.338×10^{-7}
North Subzone	81,268.55	n/a	0.839	1.013	1. 247 x 10-5	2. 587 x 10-7 (1.106)**

* Normalized to per year/km^2
** value in parentheses represents the 10.6% increase discussed in text

Table 1 shows that the rate for the Northern Subzone is 10.6% greater than the rate used for the Cuba areal source zone, on a per square km basis. Using the deaggregated PSHA results, which include the total and Cuba areal source zone contribution for a set of response periods, it is possible to compute how much the total hazard would increase if the Cuba areal source zone rate were increased by 11% (rounded from 10.6%), and then the 10,000 year UHRS.

Table 2 shows the effect of the 11% rate increase, for the seven response frequencies, on the total hazard for an annual frequency of exceedance (AFE) of 1/10,000 (the 10,000 year UHRS). Column 3 shows that the increase in AFE at the original ground motion level, corresponding to the 10,000 year UHRS, ranges between 0.5 and 3.4%. However, the increase in 10,000 year ground motion ranges between 0.2 and 1.4%. The absolute increases in 10,000 UHRS are very small, ranging between 0.0001 and 0.0009 g.

Table 2. Increase in 10,000-yr UHRS assuming 11% Increase in Cuba Areal Zone Rate

Frequency (Hz)	10,000-yr Base UHRS amplitude (g)	AFE % Increase in base 10,000-yr UHRS	Hypothetical 10,000-yr UHRS amplitude (g)	% Increase in 10,000-yr UHRS amplitude	Increase in amplitude of 10,000-yr UHRS (g)
0.5	0.0267	0.7	0.0268	0.2	0.0001
1.0	0.0343	1.6	0.0345	0.5	0.0002
2.5	0.0499	3.2	0.0504	1.1	0.0005
5	0.0661	3.4	0.0670	1.4	0.0009
10	0.0822	2.3	0.0832	1.1	0.0009*
25	0.1039	0.5	0.1042	0.3	0.0003
PGA	0.0399	1.5	0.0402	0.7	0.0003

*Subtracting column 2 from column 4 would appear to yield 0.001, however, the correct value of 0.0009 is obtained from spreadsheet, which used greater numerical precision.

Table 2 shows that if the Cuba areal source zone rate were conservatively increased by 11%, the AFE for the original 10,000 UHRS would increase at most by 3.4%, and the increase in 10,000 year UHRS would only slightly exceed 1% for 2.5, 5, and 10 Hz response frequency (1.1, 1.4 and 1.1%, respectively). More importantly, the ground motion increases would be very small, less than 0.001 g at all frequencies.

While different schemes for subdividing the Cuba areal source zone would result in some areas having greater rates than initially modeled for the single areal source zone, the conservative application of an 11% greater rate to the entire zone outlined above illustrates that these types of model changes would likely yield insignificant differences in hazard at the site.

The impact of an increase in rate for the Cuba areal source zone would be even smaller for UHRS at AFE of 10^{-5} and 10^{-6}, since the contribution from the Cuba areal source is much smaller for these AFE. Deaggregation plots for 5 and 10 Hz indicate that the Cuba source contribution, which appears in the magnitude range of M 6.0 to 7.5 and distance range of 210 to 480 kilometers (130 to 300 miles) on FSAR Figure 2.5.2-227, is much less significant for annual frequencies of 10^{-5} and 10^{-6} (FSAR Figures 2.5.2-229 and 2.5.2-231).

d) Details on the earthquake catalog completeness, methodology used to compute the *a* and *b* values, the computed *a* and *b* values and rates of earthquakes equal to or greater than moment magnitude 5. If used, please also discuss smoothing operators applied to the a and b values.

Completeness periods for Cuba were taken directly from Garcia et al. (2008) (FSAR 2.5.2 Reference 255). These are shown in the first three columns of Table 3. The number of earthquakes in each magnitude bin, taken from the project Phase 2 earthquake catalog and filtered for these completeness periods, is shown in the last column.

Table 3: Completeness periods from Garcia et al. (2008) (FSAR Reference 2.5.2-255), and event counts in each bin

Magnitude Range	Start Date	End Date	Number of Earthquakes
3.0 – 4.0	1/1960	3/2008	119
4.0 – 5.0	1/1940	3/2008	17
5.0 – 6.0	1/1850	3/2008	14
6.0 – 7.0	1/1500	3/2008	2

The objective is to solve for *a* and *b* in the Gutenberg-Richter equation for earthquake recurrence equation,

$$Log(N) = a - b(M) \qquad (1)$$

where *N* is the cumulative number of earthquakes greater than or equal to magnitude *M*.

As presented in McGuire (2004), p. 190, Eq. A5, the maximum likelihood estimate for b is

$$Mbar = \frac{\sum_i t_i m_i e^{-\beta m_i}}{\sum_i t_i e^{-\beta m_i}} \qquad (2)$$

where Mbar is the average magnitude of the data, t is the completeness duration in years, i corresponds to the magnitude bin, and β = b x ln(10). *m* refers to the midpoint of the magnitude range. This is also the formulation presented in Weichert (1980). β in equation (2) is solved for using Newton's method, as suggested in Weichert (1980). The convergence criterion for β is when the difference in β between successive iterations falls below 0.0001.

Weichert (1980) defines Na as the cumulative number of events at and above the minimum magnitude. His equation (10) (also McGuire (2004), p. 191, Eq. A9), states:

$$Na = N \frac{\sum_i e^{-\beta m_i}}{\sum_i t_i e^{-\beta m_i}} \qquad (3)$$

where N is the total number of events in the data set, Na is the number of events above the minimum per annum. Once Na is determined, a can be solved via Equation (1).

The results are:

b = 0.839

Na = 2.821

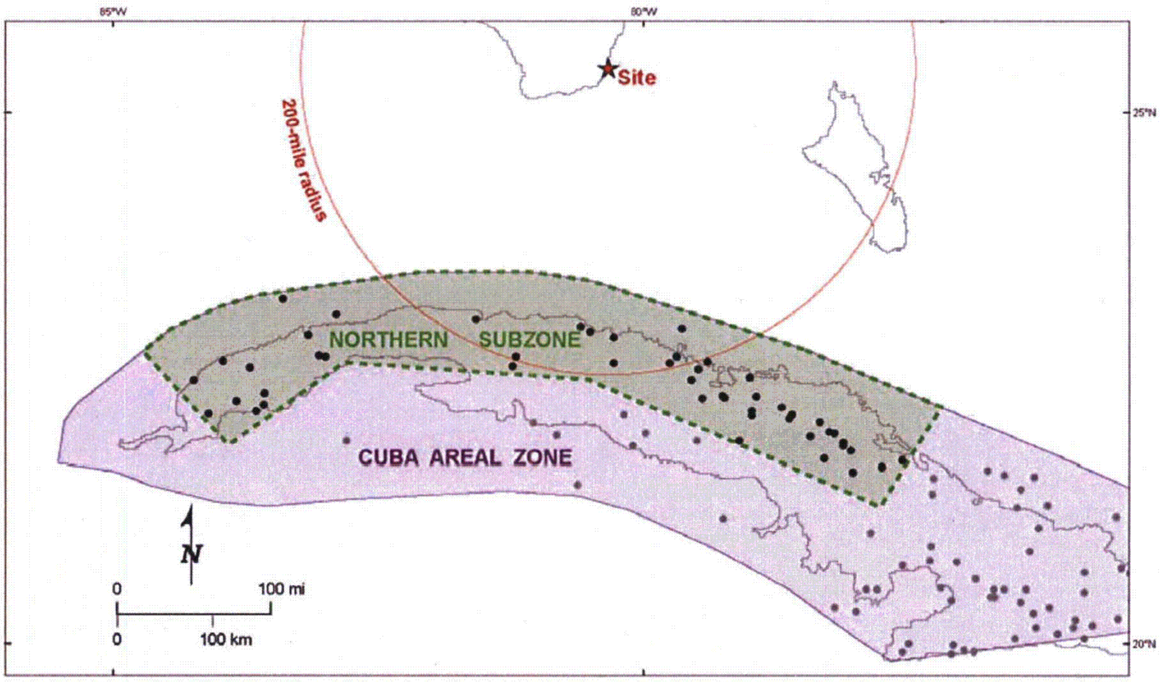
a = 2.967

From Equation (1), the number of events greater that equal to M 5 per year is 0.059. This equates to a return period of 17 years for earthquakes in this magnitude range. No smoothing operators were applied to the a and b values.

e) A detailed description of the PSHA implementation for the Cuba seismicity model. Are large earthquakes modeled as finite faults? If so, can they extend outside the zone boundary, and is there a preferred azimuth? If so, what is their closest distance of approach to the TPNPP site?

Earthquakes are modeled as point sources in the Cuba areal source zone, therefore ruptures do not extend outside the zone boundary and there is no preferred azimuth. The closest distance from the Turkey Point Units 6 & 7 site to the Cuba areal source is approximately 220 kilometers (140 miles).

Figure 1 - Seismicity Within the Cuba Areal Zone and the Northern Subzone Used to Assess Differences in Earthquake Rate on Site Hazard.



Note: The earthquakes shown here and also in Figure 3 represent events used to calculate rates. These events were filtered from the project Phase 2 catalog based on completeness periods.

Figure 2 - Cuba Areal Zone (red), Northern Subzone (green), with Events $M_w \geq 3$ from the Project Phase 2 Earthquake Catalog.

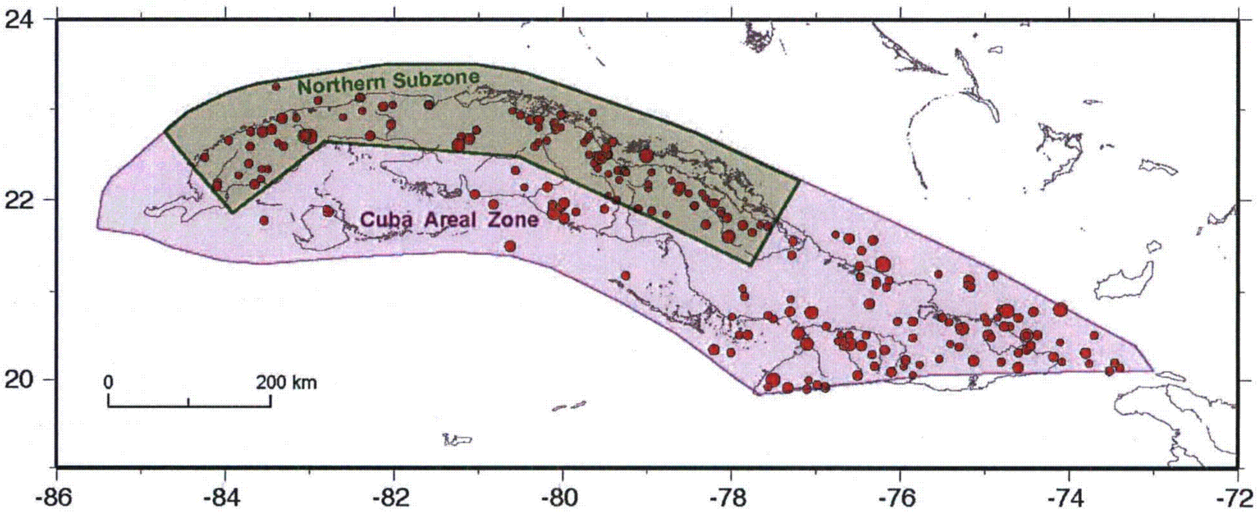
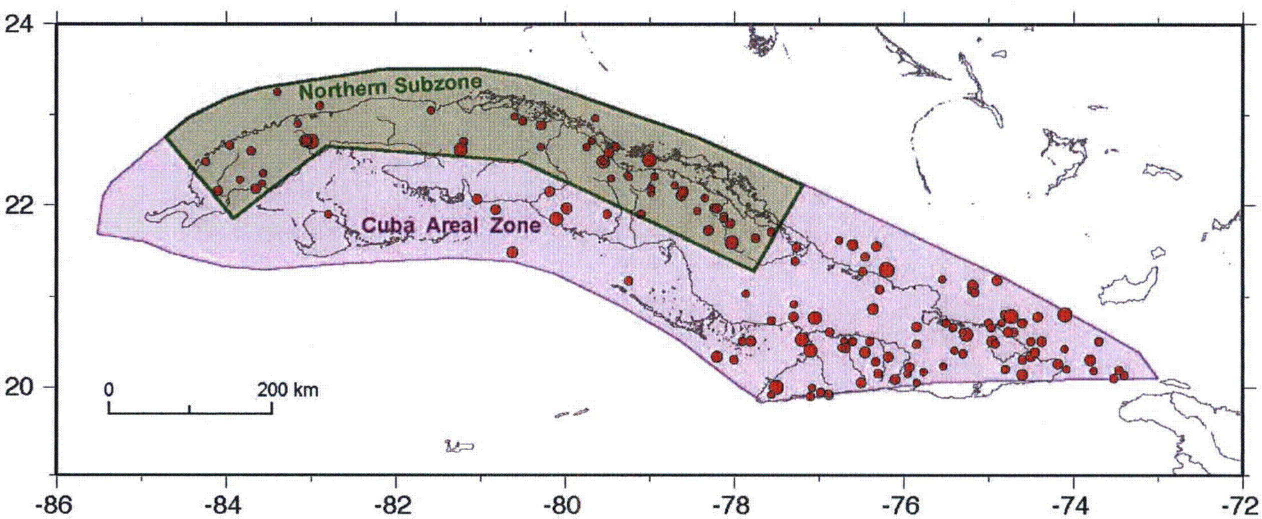


Figure 3 - Cuba Areal Zone (red). Northern Subzone (green), with Phase 2 Earthquake Catalog Events Filtered for Completeness Periods.



Note: These events, which are also shown in Figure 1, represent a subset of those shown in Figure 2.

This response is PLANT SPECIFIC.

References:

FPL Letter L-2012-001 dated January 3, 2012 to NRC, Response to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information

McGuire, R.K. (2004), Seismic Hazard Analysis, Earthquake Engineering Research Institute Monograph MNO-10, 221 pp.

Weichert, D. (1980), Estimation of the earthquake recurrence parameters for unequal observation periods for different magnitudes, Bulletin of the Seismological Society of America, 70, 1337-1347.

ASSOCIATED COLA REVISIONS:

None

ASSOCIATED ENCLOSURES:

None