Progress Energy

Serial: NPD-NRC-2009-147
July 22, 2009

10CFR52.79

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

LEVY NUCLEAR POWER PLANT, UNITS 1 AND 2
DOCKET NOS. 52-029 AND 52-030
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 047 RELATED TO PROBABLE MAXIMUM TSUNAMI FLOODING

Reference: Letter from Brian C. Anderson (NRC) to Garry Miller (PEF), dated May 20, 2009, "Request for Additional Information Letter No. 047 Related to SRP Section 2.4.6 for the Levy County Nuclear Plant, Units 1 and 2 Combined License Application"

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits our response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter.

A response to the NRC request is addressed in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Levy Nuclear Power Plant Units 1 and 2 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (919) 546-6107.

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

Executed on July 22, 2009.

Sincerely,

Garry D. Miller
General Manager
Nuclear Plant Development

Enclosure

cc : U.S. NRC Region II, Regional Administrator
Mr. Brian C. Anderson, U.S. NRC Project Manager

Progress Energy Carolinas, Inc.
P.O. Box 1551
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NRO

**Levy Nuclear Power Plant Units 1 and 2
Response to NRC Request for Additional Information Letter No. 047 Related to
SRP Section 2.4.6 for the Combined License Application, dated May 20, 2009**

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.04.06-1	L-0342	Response enclosed – see following pages
02.04.06-2	L-0343	Response enclosed – see following pages
02.04.06-3	L-0344	Response enclosed – see following pages
02.04.06-4	L-0345	Response enclosed – see following pages
02.04.06-5	L-0346	Response enclosed – see following pages
02.04.06-6	L-0347	Response enclosed – see following pages
02.04.06-7	L-0348	Response enclosed – see following pages
02.04.06-8	L-0349	Response enclosed – see following pages
02.04.06-9	L-0350	Response enclosed – see following pages
02.04.06-10	L-0351	Response enclosed – see following pages

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-1

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.1 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to determination of the PMT. This includes a discussion of the most reasonably severe geo-seismic activity possible and corresponding tsunami analysis. Please provide a discussion in the updated FSAR of the PMT assessment for the Levy County site, including the controlling source for the PMT and corresponding tsunami water level determination, or explain why such a discussion is not necessary.

PGN RAI ID #: L-0342

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including discussion of historical tsunami, their sources, and their potential impacts to the LNP site, is presented in LNP FSAR Subsection 2.4.6. LNP FSAR Subsection 2.4.6 also discusses several hypothetical but plausible tsunami-generating earthquakes and landslides and their predicted tsunami water levels based on the available literature.

RAI 02.04.06-8 provides a complete description of the analysis procedure used to calculate tsunami wave height at the site, including a discussion of the most reasonably severe geo-seismic activity possibly affecting the LNP site.

RAI 02.04.06-10 provides run-up and run-in values coincident with 10 percent exceedance high tide, sea level anomaly, and the long-term sea level rise. Based on the analysis presented in RAI 02.04.06-10, it is clear that the controlling source for the PMT is a landslide of the type that occurred in the Mississippi Canyon about 7000 years ago. In general, the size of landslide tsunami depends strongly on the volume of the landslide and its sliding speed. As shown in RAI 02.04.06-10, the Mississippi Canyon Slide volume (428 cubic km) is about 20 times larger than any other known slide in the Gulf of Mexico. Based on the results discussed in RAI 02.04.06-10, if a Mississippi Canyon-like slide were to happen again and move down slope at a velocity of 50 m/s (164 ft/s), run up and run-in values for this PMT event are predicted to be at 23.5 m (77.1 ft) NAVD88 and 2.19 km (1.36 mi), respectively.

It should be noted that tsunami waves decay in size as they run-in over land and that the LNP site is 7.9 miles inland from the Gulf of Mexico coastline. As shown in RAI 02.04.06-10, even for the extreme PMT noted above, it is estimated that the wave inundation region will not extend more than 1.36 miles from the coastline - far short of the LNP site. Therefore, the LNP site would not be affected by the very rare and extreme PMT event described above. Smaller landslide and earthquake-generated tsunamis might occur during the anticipated 60-year life span of the plant, but the site would have an even lower likelihood of being affected due to their smaller size.

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-2

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.1 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to determination of the PMT. This includes a discussion of the generation of tsunami-like waves from hill-slope failures and the stability of the coastal area. Please discuss the hill-slope failures near the Levy County site with reference to the findings in Section 2.5 of the FSAR, or explain why such a discussion is not necessary.

PGN RAI ID #: L-0343

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site is presented in LNP FSAR Subsection 2.4.6.

LNP FSAR Figure 2.4.1-203 presents a topographic map of the site. The topographic gradient at the LNP site is less than 50 feet per mile (approximately 1 percent). As stated in LNP FSAR page 2.5-320, the nominal site grade floor elevation will be at 15.5 m (51 ft.) NAVD88, with minor variations to allow drainage for an area of about 370 m by 390 m (1210 ft. by 1280 ft.) around the nuclear island. No permanent slopes or hill slopes are present near the site or within the coastal areas near the site that could adversely affect runoff near safety-related structures. Therefore, a discussion of the generation of tsunami-like waves and the stability of the coastal area due to hill-slope failures is not necessary due to the low potential for hill slope failure on the site and in the nearby coastal area based on the topographic grade of the LNP site and surrounding areas. In addition, as discussed in RAI 02.04.06-5, based on an extensive literature search and site-specific borings, no geologic evidence of paleo-tsunami or tsunami-like deposits were found in the vicinity of the LNP site or in nearby regions.

Associated LNP COL Application Revisions:

In the next revision of the LNP FSAR, the first sentence of the first paragraph of LNP FSAR Subsection 2.5.5 will be revised from:

"The site grade at the LNP site will be at 15.5 m (51 ft.) NAVD88, with minor variations to allow drainage for an area of about 370 m by 390 m (1210 ft. by 1280 ft.) around the nuclear island."

to:

"The nominal plant grade floor elevation at the LNP site will be at 15.5 m (51 ft.) NAVD88, with minor variations to allow drainage for an area of about 370 m by 390 m (1210 ft. by 1280 ft.) around the nuclear island."

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-3

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.2 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to the historical tsunami record, including paleo-tsunami evidence. Please provide a clarification of the meaning of the descriptor "impact" as used on pg. 2.4-45 of the FSAR: "...historically no Caribbean tsunami has impacted the United States Gulf Coast."

PGN RAI ID #: L-0344

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including a description of historical tsunami records, is presented in LNP FSAR Subsection 2.4.6.

As discussed in LNP FSAR Subsection 2.4.6.2.1, a tsunami is considered dangerous if the resulting runup exceeds 1 m (3.28 ft.). The descriptor "impact" as used on pg. 2.4-45 of the FSAR: "...historically no Caribbean tsunami has impacted the United States Gulf Coast" means no tsunamis are known to have originated in the Caribbean Sea and generated a runup exceeding 1.0 m (3.28 ft.) at any location along the United States Gulf Coast. In the recorded history, tsunami waves recorded along the Gulf Coast have all been less than 1 m (3.28 ft.) (LNP FSAR Reference 2.4.6-211).

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-4

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.2 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to the historical tsunami record, including paleo-tsunami evidence. In the updated FSAR, please provide a clarification as to whether any of the Maximum Water Height measurements listed in Table 2.4.6-202 are located in the Gulf of Mexico, or explain why such a discussion is not necessary.

PGN RAI ID #: L-0345

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including a description of historical tsunami records, is presented in LNP FSAR Subsection 2.4.6.

The source of LNP FSAR Table 2.4.6-202 is the NGDC Tsunami Database as discussed in LNP FSAR Subsection 2.4.6.2.3. LNP FSAR Table 2.4.6-202 details tsunami events that historically affected the Caribbean only. With this stated, none of the Maximum Water Height measurements listed in Table 2.4.6-202 are located in the Gulf of Mexico.

Associated LNP COL Application Revisions:

Subsection 2.4.6.2.3 will be revised to clarify that the data presented in LNP FSAR Table 2.4.6-202 are for the Caribbean only. To make this distinction, the word "respectively" will be added after the words "Caribbean and gulf coasts" to the second sentence of this section.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-5

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.2 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to the historical tsunami record, including paleo-tsunami evidence. Please provide a clarification on whether there is any geologic evidence of tsunami deposits at the Levy County site or at nearby regions. Additionally, indicate whether there are geologically conducive locations for the deposition and preservation of tsunami deposits in the vicinity of the Levy County site. If such paleo-tsunami evidence exists, please indicate how they are distinguished from storm wash-over deposits.

PGN RAI ID #: L-0346

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including a description of historical tsunami records, is presented in LNP FSAR Subsection 2.4.6.

Based on an extensive literature search and site-specific borings at LNP, no geologic evidence of paleo-tsunami or tsunami-like deposits or geologically conducive locations for deposition were found in the vicinity of the Levy County site or in nearby regions.

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-6

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.3 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to the source characteristics needed to determine the PMT. These characteristics include detailed geo-seismic descriptions of the controlling local tsunami generators, including location, source dimensions, and maximum displacement. Provide a discussion in the updated FSAR of submarine landslides in the Gulf of Mexico, other than East Breaks, as potential tsunami generators, including the Mississippi Canyon landslide, and landslides along the Florida Escarpment and along the slope above the Florida Escarpment, or discuss why this information is not needed in the FASR. In the updated FSAR, please clarify whether the East Breaks landslide is considered as the PMT source, in relation to discussion of the north Venezuela seismogenic tsunami as having "the most severe impacts for the Gulf Coast" (pg. 2.4-58), or explain why such a discussion is not necessary.

PGN RAI ID #: L-0347

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including detailed geo-seismic descriptions of the controlling local tsunami generators, including location, source dimensions, and maximum displacement, is presented in LNP FSAR Subsection 2.4.6 and LNP RAI 02.04.06-8.

LNP FSAR Subsection 2.4.6.3.2.2 provides a discussion on submarine landslides in the Gulf of Mexico. This discussion consists of all the potential tsunami generators including East Breaks, namely: Mississippi Canyon landslide, landslides along the Florida Escarpment, and landslides above the slope of the Florida Escarpment. The USGS 2007 report, "Evaluation of Tsunami Sources with the Potential to Impact the U.S. Atlantic and Gulf Coasts," provides a review of available literature and information regarding landslides within the Gulf of Mexico as potential tsunami generators. While the Mississippi Canyon and Fan in the "canyon/fan province" was once a source of large landslides, the area has been inactive for more than 7000 years. Similarly, the northern section of the Florida Escarpment in the "carbonate province" is considered to be relatively inactive. An excerpt from the executive summary is as follows:

> Large landslides in the Gulf of Mexico are found in the submarine canyon and fan provinces extending from present Mississippi and other former larger rivers that emptied into the Gulf. These large landslides were probably active before 7500 years ago. In other areas, landslides continue to be active, probably because of salt movement, but are small and may not pose tsunami hazard. Very little is known about the threat of landslide-generated tsunamis from the Mexican coast, particularly the Campeche escarpment. Tsunamis generated by earthquakes do not appear to impact the Gulf of Mexico coast.

Based on the executive summary from the USGS report (2007), the Mississippi Canyon and Florida Escarpment are not considered to be significant potential tsunami threats.

The following submarine landslides, which include the range of potential tsunami generators in the Gulf of Mexico, were considered for the tsunami hazard evaluation detailed in the response of LNP RAI 02.04.06-8:

1. East Breaks
2. Mississippi Canyon Landslide
3. Landslides along the Florida Escarpment
4. Along the slope above the Florida Escarpment

The geometrical parameters of the above potential tsunami generators were taken from the USGS Report to NRC (2007). These landslides were termed as the "Maximum Credible Submarine Landslides" in the USGS Report. Landslide speed can strongly affect tsunami size--generally faster moving slides make larger waves and slower moving slides make smaller waves. Landslide speed can vary considerably depending upon the properties of the slide material and the slope and distance over which the slide runs. While conducting tsunami hazard evaluation for a given slide, a range of possible slide speeds from 25 m/s to 50 m/s were considered. The 1980 Mt. St. Helens subaerial landslide reached just 50 m/s. The submarine slides considered here run on far lower slopes than the 1980 Mt. St. Helens case, so a 25 m/s slide speed is probably most applicable.

In order to determine the PMT source, both landslides and earthquakes along with associated impacts in terms of runup and run-in distance were compared using the methodology presented in the response to RAI 02.04.06-8 and summarized in Table 1 for landslides (results for earthquake tsunamis are detailed in the response of LNP RAI 02.04.06-8). The source having the most severe impact in relation to the LNP site is determined to be the PMT. Table 2 presents the most severe potential impacts of tsunamis generated by a landslide and an earthquake.

Based on Table 2, the Venezuela seismogenic tsunami is the most severe farfield PMT source and the Mississippi Canyon landslide is the most severe nearfield PMT source.

References

U.S. Geological Survey (USGS). 2007. *Evaluation of Tsunami Sources with the Potential to Impact the U.S. Atlantic and Gulf Coasts.* An Updated Report to the Nuclear Regulatory Commission by Atlantic and Gulf of Mexico Tsunami Hazard Assessment Group.

Salamon, A., Rockwell, T., Ward, S. N., Guidoboni, E., and Comastri, A. 2007. "Tsunami Hazard Evaluation of the Eastern Mediterranean: Historical Analysis and Selected Modeling." *Bulletin of the Seismological Society of America*, Vol. 97, No. 3, 1-20.

Silver, Eli, S. Day, S. N. Ward, G. Hoffmann, P. Llanes, N. Driscoll, B. Applegate, S. Saunders, 2009. Volcano Collapse and Tsunami Generation in the Bismarck Volcanic Arc, Papua New Guinea. *Journal of Volcanology and Geothermal Research.* In press.

Table 1
Tsunami Hazard Evaluation Summary

Landslide	Area A	Volume V	Thickness of the Unit T	Slide Speed Vs	Initial Wave Amplitude A_0	Water Depth of the Slide Event H_0	Diameter D	Distance of the Measurement Point from the Source R	Exponent φ	Offshore Wave Height at a Distance R from the Source A(R)	Runup η	Run-in Distance X
	(km^2)	(km^3)	(m)	(m/s)	(m)	(m)	(m)	(km)		(m)	(m)	(mi)
East Breaks	520	22	42	25	7	1750	25,719	1000	0.94	0.12	0.8	0.02
	520	22	42	50	26	1750	25,719	1000	0.94	0.42	2.2	0.08
Mississippi Canyon	3720	428	115	25	21	1689	68,822	640	0.78	2.06	7.9	0.38
	3720	428	115	50	73	1689	68,822	640	0.78	7.16	21.4	1.22
Florida Escarpment	648	16.2	25	25	4	1827	28,724	275	0.94	0.26	1.5	0.05
	648	16.2	25	50	15	1827	28,724	275	0.94	0.89	4.1	0.17
Slope above the Florida Escarpment	648	16.2	25	25	4	1827	28,724	325	0.94	0.22	1.3	0.04
	648	16.2	25	50	15	1827	28,724	325	0.94	0.77	3.6	0.15

Notes:
km^2 = square kilometer; km^3 = cubic kilometer; m = meter; mi = mile; m/s = meters per second; Vs = slide velocity

Table 2
Comparison of the Probable Maximum Tsunami Hazard Due to a Landslide and an Earthquake

Item	Runup (m)	Run-in Distance (m)	Impact on LNP Site	Notes
Most severe landslide	21.4	1.22	No	Mississippi Canyon landslide with a slide speed of 50 m/s
Most severe earthquake	5.67	0.25	No	Venezuela seismogenic tsunami
East Breaks landslide	2.2	0.08	No	East Breaks landslide with a slide speed of 50 m/s

Notes:
In Table 2, runup numbers were not corrected for 10% exceedance high tide, sea level anomaly, or long-term sea level rise.
m = meter; m/s = meters per second

Associated LNP COL Application Revisions:

See LNP RAI 02.04.06-8 for revisions to the LNP FSAR.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-7

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.3 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to the source characteristics needed to determine the PMT. These characteristics include detailed geo-seismic descriptions of the controlling distant tsunami generators, including location, source dimensions, fault orientation, and maximum displacement. In the updated FSAR, please provide clarification regarding seismologic characterization of the region offshore of Veracruz, Mexico, relative to the generation of tsunamis, or explain why such a discussion is not necessary.

PGN RAI ID #: L-0348

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including detailed geo-seismic descriptions of the controlling tsunami generators, including location, source dimensions, fault orientation, and maximum displacement, is presented in LNP FSAR Subsection 2.4.6 and LNP RAI 02.04.06-8.

As discussed in LNP FSAR Subsection 2.4.6.5.2, the test earthquake in the Gulf of Mexico off the coast of Veracruz, Mexico was intended to represent a hypothetical scenario rather an actual one. The scenario is hypothetical but plausible in view of this region's active tectonic setting, as described by the USGS below.

> The Cocos plate is moving northeastward and collides with the Pacific coast of Mexico (part of the North American plate). The Cocos plate moves beneath (subducts) coastal Mexico and leads to earthquakes such as the 1985 Michoacan event. The subduction of the Cocos plate continues to deepen and the earthquakes occurred within the subducting Cocos plate. These earthquakes probably were caused by the sinking of the Cocos plate. As the subduction of the Cocos plate continues to the northeast, it leads to formation of the Trans-Mexican Volcanic Belt (volcanoes typically form about 100 km above the surface of a subducting plate). (http://neic.usgs.gov/neis/eq_depot/1999/eq_990615/neic_0615_ts.html)

Approximately 15 to 20 earthquakes of magnitude 7 or greater have been generated near Veracruz since 1900. Most of the events on the northern coastline have originated at depths greater than 75 km. However, several of the events on the southern coastline developed near a plate subduction zone and have originated within 35 km of sea level.

As discussed in LNP FSAR Subsection 2.4.6.5.2, the hypothetical earthquake off the coast of Veracruz represents a worst-case plausible scenario having a magnitude of 8.2. Based on an analysis conducted by Knight (FSAR Reference 2.4.6-225), the LNP site would not be affected by this worst-case scenario (FSAR Figure 2.4.6-221). In addition to the large magnitude, the most efficient focal mechanism for tsunami generation (Dip angle = 45 degree, Rake angle = 90 degree) and propagation toward the LNP site were selected to create a worst-case plausible scenario as presented in the response to LNP RAI 02.04.06-8. The worst-case for the scenario earthquake produced a runup of 5.67 m and run-in distance of 0.55 mi. at the LNP site. Any actual earthquake in the Veracruz region would only be expected to produce a smaller tsunami. Based on these results, the LNP site will not be affected by a tsunami generated by any plausible earthquake in the Gulf of Mexico off the coast of Veracruz, Mexico regardless of its characteristics such as location, source dimensions, fault orientation, and maximum displacement. Therefore, a detailed discussion of the seismology for the region offshore of Veracruz, Mexico is not necessary.

Associated LNP COL Application Revisions:

No COLA revisions have been identified associated with this response.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-8

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.4 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to tsunami analysis. This includes providing a complete description of the analysis procedure used to calculate tsunami wave height and period at the site, including the theoretical bases of the models, their verification and the conservatism of all input parameters. Please provide theoretical basis, assumptions (e.g., source parameterization), and applicability to the Levy County site for the tsunami attenuation function discussed on pg. 2.4-53 (Equation 2.4.6-1) and make available the details of the Monte Carlo analysis used to estimate the maximum wave height and where the maximum wave height estimate is geographically located. For this and other methods of tsunami analysis indicated in the FSAR, please provide the procedure used to calculate tsunami propagation, runup, and inundation (i.e., tsunami water levels) at the Levy County site from offshore tsunami amplitude.

PGN RAI ID #: L-0349

PGN Response to NRC RAI:

The analysis procedure used to calculate tsunami wave height at the LNP site, initial tsunami size, propagation, runup, and inundation specific to the LNP site, along with its theoretical basis, assumptions, and source parameterization, is presented in LNP Calculation Package LNG-0000-X7C-043, "Probable Maximum Tsunami". A copy of this calculation will be provided in the Progress Energy-provided Reading Room for NRC's review and is summarized below.

The application of the tsunami simulation approaches to earthquake and landslide generated tsunamis has been thoroughly presented by Ward (2002), Ward and Asphaug (2002), and Ward and Day (2008). An analysis has been derived based on the linear dispersive water wave theory (Salamon et al., 2007). This approach is mode and ray based and includes landslide evolution, geometrical spreading, dispersive spreading, frequency dependent shoaling, and diffractive corrections. Like many tsunami analyses, this approach takes the waves to a shallow water location near the site of interest.

Methodology

The approach utilizes estimates of source amplitude, propagation loss, shoaling correction, and beaching amplification to calculate the maximum runup and run-in distance for a given landslide or earthquake event. This approach was used to predict the maximum runup and run-in distance which would occur at the proposed Levy Nuclear Plant (LNP) site resulting from a number of historic landslides and earthquakes.

Using the formula based approach the following worst case tsunamis were analyzed:

1. Florida Shelf Landslide Tsunami, Gulf of Mexico
2. Mississippi Canyon Landslide Tsunami, Gulf of Mexico
3. Mid-Gulf Tsunamigenic Earthquake
4. Veracruz Tsunamigenic Earthquake
5. Venezuela Tsunamigenic Earthquake

This analytical based approach embodies the same processes (generation, spreading, shoaling, runup) as a simulation based approach, but it uses simplified approximations of the processes included in the computer calculations (Silver et al., 2007). These simplifications are compensated for by the use of conservative assumptions which in many situations may overestimate the magnitude of wave runup.

Using this approach, the wave runup, η, can be represented as a product of following components:

$$\eta = A_0 PSB \tag{1}$$

where, A_0 is the source amplitude, P is the propagation loss (less than 1.0), S is the shoaling correction (usually more than 1.0), and B is the amplification due to beaching. The procedures to calculate these components are explained below.

Determination of Source Amplitude A_0

In the case of a landslide, A_0 is given as

$$A_0 = 3.5T \left(\frac{V_s}{\sqrt{gH_0}} \right)^{1.8} \tag{2}$$

where, T is the thickness of the landslide unit, V_s is the landslide speed, g = 9.8 m/s^2, and H_0 is the water depth at the slide. Faster moving slides tend to produce bigger waves.
In case of an earthquake, A_0 is given as:

$$A_0 = \alpha \Delta u. \tag{3}$$

where, Δu is earthquake slip and α is a fraction of slip that transforms into uplift. This factor depends upon the style of the fault. Mathematically, α can be determined using the following relationship:

$$\alpha = (1 - \phi/180) Sin(\phi) |Sin(\rho)| \tag{4}$$

where ϕ and ρ are the dip and rake angles, respectively, in degrees. Combining equations (3) and (4), A_0 for an earthquake is given as:

$$A_0 = (1 - \phi/180) Sin(\phi) |Sin(\rho)| \Delta u \tag{5}$$

The most efficient mechanism for tsunami generation have ϕ near 45 degrees and ρ= plus or minus 90 degrees. Our test earthquakes employed these values.

Determination of Propagation Loss P

Propagating tsunami waves go through significant transformations such as modification in wave shape, duration, and attenuation in amplitude. The attenuation in tsunami wave amplitude is roughly proportional to the inverse distance traveled due to geometrical spreading and frequency dispersion (Chesley and Ward, 2006). For a constant depth ocean, Ward and Asphaug (2002) fit the peak tsunami amplitude by the following relationship:

$$P = \left(1 + \frac{2R}{D}\right)^{-\varphi} \tag{6}$$

where R is the distance of measurement point from the source, D is the dimension of the tsunami source, and φ is an exponent defined as

$$\varphi = 0.5 + 0.575\exp\left(-0.0175\frac{D}{H_0}\right) \tag{7}$$

The first term in (7) accounts for geometrical spreading. The second term in (7) accounts for additional wave height losses due to frequency dispersion. Generally larger dimensioned sources decay slower with distance on this account. Typically (7) is between 0.7 and 1.0. Combining equations (5), (6) and (7), the peak wave amplitude at a distance R from the source A(R) can be determined by the following equations:

For Landslide:

$$A(R) = A_0 P = 3.5T\left(\frac{V_s}{\sqrt{gH_0}}\right)^{1.8}\left(1 + \frac{2R}{D}\right)^{-\left[0.5+0.575\exp\left(-0.0175\frac{D}{H_0}\right)\right]} \tag{8a}$$

For Earthquake:

$$A(R) = A_0 P = \left(1 - \frac{\phi}{180}\right)Sin(\phi)|Sin(\rho)|\Delta u\left(1 + \frac{2R}{D}\right)^{-\left[0.5+0.575\exp\left(-0.0175\frac{D}{H_0}\right)\right]} \tag{8b}$$

Determination of Shoaling Correction S

Equation (6), which led to (8), assumes oceans of constant depth H_0. Toward shore, however, real oceans shallow to depth H_S. When tsunamis reach shallow water they slow and grow to conserve energy flux. For the waves of interest, deep water amplitude A(R) given by equation (8) needs to be corrected to account for shoaling. According to linear theory, the shoaling correction, S, is given by the following relationship (Chesley and Ward, 2006):

$$S = \left[\frac{V_G(\omega_{\max}, H_0)}{V_G(\omega_{\max}, H_S)}\right]^{\frac{1}{2}} \qquad (9)$$

Where $V_G(\omega_{\max}, H_0)$ and $V_G(\omega_{\max}, H_S)$ are the tsunami wave group velocities at ocean depths H_0 and H_S, respectively. It is clear from equation (9) that the shoaling amplification depends on the ratio of group velocity at the source site and the coast site evaluated at the frequency associated with the peak tsunami height. Equation (9) can be approximated using a long wave assumption (Chesley and Ward, 2006) as:

$$S = \left(\frac{H_0}{H_S}\right)^{\frac{1}{4}} \qquad (10)$$

Using equation (10), the shoaled amplitude A(S) is defined as a function of the peak wave amplitude A(R) at distance R as:

$$A(S) = A(R)\left(\frac{H_0}{H_S}\right)^{\frac{1}{4}} \qquad (11)$$

Applying Beaching Correction

Onshore peak wave runup height η is estimated using the following empirical formula given by Chesley and Ward (2006):

$$\eta = A(S)^{4/5} H_S^{1/5} \qquad (12)$$

Using equation (12), one can estimate wave runup at the beach from offshore shoaled wave height. Combining equations (11) and (12), the peak wave runup can be calculated using the following relationship:

$$\eta = A(R)^{4/5} H_0^{1/5} \qquad (13)$$

Using equation (13), one can estimate wave runup at the beach using offshore wave height A(R) and source water depth H_0.

Determination of Run-In Distance

Hills and Mader (Gerardi et. al, 2008) suggested the equation for inundation distance from the shore:

$$X = 0.06\eta^{1.33} n^{-2} \qquad (14)$$

where X is the run-in distance of landward inundation in meters, η is the runup height at the shoreline in meters, and n is Manning's roughness coefficient. This equation was modified by McSaveney and Rattenbury (Gerardi et. al, 2008) to include a slope factor:

$$H_{Loss} = \frac{16.7n^2}{\eta^{0.33}} + 5Sin(\theta) \qquad (15)$$

where H_{Loss} is the loss in wave height per meter of inundation distance, and θ is the beach slope. Combining equations (14) and (15), X is re-written as:

$$X = \frac{\eta^{1.33}}{16.7n^2 + 5\eta^{0.33}Sin(\theta)} \qquad (16)$$

It should be noted that the wave amplitude onshore cannot exceed its estimated runup height, η. As the wave runs inland, its amplitude will continuously decrease with distance travelled until wave height finally drops to zero at the maximum run-in distance X. Assuming no friction loss, the limiting run-in distance for a wave is the distance where the increase in ground elevation with respect to the shore elevation is equal to the wave runup. That is, a wave can not run inland to places where the topographic height exceeds the estimated runup height. Assuming that the land has a slope, θ, the inundation distance calculated using equation (16) is subjected to the following limiting value

$$X_{\max} = \eta Co\sec(\theta) \qquad (17)$$

Combining equations (16) and (17), the inundation distance is given as:

$$X = Min\left[\frac{\eta^{1.33}}{16.7n^2 + 5\eta^{0.33}Sin(\theta)}, \eta Co\sec(\theta)\right] \qquad (18)$$

Discussion

The analysis procedure presented in LNP Calculation Package LNG-0000-X7C-043, "Probable Maximum Tsunami " has been revised from that presented in LNP FSAR Subsection 2.4.6, Rev. 0. The tsunami attenuation function discussed on LNP FSAR Rev. 0 page 2.4-53 (Equation 2.4.6-1) has been replaced by this more comprehensive tsunami analysis approach. Calculation of wave period at the site is not applicable to this revised approach and a Monte Carlo analysis was not utilized as part of this revised approach.
The analysis procedure presented in LNP Calculation Package LNG-0000-X7C-043 utilizes various empirical equations taken from peer-reviewed publications as cited in the Calculation Package. The cited peer-reviewed publications have verified the application of the empirical equations. Conservatism in the case of earthquake tsunami is found in the use of augmented earthquake test magnitudes; that is if the largest historical or expected earthquake in the region is Magnitude = X, the examined test cases were selected to have their magnitude larger than X by at least one unit. Earthquake magnitudes examined vary by location and are given in Table 2. Conservatism in the case of landslide tsunami is found in the use of maximum landslide volume as indicated by a USGS Report (Brink et. al, 2008). Landslide volumes examined vary by landslide and are given in Table 1.

Results

Tables 1 and 2 present the tsunami generation mechanism parameters used to determine the worst case impact at the LNP site. Tables 3 and 4 present the results of the analysis presented in LNP Calculation Package LNG-0000-X7C-043. Wave height estimates given in Table 3 are either wave amplitudes just offshore the LNP site or onshore runup height near the LNP site.

Table 1
Parameters for Worst Case Landslide Tsunami

Landslide	Area A	Volume V	Thickness of the Unit T	Slide Speed Vs	Initial Wave Amplitude A_0	Water Depth of the Slide Event H_0	Diameter D	Distance of the Measurement Point from the Source R
	(km^2)	(km^3)	(m)	(m/s)	(m)	(m)	(m)	(km)
East Breaks	520	22	42	25	7	1750	25,719	1000
	520	22	42	50	26	1750	25,719	1000
Mississippi Canyon	3720	428	115	25	21	1689	68,822	640
	3720	428	115	50	73	1689	68,822	640
Florida Escarpment	648	16.2	25	25	4	1827	28,724	275
	648	16.2	25	50	15	1827	28,724	275
Slope above the Florida Escarpment	648	16.2	25	25	4	1827	28,724	325
	648	16.2	25	50	15	1827	28,724	325

Notes:
km = kilometer; km^2 = square kilometer; km^3 = cubic kilometer; m = meter; m/s = meters per second; Vs = slide velocity

Table 2
Parameters for Worst Case Earthquake Tsunami

Earthquake Location	Rigidity μ	Fault Length L	Fault Width W	Fault Area A	Average Fault Slip Δu	Dip Angle ϕ	Rake Angle ρ	α	Magnitude Mw	Water Depth at the Source H_0
	(Pa)	(km)	(km)	(km^2)	(m)	(degree)	(degree)		(Nm)	(m)
Mid-Gulf	3.0E+10	50	23	1,150	1	45	90	0.530	7.0	3,121
Vera Cruz	3.0E+10	199	93	18,507	4	45	90	0.530	8.2	2,836
Venezuela	3.0E+10	550	100	55,000	21.5	17	90	0.265	9.0	1,847

Notes:
km = kilometer; km^2 = square kilometer; m = meter; Nm = Newton meter; Pa = Pascal; Vs = slide velocity

Table 3
Formula Based Results to Some Worst Case Landslide Tsunamis

Landslide	Area A (km^2)	Volume V (km^3)	Thickness of the Unit T (m)	Slide Speed Vs (m/s)	Initial Wave Amplitude A_0 (m)	Water Depth of the Slide Event H_0 (m)	Diameter D (m)	Distance of the Measurement Point from the Source R (km)	Exponent φ	Offshore Wave Height at a Distance R from the Source A(R) (m)	Onshore Runup η (m)	Run-in Distance X (mi)
East Breaks	520	22	42	25	7	1,750	25,719	1000	0.94	0.12	0.8	0.02
	520	22	42	50	26	1,750	25,719	1000	0.94	0.42	2.2	0.08
Mississippi Canyon	3,720	428	115	25	21	1,689	68,822	640	0.78	2.06	7.9	0.38
	3,720	428	115	50	73	1,690	68,822	640	0.78	7.16	21.4	1.22
Florida Escarpment	648	16.2	25	25	4	1,827	28,724	275	0.94	0.26	1.5	0.05
	648	16.2	25	50	15	1,827	28,724	275	0.94	0.89	4.1	0.17
Slope above the Florida Escarpment	648	16.2	25	25	4	1,827	28,724	325	0.94	0.22	1.3	0.04
	648	16.2	25	50	15	1,827	28,724	325	0.94	0.77	3.6	0.15

Notes:
km = kilometer; km^2 = square kilometer; km^3 = cubic kilometer; m = meter; mi = mile; m/s = meters per second; Vs = slide velocity

Table 4
Formula Based Results to Some Worst-Case Earthquake Tsunamis

Earthquake Location	Magnitude Mw (Nm)	Water Depth at the Source H_0 (m)	Diameter or Physical size of uplift D (m)	Distance of the measurement point from the Source R (km)	Exponent φ	Offshore Wave Height at a Distance R from the Source A(R) (m)	Runup η (m)	Run-in Distance X (mi)
Mid Gulf	7.0	3,121	36,500	450	0.96	0.02	0.25	0.02
Vera Cruz	8.2	2,836	1,46,000	1,500	0.73	0.22	1.48	0.13
Venezuela	9.0	1,847	3,25,000	2,400	0.53	1.33	5.67	0.25

Notes:
km = kilometer; m = meter; mi = mile; Nm = Newton meter

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Associated LNP COL Application Revisions:

LNP FSAR Subsection 2.4.6, Rev. 0 will be revised to incorporate the revised PMT analysis and text presented in LNP calculation package LNG-000-X7C-043, Rev. 0. The procedure used to calculate tsunami propagation, runup, and inundation (i.e., tsunami water levels) at the Levy County site from offshore tsunami amplitude presented above will be included in this revision.

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-9

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.4 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to tsunami analysis. This includes providing a complete description of the analysis procedure used to calculate tsunami wave height and period at the site. In the updated FSAR, please resolve the apparent inconsistency of the statement that the Gulf of Mexico contains no sources of reverse faults (1st sentence, section 2.4.6.4.1.2, pg. 2.4-52) given the mechanism of the September 10, 2006 Mw=5.8 in the NE Gulf of Mexico (third sentence), or explain why such a discussion is not necessary.

PGN RAI ID #: L-0350

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including a description of the analysis procedure used to calculate tsunami wave height and period, is presented in LNP FSAR Subsection 2.4.6 and RAI 02.04.06-8.

The statement that the Gulf of Mexico contains no sources of reverse faults will be revised to provide additional clarification in a future amendment to the FSAR.

Associated LNP COL Application Revisions:

The first sentence of FSAR Rev. 0 Subsection 2.4.6.4.1.2 will be revised from:

> "In contrast to the Caribbean, the Gulf of Mexico contains none of the tectonic conditions, including subduction zones and sources of reverse faults, necessary to produce a tsunami via earthquake (Reference 2.4.6-214)."

to:

> "In contrast to the Caribbean, the Gulf of Mexico contains no subduction zone faults that are a primary source of large, tsunamigenic earthquakes (Reference 2.4.6-214)."

Attachments/Enclosures:

None.

NRC Letter No.: LNP-RAI-LTR-047

NRC Letter Date: May 20, 2009

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.06-10

Text of NRC RAI:

To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, the applicant should provide an assessment of the Probable Maximum Tsunami (PMT) for the proposed site. Section C.I.2.4.6.5 of Regulatory Guide 1.206 (RG 1.206) provides specific guidance with respect to tsunami water levels. This includes describing the ambient water levels, including tides, sea level anomalies, and wind waves assumed to be coincident with the tsunami. Please clarify the use of the value for 10% exceedance high-tide and long-term sea-level rise coincident with maximum tsunami water levels at the Levy County site.

PGN RAI ID #: L-0351

PGN Response to NRC RAI:

An assessment of the Probable Maximum Tsunami (PMT) for the LNP site, including a description of ambient water levels, including tides and wind waves assumed to be coincident with the tsunami, is presented in LNP FSAR Subsection 2.4.6 and LNP Calculation Package LNG-0000-X7C-043, "Probable Maximum Tsunami". A copy of this calculation will be provided in the Progress Energy-provided Reading Room for NRC's review and is summarized below.

Regulatory Guide 1.59 requires that the 10 percent exceedance astronomical high spring tide be used as the antecedent water level for the storm surge due to a probable maximum hurricane (PMH) event. The same antecedent water level condition is also used to obtain the PMT maximum water level. As presented in LNP Calculation Package LNG-0000-X7C-043, "Probable Maximum Tsunami", the 10 percent exceedance antecedent high spring tide at the Crystal River coastline near the LNP site is taken as 1.3 m (4.3 ft.) mean low water (MLW) [which is equivalent to 0.82 m (2.68 ft.) NAVD88].

As presented in LNP FSAR Subsection 2.4.5.2.2, and according to the Regulatory Guide 1.59, the sea level anomaly for the Crystal River is 0.18 m (0.6 ft.).

As described in RAI 02.04.03-2, the expected sea level rise is 0.39 ft. for a design period of 60 years for the LNP site.

Combining the 10 percent exceedance high spring tide (2.68 ft. NAVD88), sea level anomaly (0.6 ft.), and the long-term sea level rise (0.39 ft.) with the postulated conservative tsunami runup values at the Florida Gulf Coast shoreline near the LNP site presented in RAI 02.04.06-8 results in an increase of 3.67 ft. (1.1 m) NAVD88 (2.68+0.6+0.39 = 3.67). The associated coincident PMT wave runup and run-in are presented below in Tables 1 and 2.

Table 1
Coincident Runup and Run-in for the Worst Case Landslide Tsunamis

Name	Runup without Corrections m (ft) (from RAI 0.2.04.06-8)	Corrected Runup m NAVD88 (ft NAVD88)	Corrected Run-in Distance X (mi)
East Breaks (Vs = 25 m/s)	0.8 (2.6)	1.9 (6.2)	0.07
East Breaks (Vs = 50 m/s)	2.2 (7.2)	3.4 (11.2)	0.13
Mississippi Canyon (Vs = 25 m/s)	7.9 (25.9)	9.0 (29.5)	0.44
Mississippi Canyon (Vs = 50 m/s)	21.4 (70.2)	22.5 (73.8)	1.29
Florida Escarpment (Vs = 25 m/s)	1.5 (4.9)	2.6 (8.5)	0.10
Florida Escarpment (Vs = 50 m/s)	4.1 (13.5)	5.2 (17.1)	0.23
Slope above the Florida Escarpment (Vs = 25 m/s)	1.3 (4.3)	2.5 (8.2)	0.09
Slope above the Florida Escarpment (Vs = 50 m/s)	3.6 (11.8)	4.8 (15.7)	0.21
Maximum	**21.4 (70.2)**	**22.5 (73.8)**	**1.29**

Note:
m/s =meters per second; Vs = slide velocity

Table 2
Coincident Runup and Run-in for the Worst Case Earthquake Tsunamis

Name	Runup without corrections m (ft) (from RAI 0.2.04.06-8)	Corrected Runup m NAVD88 (ft NAVD88)	Corrected Run-in Distance X (mi)
Mid Gulf	0.3 (1.0)	1.4 (4.6)	0.04
Vera Cruz	1.5 (4.9)	2.6 (8.5)	0.10
Venezuela	5.7 (18.7)	6.8 (22.3)	0.31
Maximum	**5.7 (18.7)**	**6.8 (22.3)**	**0.31**

As can be seen in Tables 1 and 2, the maximum runup values after applying the 10 percent exceedance high spring tide, sea level anomaly, and long-term sea level rise corrections are 22.5 m (73.8 ft) NAVD88 and 6.8 m (22.3 ft) NAVD88 for the worst-case landslide and earthquake, respectively. The corresponding run-in distances are 1.29 mi and of 0.31 mi respectively. These latter values remain well below the 7.9-mile distance that the LNP site sits inland from the Gulf of Mexico coastline. Therefore, the LNP site will not be affected by either a landslide or an earthquake generated PMT.

Associated LNP COL Application Revisions:

LNP FSAR Subsection 2.4.6, Rev. 0 will be revised to incorporate the revised PMT analysis and text presented in LNP calculation package LNG-000-X7C-043, Rev. 0. The use of the value for 10 percent exceedance high spring tide and long-term sea-level rise coincident with maximum tsunami water levels at the Levy County site presented above will be included in this revision.

Attachments/Enclosures:

None.