NRR-PMDAPEm Resource

From:	Bentley, Donald E <DBENTLE@entergy.com>
Sent:	Tuesday, July 26, 2016 6:31 PM
To:	Bernardo, Robert
Cc:	BOTTEMILLER, CHARLES A; Byrne, Robert M
Subject:	[External_Sender] Probable Maximum Wind Storm for Pilgrim Nuclear Power Station
Attachments:	FINAL_01.0171705.42_PMWS_Wind-Wave_Effects_07-21-16.pdf

Bob,

This is a follow-up to our conversations of July 13, 2016 and July 21, 2016 related to the audit webinar held on June 16, 2016.

The NRC staff requested a reference document be provided from our evaluation of the Probable Maximum Wind Storm (PMWS) scenario at Pilgrim Nuclear Power Station. This reference is needed so that the NRC staff may reference their review of the PMWS in the Mitigating Strategies Flood Hazard Information (MSFHI) response letter. The NRC staff has included both the hurricane and wind storm events in the MSFHI response letter tables.

Entergy agrees that PMWS Plus Wind Wave Effects Near the Reactor Building (from Transect 3) is 15.3’ MSL Stillwater Elevation with 7.1’ Significant Wave Height (Wave) resulting in a 22.4’ MSL Maximum Elevation (Reevaluated Hazard Elevation). The attached document File No. 01.0171705.42 dated July 21, 2016 may be used as the needed reference.

Don

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MEMORANDUM – VIA EMAIL

July 21, 2016
File No. 01.0171705.42

From: **GZA GeoEnvironmental, Inc.**
Michael A. Mobile, Ph.D.; Chad W. Cox, P.E.

To: **Ms. Cynthia A. Fasano, P.E., AREVA, Inc. (AREVA)**

Re: **Pilgrim Nuclear Power Station Coastal Flooding – Wind-Wave Effect Calculations for the Probable Maximum Wind Storm Scenario**

Wind-wave effects were calculated at three locations along the Pilgrim Nuclear Power Station (PNPS) shoreline using waves predicted by the nearshore SWAN model for the probable maximum wind storm (PMWS) scenario. These analyses were completed as part of a response to Information Needs requests developed by the Nuclear Regulatory Commission dated March 10, 2016 in reference to the flood re-evaluation report for PNPS. The techniques applied to calculate wave runup at the selected locations followed the same methodology applied to the probable maximum hurricane (PMH) scenario (i.e., FEMA, 2007 and ASCE, 2010). Wind-wave effects for the PMWS scenario were not originally examined because, based on nearshore SWAN modeling, the PMH was shown to generate a higher maximum stillwater elevation and greater significant wave heights in comparison to the PMWS. The methodology and results associated with calculations for PMWS wind-wave effects are summarized below.

METHODOLOGY

As indicated in the Combined Effects calculation (AREVA, 2015a), the intake at PNPS (i.e., Transect 1, refer to **Figure 1**) is a vertical structure; therefore, reflected wave crest heights were calculated at the intake based on the Sainflou formula, as presented in the USACE Coastal Engineering Manual (CEM) (USACE, 2006). This approach was used to estimate the vertical shift in wave height on a vertical wall, (δ_o), above the stillwater elevation. In this approach, the “standing” wave crest height, η, on a vertical wall is equal to:

$$\eta = \delta_o + H$$

δ_o is calculated using the following equation (Table VI-5-52 of USACE, 2006):

$$\delta_o = \frac{\pi {H_s}^2}{L} coth \frac{2\pi d}{L}$$

Where:

H_s = significant wave height [feet]

L= wavelength at the structure toe [feet]

d = depth at the structure toe [feet]

δ_o= Vertical shift in the wave crest [feet]

The wavelength at the structure toe was calculated by the SWAN model (AREVA, 2015a, Appendix C). The calculated "standing" (i.e., also referred to as "reflected") wave crest height is added to the stillwater elevation to calculate the elevation of the reflected wave crest at the intake structure.

Wave runup on impermeable riprap slopes (i.e., Transects 2 and 3, refer to **Figure 1**) was calculated in accordance with methods outlined in the United States Army Corps of Engineers Coastal Engineering Manual (USACE CEM) EM 1110-2-1100 - Part VI (USACE, 2006). This document presents the following equation for calculating runup on impermeable riprap slopes:

$$\frac{R_{ui\%}}{H_s} = \begin{cases} A\xi_{om} \text{ for } 1.0 < \xi_{om} \leq 1.5 \\ B(\xi_{om})^C \text{ for } \xi_{om} > 1.5 \end{cases}$$

Where:

$R_{ui\%}$ = Runup (feet)

H_s = Significant wave height (feet)

$$\xi_{om} = surf\ similarity\ parameter = \tan\alpha/\left(2\pi H_s/gT_{om}{}^2\right)^{1/2}$$

$$T_{om} = mean\ wave\ period\ (seconds);$$

$$g = acceleration\ due\ to\ gravity\ \left(32.2\frac{ft}{sec^2}\right);$$

$$\tan\alpha = slope\ of\ revetment$$

Coefficients A, B and C are given in Table VI-5-5 (USACE, 2006).

As indicated in the Combined Effects calculation (AREVA, 2015a), conditions where calculated runup heights exceeded the top elevation of the shoreline revetment exist for Transects 2 and 3. To determine "realistic" runup elevations, FEMA provides an approach based on Figure 16 (FEMA, 2007) in the Combined Effects calculation (AREVA, 2015a) where hypothetical runup elevation (R) is translated to an adjusted runup elevation (Ra). This approach is considered to be "realistic" because it does not erroneously assume that the revetment slope extends an infinite distance inland.

Using the above-described method and Figure 17 from the Combined Effects calculation (AREVA, 2015a), the inland limit of runup onto the bluff crest can be determined. The adjusted runup height can then be calculated based on the following equation:

$$R_a = (C + mX)$$

Where:

R_a = Adjusted runup height (feet)

C = structure crest elevation (feet, MSL)

m = plateau slope (i.e. the site grade)

X = Inland limit of runup (in feet)

This methodology was applied to calculate wave runup on the PNPS revetment (i.e., Transects 2 and 3).

RESULTS

The following table summarizes the PMWS scenario results at Transects 1, 2 and 3:

Table 1: PMWS Total Water Levels

PMWS		
	Stillwater Elevation (ft, MSL)	Maximum Water Elevation (ft, MSL)
Transect 1 – Intake (Node 12)	15.3	18.7
Transect 2 – Reactor Building (Node 15)		21.7
Transect 3 – Boat Ramp (Node 20)		**22.4**

Notes:
1. Stillwater elevation includes wave setup
2. Results for Transect 1 represent the total WSE (i.e., total water surface elevation at the PNPS intake)
3. Results for Transects 2 and 3 indicate conditions associated with the calculated maximum wave height and the adjusted wave runup elevation
4. Critical elevation = 23.0 ft MSL

The maximum incident significant wave height near the intake (i.e., Transect 1) for the PMWS scenario was calculated in SWAN to be approximately 2.4 feet with a wavelength of 18.3 feet. This wave results in a reflected wave crest height of approximately 3.4 feet and an elevation of 18.7 feet MSL based on a stillwater elevation of 15.3 feet MSL. This elevation is approximately 2.8 feet below grade at the top of the intake structure (PNPS, 2005). Furthermore, this elevation is approximately 1.1 feet below the maximum elevation calculated for the PMH scenario – 19.8 ft MSL (AREVA, 2015a).

The maximum runup elevation along the shoreline revetment adjacent to the reactor building (i.e., Transect 2) for the PMWS scenario was calculated to be 21.7 feet MSL. This result is associated with a significant wave height of 5.6 feet and a mean period of 10.6 seconds, both calculated by SWAN. This elevation is approximately 1.3 feet below the critical elevation at PNPS of 23.0 ft MSL (AREVA, 2015a). Furthermore, this elevation is approximately 0.2 feet lower than the maximum elevation calculated for the PMH scenario at this location – 21.9 ft MSL (AREVA, 2015a).

The maximum runup elevation along the shoreline revetment in the vicinity of the boat ramp (i.e., Transect 3) caused by the PMWS was 22.4 feet MSL at Transect 3. This result is associated with a significant wave height of 7.1 feet and mean period of 12.7 seconds, both calculated by SWAN. This elevation is approximately 0.6 feet below the critical elevation at PNPS of 23.0 ft MSL (AREVA, 2015a). This elevation is roughly equal to (approximately 0.3 feet higher) the maximum elevation calculated for the PMH scenario at this location – 22.1 ft MSL (AREVA, 2015a).

Using only maximum calculated elevations as a basis, the results presented above confirm the PMH as the controlling event type in the vicinity of the PNPS intake (i.e., Transect 1) and along the revetment adjacent to the reactor building (i.e., Transect 2). The PMWS is, however, identified as generating approximately the same or a slightly higher maximum water surface elevation in comparison to the PMH for the revetment area in the vicinity of the boat ramp (i.e., Transect 3) despite having a lower maximum stillwater elevation and lesser significant wave height relative to SWAN-calculated results in this area during the PMH scenario. This result is attributable to a difference in wave period conditions during the two simulated event types (i.e., 9.5 seconds for the PMH scenario versus 12.7 seconds for the PMWS scenario).

In comparing the characteristics of flooding due to the two event types, it is important to note that the PMWS has a duration of elevated stillwater elevations and high intensity wave action that is greater than that associated with the PMH. Figures 2 through 5 provide locations and time series associated with output from the ADCIRC+SWAN model, which is described in the Combined Effects calculation (AREVA, 2015a). These figures show the resulting water levels for the PMH and PMWS scenarios, respectively. As noted from these figures, the elevated water levels associated with the PMH persist for approximately 10 hours; whereas, the PMWS generates high water levels for approximately 50 hours.

References

1. **AREVA, 2015a**. "Pilgrim Nuclear Power Station Flood Hazard Re-evaluation – Combined Effects", Revision 0, AREVA Document No. 32-9226937-000, 2015.

2. **AREVA, 2015b**. "Pilgrim Nuclear Power Station Flood Hazard Re-evaluation Report", AREVA Document No. 51-9226940, 2015.

3. **ASCE, 2010**. "Minimum Design Loads for Buildings and Other Structures", ASCE/SEI 7-10, American Society of Civil Engineers (ASCE), 2010.

4. **FEMA, 2007**. "Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update", Federal Emergency Management Agency, February 2007.

5. **PNPS, 2005**. "Intake Structure Sections", Drawing No. C46, Pilgrim Nuclear Power Station, Date Revised: December 2005.

6. **USACE, 2006**. Coastal Engineering Manual – Part VI, Chapter 5, "Fundamentals of Design," EM 1110-2-1100, U.S. Army Corps of Engineers, June 2006.

Figure 1: PNPS Wave Transects (AREVA, 2015b – Figure 3-49)

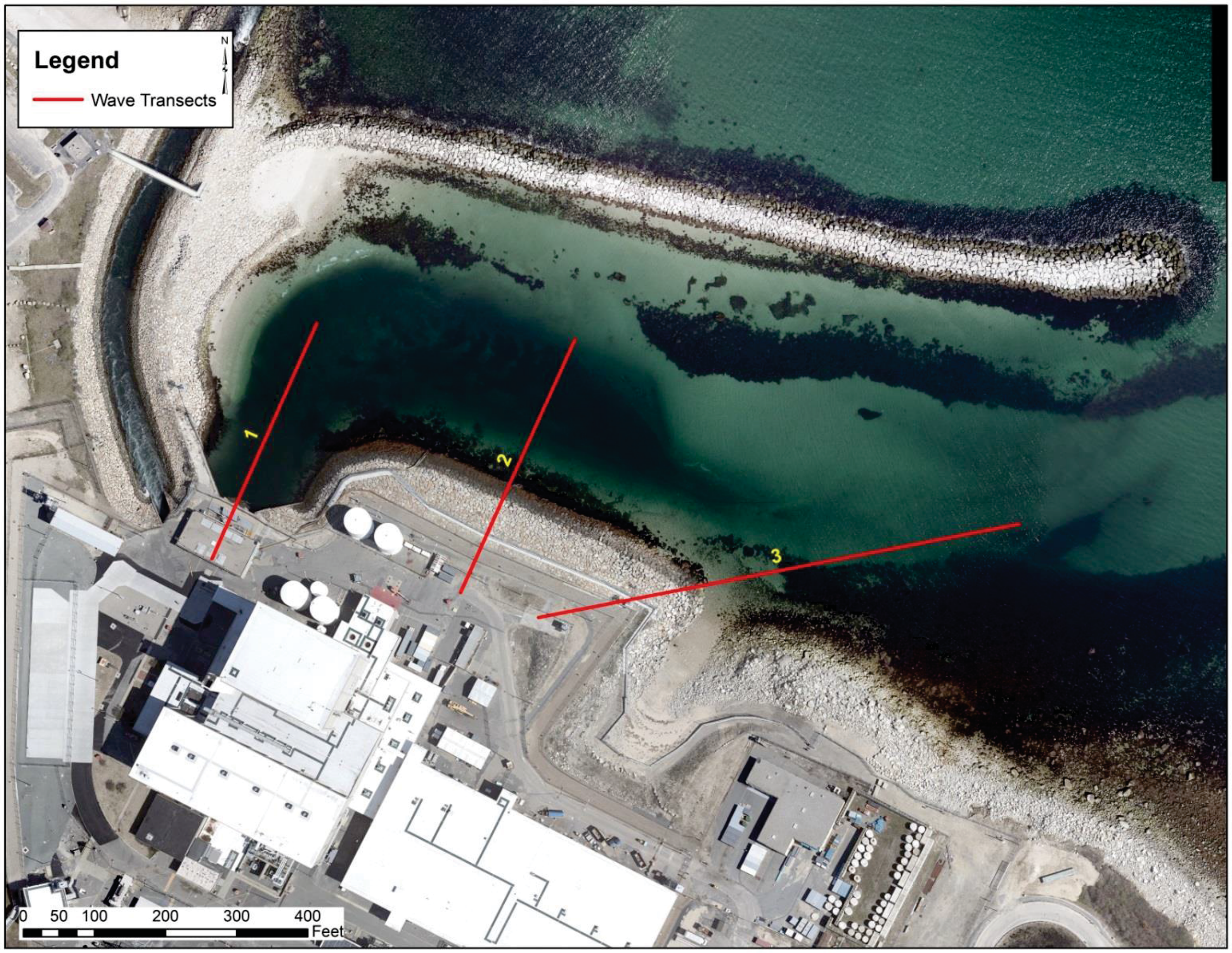
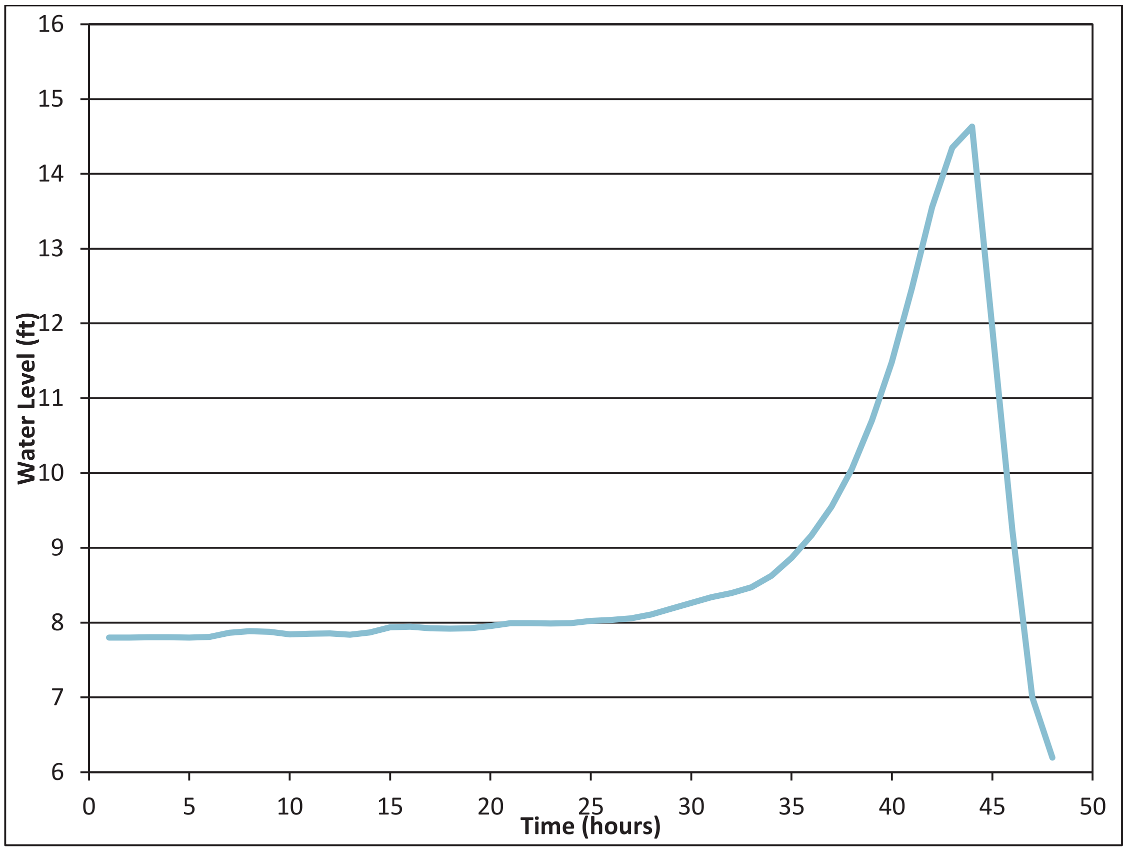


Figure 2: Coupled ADCIRC+SWAN Simulation Output Locations – PMH (AREVA, 2015b – Figure 3-39)

Figure 3: Coupled ADCIRC+SWAN Simulation Output Locations – PMH (AREVA, 2015b – Figure 3-42)

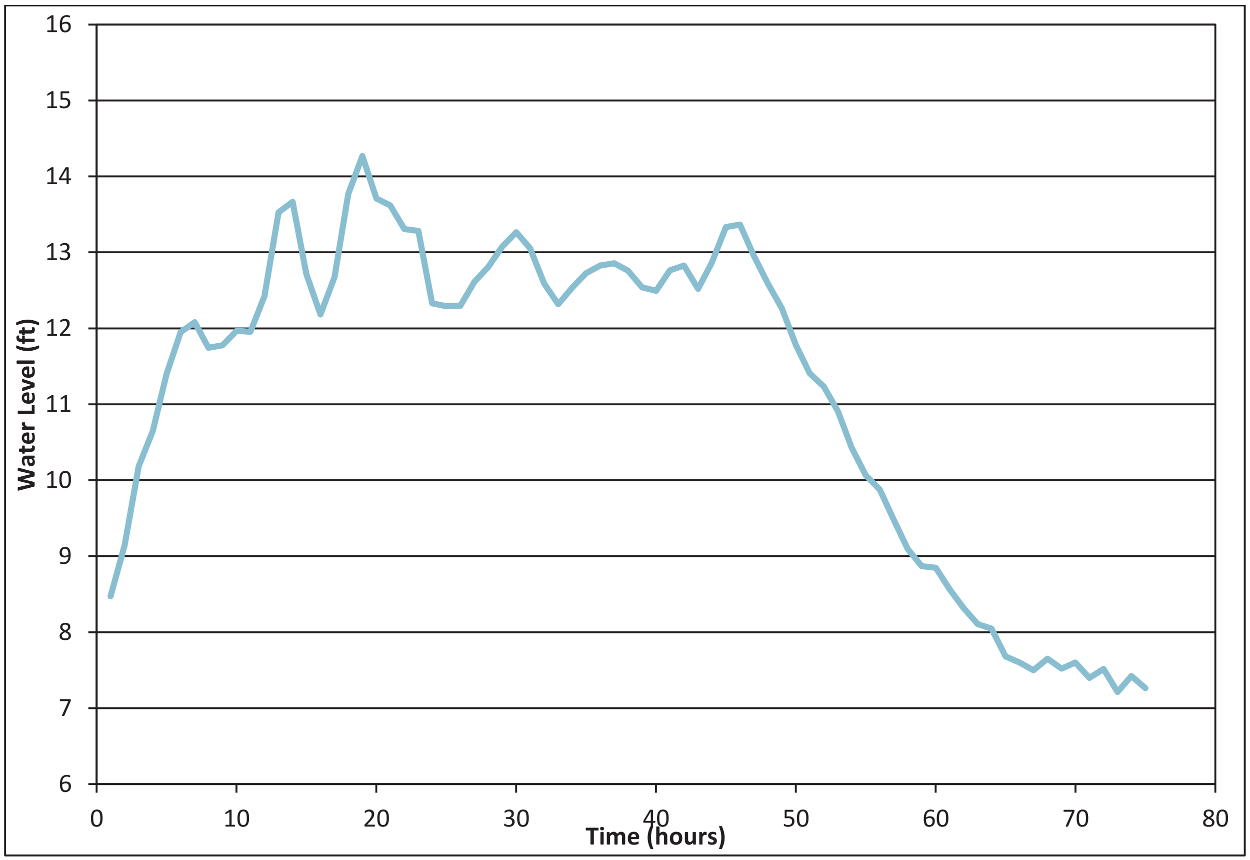


Notes:

1. Elevations referenced to the NAVD88 vertical datum.
2. Results from coupled ADCIRC+SWAN simulation at representative output location V2: -70.5722412556 longitude, 41.9465878842 latitude; see **Figure 2** for location.

Figure 4: Coupled ADCIRC+SWAN Simulation Output Locations – PMWS (AREVA, 2015b – Figure 3-40)

Figure 5: Coupled ADCIRC+SWAN Simulation Output Locations – PMWS (AREVA, 2015b – Figure 3-44)



Notes:

1. Elevations referenced to the NAVD88 vertical datum.
2. Results from coupled ADCIRC+SWAN simulation at representative output location V2: -70.5722412556 longitude, 41.9465878842 latitude; see **Figure 4** for location.