UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 21, 2016

Mr. Thomas A. Vehec
Site Vice President
NextEra Energy
Duane Arnold Energy Center
3277 DAEC Road
Palo, IA 52324-9785

SUBJECT: NUCLEAR REGULATORY COMMISSION REPORT FOR THE AUDIT OF NEXTERA ENERGY, LLC'S FLOOD HAZARD REEVALUATION REPORT SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR DUANE ARNOLD ENERGY CENTER (CAC NO. MF3683)

Dear Mr. Vehec:

The purpose of this letter is to provide you with the final audit report which summarizes and documents the U.S. Nuclear Regulatory Commission's (NRC's) regulatory audit of NextEra Energy Duane Arnold, LLC's (NextEra's, the licensee's) Flood Hazard Reevaluation Report (FHRR) submittal related for Duane Arnold Energy Center (Duane Arnold). The FHRR was submitted as part of implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear plant. Specifically, the FHRR documents the results of the flood hazard reevaluation being completed as part of NRC Near-Term Task Force Recommendation 2.1.

By letter dated June 17, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15160A715), the NRC informed you of the staff's plan to conduct a regulatory audit of NextEra's FHRR submittal for Duane Arnold. The audit was intended to support the NRC staff's review of the licensee's FHRR and the subsequent issuance of a staff assessment documenting the staff's review. The audit was conducted remotely during the months of July 2015 – March 2016, with periodic meetings to discuss NRC staff information needs. The NRC staff and NextEra held an exit meeting on March 28, 2016, during which the remaining documentation needs were discussed. The audit was performed consistent with NRC Office of Nuclear Reactor Regulation Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195). The details of this audit have been discussed with Mr. Tim Holt of your staff.

If you have any questions, please contact me at (301) 415-1056 or by e-mail at Lauren.Gibson@nrc.gov.

Sincerely,

Lauren Kate Gibson

Lauren K. Gibson, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-331

Enclosure:
Audit Report

cc w/encl: Distribution via Listserv

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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AUDIT REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FOR THE AUDIT OF NEXTERA ENERGY DUANE ARNOLD, LLC'S

FLOOD HAZARD REEVALUATION REPORT

SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-

FLOODING FOR DUANE ARNOLD ENERGY CENTER

DOCKET NO. 50-331

BACKGROUND AND AUDIT BASIS

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), "Conditions of Licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force report. Recommendation 2.1 in that document recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites using current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 and SECY-11-0137 instructed the NRC staff address this recommendation through the issuance of requests for information to licensees pursuant to 10 CFR 50.54(f).

By letter and enclosure dated March 10, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML14072A019 and ML14072A020, respectively), NextEra Energy Duane Arnold, LLC (NextEra, the licensee) submitted its Flood Hazard Reevaluation Report (FHRR) for Duane Arnold Energy Center (Duane Arnold, DAEC). The NRC is in the process of reviewing the aforementioned submittals and has completed a regulatory audit of NextEra to inform the licensee of its review of the submittals, identify any similarities/differences with past work completed, and ultimately aid in its review of licensees' FHRR. This audit summary is being completed in accordance with the guidance set forth in NRC Office of Nuclear Reactor Regulation Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195).

AUDIT LOCATION AND DATES

The audit was completed by document review via electronic reading room and teleconferences held on the following dates: September 10, 2015, November 5, 2015, December 14, 2015,

Enclosure

February 4, 2016, and March 21, 2016. A closeout meeting was held by telephone on March 28, 2016.

AUDIT TEAMS

Title	Team Member	Organization
Team Leader, NRR/JLD	Anthony Minarik	NRC
Branch Chief, NRO/DSEA	Aida Rivera	NRC
Technical Manager	Richard Rivera-Lugo	NRC
Lead Hydrologist	Mike Lee	NRC
Lead Meteorologist	Kevin Quinlan	NRC
Technical Support (hydro.)	Rajiv Prassad	Pacific NW National Lab
Technical Support (hydro.)	Nancy Boyd	Pacific NW National Lab
Technical Support (hydro.)	Yuan Yong	Pacific NW National Lab
Technical Support (met.)	Scott DeNeale	Oak Ridge National Lab
Technical Support (met.)	David Watson	Oak Ridge National Lab
Technical Support (met.)	Shieh-Cheh Kao	Oak Ridge National Lab
Site Fukushima Response Mgr	Curt Bock	NextEra (DAEC)
Licensing Engineer	Tim Holt	NextEra (DAEC)
Licensing Engineer	Clara Rushworth	NextEra (DAEC)
Fukushima Response Mgr	Ronnie Lingel	NextEra (Corp.)
Fleet Licensing Mgr	Bill Cross	NextEra (Corp.)
Technical Lead (hydro.)	Shaun Kline	Enercon
Technical Support (Hydro.)	Chris Moyer	Enercon
Technical Support (Hydro.)	Justin Pistininzi	Enercon
Technical Support (Hydro.)	Paul Martinchich	Enercon
Technical Manager (Hydro.)	Wayne Miller	Enercon
Technical Lead (Met.)	Bill Kappel	Applied Weather Assc. (AWA)
Technical Support (Met.)	Doug Hultstrand	AWA

DOCUMENTS AUDITED

Attachment 1 of this report contains a list which details all the documents that were reviewed by the NRC staff, in part or in whole, as part of this audit. The documents were located in an electronic reading room during the NRC staff review.

AUDIT ACTIVITIES

In general, the audit activities consisted of the following actions:

- Review background information on site topography and geographical characteristics of the watershed.

- Review site physical features and plant layout.

- Understand the selection of important assumptions and parameters that would be the basis for evaluating the individual flood-causing mechanisms described in the 50.54(f) letter.

- Review model input/output files to computer files, such as Hydrologic Engineering Center (HEC)-River Analysis System (RAS), FLO-2D, and HEC- Hydrologic Modeling System (HMS), to have an understanding of how modeling assumptions were programmed and executed.

Attachment 2 of this report provides more detail and summarizes specific technical topics (and resolution) of important items that were discussed and clarified during the audit. The items discussed in Attachment 2 may be referenced/mentioned in the staff assessment in more detail.

EXIT MEETING/BRIEFING:

On March 28, 2016, the NRC staff closed out the discussion of the technical topics described above. The NRC staff identified certain information that needed to be provided on the docket in order to resolve some of the items discussed during the audit. The information would update or supplement the FHRR based on the audit discussions. This information included the following:

1) A formal response providing flood elevation levels for the local intense precipitation event, and the riverine flooding event,
2) An explanation of the effects that changing the drainage basin area had on the FHRR values, and
3) The wind/wave analysis and justifications for using a fetch length that is smaller than the inundation area of the plant (i.e. mature vegetation and obstacles).

The requested information was received by letter dated August 12, 2016 (ADAMS Accession No. ML16229A159).

Attachments:
1. Audit Documents
2. Duane Arnold Information Needs – Audit/Post-Audit Summary

ATTACHMENT 1

Audit Documents
Alexeev, G. A., I. L. Kaljuzhny, V. Y. Kulik, K. K. Pav- lova and V. V. Romanov. 1972. "Infiltration of Snowmelt Water into Frozen Soil: The Role of Snow and Ice in Hydrology," Proceedings of the Banff Symposia, Vol. 1, Geneva, WMO, IAHS, UNESCO, Banff, pp. 313-325.
Dingman, S.L. 1975. "Hydrologic Effects of Frozen Ground: Literature Review and Synthesis." Cold Regions Research and Engineering Laboratory (CRREL) Special Report 218, U.S. Army CRREL, Hanover, NH.
Hinkel, K.M., S.I. Outcalt, and A.E. Taylor. 1997. "Seasonal patterns of coupled flow in the active layer at three sites in northwest North America." Canadian Journal of Earth Sciences, 34, pp. 667-678.
Luo, L., A. Robock, K.Y. Vinnikov, C.A. Schlosser, A.G. Slater, A. Boone, H. Braden, P. Cox, P. de Rosnay, R.E. Dickinson, Y. Dai, Q. Duan, P. Etchevers, A. Henderson-Sellers, N. Gedney, Y.M. Gusev, F. Habets, J. Kim, E. Kowalczyk, K. Mitchell, O.N. Nasonova, J. Noilhan, A.J. Pitman, J. Schaake, A.B. Shmakin, T.G. Smirnova, P. Wetzel, Y. Xue, Z.-L. Yang, and Q. Zeng. 2002. "Effects of Frozen Soil Temperature, Spring Infiltration, and Runoff: Results from the PILPS 2(d) Experiment at Valdai, Russia." Journal of Hydrometeorology, 4, pp. 334-351.
Sutinen, R., P. Hänninen and A. Venäläinen. 2008. "Effect of mild winter events on soil water content beneath snowpack." Cold Reg. Sci. Technol., 51, pp. 56–67.
U.S. Army Corps of Engineers (USACE). 1998. "Runoff from Snowmelt." Engineer Manual EM-1110-2-1406, Department of the Army, Washington, DC.
USACE 1984. "Shore Protection Manual, Volumes 1 and 2."
USACE 2008. "Coastal Engineering Manual," EM 1110-2-1100 Part II.

ATTACHMENT 2

Duane Arnold Information Needs – Audit/Post-Audit Summary

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
1	Local Intense Precipitation (LIP) Flood: Choice of Model Parameters Evaluation of the effects of flooding LIP on water surface elevations at the Duane Arnold Energy Center (DAEC) site is requested in the 50.54(f) letter. The licensee selected Manning's roughness coefficient values based on FLO-2D guidance. However, the staff noticed that for most land-use types, the licensee-selected values were at the lower end of the range of recommended values in the FLO-2D guidance. Because lower values of Manning's n roughness coefficient enhance water drainage away from site areas that may contain safety-related buildings, the estimated flood depth elevations could be underestimated near those critical facilities. The staff requests the licensee to provide justification explaining its rationale for selecting Manning's roughness coefficient values that are toward the lower range of recommended values.	The licensee noted that it had considered four land-use classes for the purposes of the LIP flood analysis. Those classes and the corresponding Manning's n values (the corresponding FLO-2D recommended ranges are in parentheses) were: Asphalt (0.02 – 0.05) Mixed asphalt and grass (licensee reasoned that asphalt with grass will have a higher roughness) Open ground with debris (0.1 – 0.2) Shrubs and forest litter (0.3 – 0.4) The Manning's n roughness values chosen by the licensee for asphalt-covered surfaces is 0.02 because the center of the DAEC powerblock site was completely impervious. For areas surrounding the site that are a mixture of impervious-covered surfaces and maintained pervious land cover, the licensee used the higher-end of the "asphalt" range (0.05). The licensee used a value of 0.2, the higher-end of the "open ground with debris" range for areas that were judged to consist of non-concrete/asphalt and un-forested surfaces. Forested areas north of the DAEC site were considered "shrubs and forest litter, pasture," with a corresponding roughness coefficient of 0.3, the lower-end of the suggested range. The licensee also noted that they had performed a sensitivity analysis using the higher-end of the recommended range of Manning's roughness values for all surfaces and found that the maximum increase in flood depths at the critical door locations identified in the FHRR was approximately 1 inch (in.). Although the degree of imperviousness of a surface does not control its roughness, the staff concluded that the licensee used the degree of imperviousness as a

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
		surrogate for vegetation growth cover that would affect roughness of a surface. The licensee's sensitivity analysis showed that the maximum water-surface elevations near critical door locations are not sensitive to Manning's roughness. The staff found that the licensee's explanation (reasoning) for choosing the values of Manning's roughness coefficient was reasonable. The staff concluded that the licensee's approach was reasonable and had met the general intent of the 50.54(f) letter. No further action is necessary.
2	LIP Flood: Model Configuration Evaluation of the effects of flooding of LIP on water surface elevations at the DAEC site is requested in the 50.54(f) letter. The FHRR described the use of area reduction factors (ARFs) and width reduction factors (WRFs) for representing permanent and temporary obstructions to flow within the licensee's FLO-2D modelling domain. The FHRR also stated that WRFs were used for grid cells corresponding to the location of the vehicle barrier system (VBS). The staff's review of the licensee's FLO-2D model setup revealed that the FLO-2D input files did not contain any data for ARFs for buildings and other temporary site structures. The staff review also revealed that although ARFs and WRFs for the VBS	The licensee confirmed that ARFs were not used in any of the FLO-2D LIP flood simulations. The licensee also stated that they did not include WRFs for those grid cells corresponding to the locations of the VBS in their LIP flood simulations. The licensee stated that a sensitivity run was performed with FLO-2D Pro Build 14.08.09, instead of the previously-used Build 13.11.06.[1] For the center-loaded temporal distribution of the site-specific LIP event, the licensee reported that the difference in simulated water depths at the selected doors was minimal between the two model runs. The staff verified that correctly including WRFs for grid cells corresponding to the location of the VBS in the FLO-2D model resulted in minimal difference in water depths at selected door locations. The staff concluded that the licensee's approach was reasonable and had met the general intent of the 50.54(f) letter. No further action is necessary.

[1] In Build 14.08.09, the FLO-2D developer had fixed a number of issues related to representation of grid cells with ARFs specified. One of these issues with earlier Build 13.11.06 was that meteoric water was retained on building roofs if the ARFs for those corresponding grid cells were set to a value of 1.

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	were specified in the licensee's FLO-2D input file, an option flag that turns on the use of ARFs and WRFs was actually turned off during all model simulations. The staff requests the licensee to clarify and resolve the inconsistency between the FHRR description and the actual model configuration in the modeling of buildings and VBS structures in the FLO-2D model.	
3	LIP Flood: Model Configuration Evaluation of the effects of flooding of LIP on water surface elevations at the DAEC site is requested in the 50.54(f) letter. The licensee's FLO-2D model considered building roofs as elevated flat surfaces from which roof runoff was allowed to drain evenly to surrounding areas. Section 11.4 of American National Standards Institute/American Nuclear Society (ANSI/ANS)-2.8-1992 recommends that building runoff used in the LIP flood assessment allow evaluation of worst-case roof drainage, including analysis of alternative points of roof drainage to maximize flood elevation adjacent to points of access and egress at safety-related structures, systems and components. Allowing roof runoff to drain adjacent to turbine building doors could substantially increase the water depths at those locations. A preliminary sensitivity analysis by the staff that directed part of the roof to drain near	In response to this information need request, the licensee noted that there was a possibility that secondary scuppers located on the building roofs could concentrate flow above the rolling doors on the north and south sides of the DAEC turbine building. However, the licensee showed that the estimated discharge in front of the doors in question would be about 1 cubic foot per second (cfs), but this would not occur at the time of the peak discharge during the LIP event. Additionally, because the roof parapets are approximately 13.5-in. high, minimal overtopping from the site-specific LIP depth of 14.1 in. is expected. The licensee's FLO-2D LIP flood model does not incorporate parapets and therefore does not take credit for water stored on the roofs. The staff agrees with the licensee that the FHRR LIP flood model is reasonably conservative, because it does not take credit for water stored on roofs. The staff concluded that the licensee's approach was reasonable and had met the general intent of the 50.54(f) letter. No further action is necessary.

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
	the turbine building doors showed that water depths adjacent to the doors would substantially increase. The staff requests the licensee to describe how drainage from facility roofs as represented in FLO-2D analyses is consistent with the recommendations of ANSI/ANS-2.8-1992, Section 11.4 or provide a revised analysis.	
4	Streams and Rivers: Drainage Area Used for the Probable Maximum Precipitation Estimation In developing the probable maximum precipitation (PMP) used to estimate the probable maximum flood (PMF) at the DAEC site, the licensee selected the complete drainage area of the Cedar River watershed at the point where the Cedar River joins the Iowa River. The FHRR reported that the area of the watershed upstream of the DAEC site is 6,250 mi^2, and the total drainage area at the mouth of the Cedar River is 7,824 mi^2. Because the area upstream of the DAEC site is about 20 percent smaller than the total watershed area, there could be a significant increase in the PMP if the smaller area is used with depth-area-duration curves to estimate basin average precipitation. The staff estimated that the maximum increase to both the Hydrometeorological Report (HMR) and the site-specific PMP depths for various durations could be as much as 9 percent. The staff requests the	The NRC staff noted that the upstream watershed area of 6,250 mi^2 area, corresponding to the watershed immediately above the DAEC site, is the appropriate area to use for the FHRR as it is (a) consistent with how the current design basis was developed and (b) accepted engineering practice for the conduct of such types of analyses. In an electronic reading room document (dated January 11, 2016), the licensee described a revised PMP analysis for a drainage area corresponding to 6,250 mi^2. In doing so, the licensee also removed those downstream subbasins (specifically subbasins SB30, SB31, SB32, SB33, and SB34) that no longer applied to their revised hydrologic model. The licensee's revised model relied on site-specific PMP depth-area duration values obtained from the HMR52 software to estimate the all-season and the cool-season PMP hyetographs for the subbasins comprising the 6,250 mi^2 drainage area. The licensee used seven storm centers, all located upstream of the DAEC site, and five temporal distributions for the precipitation estimates in the HEC-HMS simulations. The licensee repeated the all-season and the cool-season PMF analysis using the newly-estimated PMP hyetographs, keeping all other model parameters

<table>
<tr><th>INFO NEED</th><th>INFORMATION NEED DESCRIPTION</th><th>ACTION (POST-AUDIT)</th></tr>
<tr><td></td><td>licensee to justify the use of the larger watershed area as the basis for PMP estimation.</td><td>unchanged. The licensee determined that the all-season, front-third-loaded PMP storm centered on storm center 4 resulted in the highest peak discharge in the HEC-HMS simulations. The licensee found that the peak discharge for the all-season PMF increased by 4 percent, from 319,119 cfs to 331,973 cfs. The licensee determined that the cool-season, center-loaded PMP storm centered on storm center 4 resulted in the highest peak discharge in the HEC-HMS simulations. For the cool-season PMF, Alternative 3 (100-year snowpack and coincident snow-season PMP), the smaller (corrected) drainage area resulted in an increase of 1.5 percent in the peak discharge, from 402,509 cfs to 408,383 cfs. Using the newly-estimated discharge hydrographs at J27-28 (river discharge), SB28 (inflow), and SB29 (inflow) in the hydraulic model, the licensee found that the maximum stillwater water surface elevation (WSE) at the DAEC site increased to 765.2 ft North American Vertical Datum of 1988 (NAVD88) from the 763.5 ft NAVD88 reported in the FHRR.

Subsequently, in material provided to the NRC in connection with the audit (on February 22, 2016), the licensee presented an analysis using a “refined PMP depth-area-duration relationships” that were accepted by NRC’s review of the licensee’s site-specific PMP. The refined analysis, using the 6,250 mi^2 drainage area, resulted in a stillwater WSE of 764.8 ft NAVD88 at the DAEC site. The refined PMP depth-area-duration relationship is reproduced below.

<table>
<tr><td rowspan="2">Area (mi^2)</td><td colspan="5">Duration (hr)</td><td></td></tr>
<tr><td>6</td><td>12</td><td>24</td><td>48</td><td>72</td><td></td></tr>
<tr><td>10</td><td>7.1</td><td>9.6</td><td>13.6</td><td>15.5</td><td>15.6</td><td></td></tr>
<tr><td>100</td><td>6.9</td><td>9.3</td><td>13.4</td><td>14.8</td><td>14.9</td><td></td></tr>
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		<table><tr><td>200</td><td>6.7</td><td>9.0</td><td>13.1</td><td>14.4</td><td>14.5</td><td></td></tr><tr><td>500</td><td>6.4</td><td>8.5</td><td>12.4</td><td>13.8</td><td>13.9</td><td></td></tr><tr><td>1000</td><td>6.1</td><td>8.1</td><td>11.7</td><td>13.2</td><td>13.3</td><td></td></tr><tr><td>2000</td><td>5.7</td><td>7.6</td><td>11.0</td><td>12.5</td><td>12.6</td><td></td></tr><tr><td>5000</td><td>5.2</td><td>6.9</td><td>9.9</td><td>11.5</td><td>11.6</td><td></td></tr><tr><td>10,000</td><td>4.5</td><td>6.1</td><td>8.7</td><td>10.5</td><td>10.6</td><td></td></tr><tr><td>20,000</td><td>3.6</td><td>5.3</td><td>7.4</td><td>9.3</td><td>9.4</td><td></td></tr><tr><td colspan="6">Precipitation depths are reported in inches.</td><td></td></tr></table> The staff reviewed the model files and results summary associated with the licensee's refined HEC-HMS analysis, and verified the resulting stillwater WSE of 764.8 ft NAVD88 at the DAEC site. The staff concluded that the licensee's approach was reasonable and had met the general intent of the 50.54(f) letter. No further action is necessary. (The licensee also revised its wind-wave estimate for the higher WSE resulting from the refined PMF analysis. See Information Need 8, below.)
5	Streams and Rivers: Loss Rates for a PMF Event In its FHRR, the licensee stated that a constant loss rate was calibrated for each subbasin based on the historical event simulated in the calibration. The constant loss rates range from 0.11 to 0.3 in/hr. These constant loss rates lead to very large losses of the PMP rainfall and snowmelt in the PMF model,	In response to this information need request (dated July 23, 2015), the licensee asserted that modeling the whole Cedar River watershed PMF in a saturation-excess state would be overly-conservative. In support of that position, the licensee estimated that the depth of precipitation required to create saturated runoff conditions in the watershed would be approximately 25 in., which exceeds current

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	on the order of 50 percent of the total input. A real flood on the order of a PMP event would have saturated ground and after some time would not allow any additional infiltration; hence, the most conservative and typical assumption for PMF modeling is that ongoing losses are zero or minimal. The staff's sensitivity analyses with reduced constant loss rates show a significant increase in peak discharge and associated water-surface elevation near the DAEC site. The staff requests that the licensee justify the use of these large constant loss rates in the PMF model or revise the model with more commonly accepted constant loss rates.	estimates of the combined flood depth associated with snowmelt and a cool-season PMP. In a subsequent response (dated October 27, 2015), the licensee further asserted that most of the calibrated and validated infiltration rates for the DAEC watershed were at or below the minimum for NRCS Soil Group B, which is the dominant soil type for this particular watershed. The licensee also provided the references it cited as rationale for its selection of loss rate values, including allowance for infiltration capacity in frozen soils – i.e., Alexeev et al. (1972); Dingman (1975); Hinkel et al. (1997); USACE (1998); Luo et al. (2002); and Sutinen et al. (2008). These references were later examined by the staff. While the staff agrees that some infiltration can take place even under frozen soil conditions, the staff's sensitivity analyses demonstrated that the maximum PMF stillwater elevation at the DAEC site is very sensitive to selected loss rates in the DAEC watershed upstream of the site. The staff concluded that the licensee's approach was reasonable and met the general intent of the 50.54(f) letter. No further action is necessary. *References cited:* *Alexeev, G. A., I. L. Kaljuzhny, V. Y. Kulik, K. K. Pav- lova and V. V. Romanov. 1972. "Infiltration of Snowmelt Water into Frozen Soil: The Role of Snow and Ice in Hydrology," Proceedings of the Banff Symposia, Vol. 1, Geneva, WMO, IAHS, UNESCO, Banff, pp. 313-325.* *Dingman, S.L. 1975. "Hydrologic Effects of Frozen Ground: Literature Review and Synthesis." CRREL Special Report 218, U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, Hanover, NH.* *Hinkel, K.M., S.I. Outcalt, and A.E. Taylor. 1997. "Seasonal patterns of coupled flow in the active layer at three sites in northwest North America." Canadian Journal of Earth Sciences, 34, pp. 667-678.*

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		U.S. Army Corps of Engineers. 1998. "Runoff from Snowmelt." Engineer Manual EM-1110-2-1406, Department of the Army, Washington, DC. *Luo, L., A. Robock, K.Y. Vinnikov, C.A. Schlosser, A.G. Slater, A. Boone, H. Braden, P. Cox, P. de Rosnay, R.E. Dickinson, Y. Dai, Q. Duan, P. Etchevers, A. Henderson-Sellers, N. Gedney, Y.M. Gusev, F. Habets, J. Kim, E. Kowalczyk, K. Mitchell, O.N. Nasonova, J. Noilhan, A.J. Pitman, J. Schaake, A.B. Shmakin, T.G. Smirnova, P. Wetzel, Y. Xue, Z.-L. Yang, and Q. Zeng. 2002. "Effects of Frozen Soil Temperature, Sprint Infiltration, and Runoff: Results from the PILPS 2(d) Experiment ar Valdai, Russia." Journal of Hydrometeorology, 4, pp. 334-351.* *Sutinen, R., P. Hänninen and A. Venäläinen. 2008. "Effect of mild winter events on soil water content beneath snowpack." Cold Reg. Sci. Technol., 51, pp. 56–67.*
6	Streams and Rivers: Initial Loss for all Subbasins Evaluation of the effects of flooding of streams and rivers on water surface elevations at the DAEC site is requested in the 50.54(f) letter. The licensee stated in calculation package FPL-070-CALC-005 Rev. 0 that the initial loss was calibrated for each of the subbasins, and not the watershed as a whole. However, the NRC staff's review of the licensee's model files revealed that the initial loss values for all subbasins was set to 0.45 in. The staff requests that the licensee explain why all the initial loss values are the same.	The licensee stated that their calibration methodology assumed the same starting initial-loss value for all subbasins. It appears that the licensee also assumed the initial-loss value to be uniform across all 34 subbasins. In its response (dated July 23, 2015), the licensee explained that the starting initial-loss value for all subbasins was set at 1.0 in. prior to calibration. The initial-loss value was not calibrated for subbasins individually. The licensee used two major flood events in May 2004 and June 2008 recorded at the streamflow gauge 05464500, Cedar River at Cedar Rapids, Iowa for calibration of loss parameters. The June 2008 flood event was used as the calibration event and the May 2004 flood event was used as the validation event. The NRC staff reviewed the licensee's response and found the modeling approach initially being questioned to be reasonable. The staff concluded that the licensee's approach had met the general intent of the 50.54(f) letter. No further action is necessary.
7	Streams and Rivers: HEC-HMS Model Setup	

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
	The licensee developed a time series of incremental precipitation and snowmelt for each of 34 subbasins in the watershed. The precipitation scenario for the PMF was based on using storm center 6 and a center-loaded temporal pattern. However, while reviewing the licensee's HEC-HMS input files, the staff identified that the precipitation and snowmelt time series provided for subbasin 6 has a temporal pattern that is very different from all of the other subbasins, and appears to be from a front-loaded temporal pattern. The staff performed an HEC-HMS run with a center-loaded precipitation and snowmelt time series for subbasin 6 and determined that the peak discharge at DAEC, reported to be 402,509 cfs in the FHRR, reduced significantly. The staff requests that the licensee provide the appropriate precipitation and snowmelt input time series for subbasin 6 or to provide an explanation why the input time series currently in the licensee's HEC-HMS model is the appropriate one.	The licensee acknowledged that the FHRR PMF analysis relied on an erroneous hyetograph for subbasin 6. The licensee corrected the error and revised their HEC-HMS analysis using a center-loaded PMP with storm center 4 to be the controlling case. The staff reviewed the licensee's response and found it acceptable. The staff concluded that the licensee's approach had met the general intent of the §50.54(f) letter. No further action is necessary.
8	Streams and Rivers: Wind-Wave Activity In its FHRR, the licensee described the estimation of wind-wave activity coincident with the PMF in rivers and streams. Table 4-21 in the FHRR provides the wind setup and runup estimates used. However, the licensee did not provide details of the method it used to estimate wind wave activity.	In a response dated March 2, 2016, the licensee stated that a detailed description of the procedure to estimate wind-wave effects were contained in a document entitled "Calculation FPL-070-Cal-012 Revision 0, 'Co-Incident Wind Wave and Runup'." In its review of that calculation package, the staff determined that the licensee used the USACE *Shore Protection Manual* (USACE, 1984) and the *Coastal Engineering Manual* (USACE, 2008) to estimate wind-wave effects; use of

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
	The staff requests the licensee to provide a detailed description of wind wave estimation procedure including citations. It is requested that the licensee provide a detailed description of wind wave estimation procedure including the identification of appropriate citations.	these two documents in the estimation of wind-wave effects is consistent with current NRC guidance. The licensee also provided an updated wind-wave analysis based on the USACE methodology, but updated for higher stillwater PMF elevation, 764.8 ft NAVD88, for the corrected 6,250-mi^2 drainage area. The licensee's initial response, though, did not provide technical justification for the selection of fetch length. The staff subsequently requested that the licensee provide this information. In response to an e-mail inquiry (dated June 20, 2016), the licensee described its wind-wave analysis and provided clarification regarding the manner in which the fetch length was arrived at for the purposes of the FHRR wind/wave analysis. In its response, the following points are noteworthy: • Fetches affecting the DAEC site are restricted by geometry and limit wave growth. • Wave runup from the east, west, south, southwest, and southeast directions were evaluated because the longest unobstructed fetches occur in those directions. • The longest fetch length estimated was 11,200 ft in the south direction from the plant. • The southern fetch runs from the DAEC site to an elevated highway (the Briars Ferry Road location, to the south of the DAEC site) where the PMF stillwater elevation on the Cedar River is approximately 20 ft above the ground surface. • Mature vegetation would not be completely inundated by the floodwaters near the highway. Therefore, the licensee concluded that the longest fetch length in the south direction would be 11,200 ft.

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		The licensee's wind-wave results for the corrected 6,250-mi^2 drainage area for the various fetch directions are, based on a 2-year wind speed estimated by the licensee of 40 mph, were as follows (in feet):

Fetch Direction	PMF Stillwater Elevation (NAVD88)	Fetch Length	Sibul Wind Setup	Wave Setup	Wave Run-up	Total WSE (NAVD88)	Total WSE (MSL)
South	764.8	11,200	0.135	0.289	2.17	767.4	767.8
Southwest	764.8	10,000	0.122	0.276	2.06	767.3	767.7
Fetch Direction	PMF Stillwater Elevation (NAVD88)	Fetch Length	Sibul Wind Setup	Wave Setup	Wave Runup	Total WSE (NAVD88)	Total WSE (MSL)
West	764.8	1,600	0.031	0.117	0.85	765.8	766.2
Northeast	764.8	6,400	0.083	0.228	1.69	766.8	767.2
East	764.8	3,600	0.053	0.174	1.28	766.3	766.7
Southeast	764.8	3,600	0.053	0.174	1.28	766.3	766.7

The NRC staff reviewed the licensee's response and found the response to include a detailed description of the wind-wave activity calculation associated with the higher stillwater WSE obtained from the revised PMF calculation. Upon review, the staff concluded that the licensee provided adequate justification for the selection of the longest straight-line fetch and that their approach was reasonable. No further action is necessary.

References cited:

USACE 1984. "Shore Protection Manual, Volumes 1 and 2."

USACE 2008. "Coastal Engineering Manual," EM 1110-2-1100 Part II.

INFO NEED	INFORMATION NEED DESCRIPTION	ACTION (POST-AUDIT)
9	Ice Jams: Potential Ice Jam Location In its FHRR, the licensee described the potential for site flooding as a result of ice jams above and below the DAEC site. Based on its FHRR analysis, the licensee concluded that the current design basis bounds this particular flood hazard. However, when reviewing the description of the licensee's analysis, it is not clear whether the closest structure traversing the Cedar River to the DAEC site – the Blairs Ferry Road bridge – was considered as a potential location for the formation of an ice dam. The staff requests the licensee clarify whether the Blairs Ferry Road bridge location was considered as a potential location for the formation of an ice dam for the purposes of the FHRR analysis. Alternatively, if the site was considered, explain whether the flooding effects at this particular location could be discounted and thus are bounded by the current design basis flood elevation.	In response to this information need request, the licensee noted that it had considered ice jams at the Blairs Ferry Road bridge location. The staff reviewed the licensee's response and found it acceptable. The staff concluded that the licensee's approach had met the general intent of the 50.54(f) letter. No further action is necessary.

If you have any questions, please contact me at (301) 415-1056 or by e-mail at Lauren.Gibson@nrc.gov.

Sincerely,

/RA/

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Docket No. 50-331

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