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

May 31, 2018

Vice President, Operations
Entergy Nuclear Operations, Inc.
Indian Point Energy Center
450 Broadway, GSB
P.O. Box 249
Buchanan, NY 10511-0249

SUBJECT: NUCLEAR REGULATORY COMMISSION REPORT FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC.'S FLOOD HAZARD REEVALUATION REPORT SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 AND 3 (CAC NOS. MF3313 AND MF3314)

Dear Sir or Madam:

By letter dated May 6, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15124A340), the U.S. Nuclear Regulatory Commission (NRC) informed you of the staff's plan to conduct a regulatory audit of Entergy Nuclear Operations, Inc.'s (the licensee) Flood Hazard Reevaluation Report (FHRR) submittal related to the Near-Term Task Force Recommendation 2.1-Flooding for Indian Point Nuclear Generation Unit Nos. 2 and 3. The audit was intended to support the NRC staff review of the licensee's FHRR and the subsequent issuance of a staff assessment.

The NRC conducted audits at AREVA's offices in Washington, D.C. from June 11 to 12, 2015, at NRC Headquarters, in Rockville, MD, from February 2 to 3, 2016, and via webinars June 17, 2015, October 1, 2015, October 22, 2015, December 9, 2015, December 16, 2015, February 11, 2016, and March 24, 2016. The audits were performed consistent with NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008, (ADAMS Accession No. ML082900195). The purpose of this letter is to provide you with the final audit report which summarizes and documents the NRC's regulatory audit of the licensee's FHRR submittal.

Enclosure 1 transmitted herewith contains Security-Related Information and Critical Electric Infrastructure Information (CEII). When separated from Enclosure 1, this document is decontrolled.

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If you have any questions, please contact me at (301) 415-1132 or by e-mail at Joseph.Sebrosky@nrc.gov.

Sincerely,

Joseph M. Sebrosky, Senior Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket Nos. 50-247 and 50-286

Enclosures:
1. Audit Report (Non-Public)
2. Audit Report (Public)

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NUCLEAR REGULATORY COMMISSION AUDIT REPORT

FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC'S.

FLOOD HAZARD REEVALUATION REPORT SUBMITTALS

RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR

INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 AND 3

BACKGROUND AND AUDIT BASIS

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), 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 license" (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 Near-Term Task Force Review of Insights from the Fukushima Dai-ichi accident. 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 against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY 11-0124 and SECY-11-0137, instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

By letter dated December 23, 2013 (ADAMS Accession No. ML13364A005), Entergy Nuclear Operations, Inc. (Entergy, the licensee) submitted its Flood Hazard Reevaluation Report (FHRR) for Indian Point Nuclear Generating Unit Nos. 2 and 3 (Indian Point) and revised its FHRR on December 9, 2014 (ADAMS Accession No. ML14357A052). The NRC has completed a regulatory audit of the licensee to better understand the development of the submittal, identify any similarities/differences with past work completed and ultimately aid in its review of the 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 NRC conducted audits at AREVA's offices in Washington, D.C. from June 11 to 12, 2015, at NRC Headquarters, in Rockville, MD, from February 2 to 3, 2016, and via webinars June 17, 2015, October 1, 2015, October 22, 2015, December 9, 2015, December 16, 2015, February 11, 2016, and March 24, 2016. The audit was completed by document review with the use of the licensee's established electronic reading room (ERR).

AUDIT TEAM

The NRC audit team, and audit partipants were as follows:

Title	Team Member	Organization
Team Leader, NRR/JLD	Victor Hall	NRR
Team Leader, NRR/JLD	Tekia Govan	NRR
Technical Deputy Division Director	Andy Campbell	NRO
	Scott Flanders	NRO
Branch Chief, NRR/JLD	Mohamed Shams	NRR
Technical Branch Chief	Christopher Cook	NRO
Technical Branch Chief, NRO/DSEA	Aida Rivera-Varona	NRO
Technical Support	Mike Lee	NRO
Technical Support	Michelle Bensi	NRO
Technical Branch Chief, NRO/DSEA	Ken Erwin	NRO
Technical Lea	Brad Harvey	NRO
Technical Support	Barbara Hayes	NRO
Technical Support	Henry Jones	NRO
Technical Support	Kevin Quinlan	NRO
Technical Support	Richard Rivera-Lugo	NRO
Technical Monitor	Laura Quinn-Willingham	NRO
NRC Contractor	Scott DeNeale	Oak Ridge National Laboratory (ORNL)
NRC Contractor	David Watson	ORNL
NRC Contractor	Shih-Chieh Kao	ORNL
NRC Contractor	Chris Bender	Taylor Engineering (TE)
NRC Contractor	Pat Fitzpatrick	TE
NRC Contractor	Jim Marino	TE
Technical Support	Rajiv Prasad	Pacific Northwest National Laboratory (PNNL)
Technical Support	Nancy Kohn	PNNL
Technical Support	Adam Maxwell	PNNL
AUDIT PARTICIPANTS		
	Don Bentley	Entergy
	Mike Krupa	Entergy
	Bryan Ford	Entergy
	Virginia Conrad	Entergy
	Richard Drake	Entergy
	Mirzai Mahvash	Entergy
	Barbara Owens	Entergy
	Steve Prussman	Entergy
	Steve Saunders	Entergy
	John Skonieczny	Entergy

Title	Team Member	Organization
	Cindy Fasano	Areva
	Alan Thomas	Areva
	Chad Cox	GZA GeoEnvironmenta, Inc.
	Terie Dube	GZA
	David Leone	GZA
	Mike Mobile	GZA
	Jeremy Picard	GZA
	Dan Stapleton	GZA
	Christine Stonier	GZA
	Bill Kappel	AWA

AUDIT ACTIVITIES

In general, the audit activities consisted mainly 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 analyses such as Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) and FLO-2D to have an understanding of how modeling assumptions were programmed and executed.

Table 1 summarizes specific technical topics (and resolution) of important items that were discussed and clarified during the audit. The items discussed in Table 1 may be referenced/mentioned in the staff assessment in more detail.

EXIT MEETING/BRIEFING

By letter dated April 25, 2016 (ADAMS Accession No. ML16112A172), the NRC staff issued a summary of the reevaluated flood-causing mechanisms. That letter concluded that the licensee's reevaluated flooding hazard information is a suitable input for assessments associated with Near-Term Task Force Recommendation 2.1 "Flooding," thus closing out the discussion of the technical topics described above.

Table 1: Indian Point Information Needs – Audit/Post-Audit Summary

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
1	**All Flood Causing Mechanisms: Comparison of Reevaluated Flood Hazard with Current Design Basis (CDB)** The Flood Hazard Reevaluation Report (FHRR) for the Indian Point Energy Center (IPEC) site provides comparisons of the reevaluated flood hazards with the current licensing basis (CLB) for all flood-causing mechanisms for which a CLB had been established. Table 4.1.1 of the FHRR has a tabulated summary of this comparison. The request made of the licensee was to reconcile the CDB/CLB inconsistencies identified in the first version of the FHRR (Entergy, 2013a) and submit a revised hazard comparison consistent with the instructions provided in the 50.54(f) letter.	In responding to this request, during the June 4, 2015, audit meeting, the licensee noted that it had used the terms "CLB" and the "CDB" interchangeably in the revised 2014 version of the FHRR (Entergy, 2014) as they were viewed to be synonymous. In response, the staff noted that both the terms have distinct regulatory meanings. The staff concluded that the information provided by the licensee was sufficient to address this information need request.
2A	**Local Intense Precipitation (LIP): Detailed Modeling of the Yard Common to the IPEC Unit 2 Reactor and Turbine Buildings** Evaluation of the effects of flooding due to LIP on safety-related facilities at the IPEC site is requested in the 50.54(f) letter. In its FHRR, the licensee described its LIP analysis in Section 2.2.1. That analysis was based on a site-specific probable maximum precipitation (PMP) estimate rather than the staff-recommended approach to use an appropriate precipitation value obtained from the National Weather Service's *Hydrometeorological Reports* (or HMRs). Using the licensee's FLO-2D model for the IPEC site, the staff conducted an alternative LIP simulation using the HMR precipitation value that produced a probable maximum flood (PMF) elevation notably greater than the elevation obtained by the licensee using a site-specific PMP (ssPMP). This higher flood elevations would occur in the open yard between the Turbine Building and Reactor Building for Unit 2 where the maximum flood level is expected, as well as other powerblock area areas. During the audit, the licensee noted that this yard location is underlain by a French drain	The licensee placed a document in the ERR in December 2015 in response to this information need request. The licensee reported that there was no French drain system associated with the Unit 2 Turbine Building. The licensee did note, however, that there was a series of gravel-filled cisterns immediately behind the building that passively collect rainwater. Following a precipitation event, these cisterns are mechanically drained by reactor personnel using portable pumps (see Information Need 5). In order to determine the appropriateness of the ssPMP values used by the licensee and the resulting estimated water surface

[1] Some information need requests were points of clarification concerning information described in the FHRR or one of its references. Details concerning the results from that type of inquiry are captured in the staff's assessment of the licensee's 50.54(f) FHRR rather than in this table. Questions concerning such clarifications correspond to the numbered information needs are not included in this table and thus explains why the numbering system may have omissions.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
	system that passively directs flood water away from this location in recognition that this area has a propensity to collect rain water, albeit temporarily. It is requested that the licensee provide information concerning how the French drain system will drain the water accumulated in the open yard between the Turbine Building and Reactor Building for Unit 2. The licensee was asked to describe the sensitivity of the estimated LIP elevations to the efficiency of the drainage system at this particular location. It was asked that this information be based on a sensitivity analysis of the model to alternative conditions (system states) for this particular feature (at this location). For example, was the French drain at the location in question assumed to be fully functional and operating at 100 percent efficiency during the LIP event or, alternatively, was the drain assumed to be partially obstructed and not fully functioning? The licensee was also asked to describe any Technical Specifications, administrative controls or procedures for maintaining the efficiency of the drainage system.	elevations (WSEs) at the common yard location, the staff independently evaluated the sensitivity of the licensee's FLO-2D LIP model. The staff compared WSEs from the ssPMP with the WSEs modeled at the location in question using precipitation values obtained from HMR-52 (NOAA, 1982). The 1-h, 1-mi² PMP value at the Point Beach (NY) site estimated using the HMR-52 method was 17.3 inch (in.), compared to the 9.4 in. estimated using the ssPMP; this resulted in a 46% difference in the total estimated rainfall depth. The sensitivity analysis resulted in a WSE difference of about 1.27 feet (ft.) (71%) in the open yard between the Turbine Building and Reactor Building for Unit 2. The results of the staff's sensitivity analysis indicated that the WSEs estimated using the HMR-derived value were significantly higher than the WSEs estimated using the licensee's ssPMP-based value. As a consequence, the NRC staff determined that it should review how the licensee generically derived the ssPMP for sites. This generic review action was undertaken as an activity applicable to all of the FHRR submittals relying on a ssPMP-derived estimate. No further action is necessary for this information need request.
5	**LIP: Supercritical Flow** Evaluation of the effects of flooding of LIP on WSEs at the IPEC site is requested in the 50.54(f) letter. Using the revised FLO-2D simulation, the licensee determined that supercritical flow would occur along the steeply-	During the June 17, 2015, audit meeting the licensee noted that the FLO-2D computer code did not have the capability to explicitly model hydraulic jumps. As a consequence,

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
	sloped access road on the northeast side of the Unit 2 Turbine Building (referred to locally as 'heart attack hill"), and along the sloped access road on the southwest side of the power block. The licensee described that the steeply-sloped access roads transition to less steeply-sloped areas. The licensee did not analyze if a transition from supercritical flow back to subcritical flow could occur at or near the transition areas and also did not consider how flood WSEs could change both upstream and downstream of the transition points or potential impacts on flood elevations at structures, systems, and components (SSCs). It was requested that the licensee provide an analysis of the supercritical- to the subcritical-flow transition, and what the related effects of any potential transition may be on flood-related WSEs and associated effects such as hydrodynamic loading including debris in Unit 2 transformer yard and adjacent to points of access and egress at safety-related SSCs.	the licensee presented an alternative calculation to support its view that a hydraulic jump would not form downstream along the base of the steeply-sloped north access road. In that supplemental analysis, the licensee estimated that the Froude number for the upstream cross-section at the downslope end of the north access road was approximately 2.9, suggesting supercritical flow conditions generally exist in this area. Using the conjugate depth equation, the licensee estimated that the flow depth following a hydraulic jump in a uniform-width cross-section would be about 1.6 ft. Because the FLO-2D computer code predicted a maximum flow depth of 1.2 ft. in the area immediately west of the north access road, the licensee expressed the view that a hydraulic jump would not form, that surface flow in this area would remain supercritical, and that there would be no increase in the estimated WSE generally in this area. The licensee further stated that even if a flow transition (from supercritical to subcritical flow) were to occur, the area west of the turbine building is essentially unconfined where surface flows would be expected to dissipate. Aerial photographs of the site indicate that the area in question around Unit 2, west of the Unit 2 Turbine Building is broad and is sufficiently wide to allow the surface flow to spread laterally, flow energy to dissipate, and flow depths to remain relatively small even if a hydraulic jump were to form.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		During the discussions related to this particular information need, the licensee was also asked to explain why certain grid cells behind IPEC Unit 2 showed estimated flood elevations of up to 10 ft. based on FLO-2D computer modeling. In response, the licensee noted that the grid cells in question corresponded to topographic depressions that had been filled with permeable material that allowed for the collection of meteoric rainwater; they were not French Drains as previously suspected by the staff. (Also see information need request 2A.) Because these features would act as "sinks" of mass flow in the computer simulations, the WSEs reported by the licensee reflect how much water those depression features collected rather than representing how much rain water might actually accumulate above the nominal powerblock grade in the area behind Unit 2. The staff concluded that the information provided by the licensee was sufficient to address this information need request.
7	**Streams and Rivers: Wind Waves** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, American National Standards Institute/American Nuclear Society (ANSI/ANS)-2.8-1992 recommends consideration of wind waves induced by 2-year wind speed applied along the critical direction for floods caused by precipitation events. Wind waves could increase the depth of flooding of the reevaluated flood. Section 2.3.1 of the FHRR notes that wind-wave effects were considered in connection with the PMF. However, it is not clear whether those effects were evaluated consistent the ANSI/ANS recommendations.	During the June 4, 2015, audit meeting, the licensee noted that this information need request would be addressed in connection with its response to Information Need 21, below. To address both information need requests, the licensee made available Calculation Package No. 32-9196323-000, (entitled "Combined Events Flood Analysis – Riverine Calculation") for review in the ERR. In its review of that calculation package, the staff subsequently determined that the

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
	The staff requested that the licensee provide details concerning how the effects of wind-wave activity were considered in connection with the PMF.	licensee estimated 2-year wind speed using measured wind data from a National Climatic Data Center (NCDC) station. The licensee then relied a Gumbel type distribution to statistically represent the distribution of the fastest 2-minute wind speeds. The Gumbel distribution is commonly used to model the statistical properties of extreme events. The licensee estimated fetch line lengths on the Hudson River as the longest wetted top width perpendicular to the IPEC shoreline. Lastly, the licensee estimated the wind wave height, period, and wave runup using the U.S. Army Corps of Engineer's (USACE's) CEDAS-ACES v.4.03 software. The CEDAS-ACES software (VTE, 2017) is commonly used as the tool for performing wind wave calculations. Consequently, the staff determined that the licensee's wind-wave estimation methodology was consistent with standard engineering practice. The staff concluded that the information provided by the licensee was sufficient to address this information need request.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
8	**Streams and Rivers: Snowmelt and Rainfall Timing** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, the licensee stated that hourly snowmelt rates were calculated for each subwatershed (e.g., subbasin), and an "... additional 4.6 inches (in.) of snow-water equivalent (varies by subbasin location) was added to the 72-hour (hr) Cool Season [probable maximum precipitation] PMP ...." Timing issues of the snowmelt and rainfall-runoff processes would have an impact on the characteristics of the flooding characteristics near the IPEC site. It is requested that the licensee provide information describing the time-distribution of the snowmelt hydrograph and how it was added to the site-specific, cool-season PMP time distribution.	During the June 17, 2015, audit meeting, the licensee noted that it relied on both the Federal Energy Regulatory Commission's (FERC's) "Engineering Guidelines for the Evaluation of Hydropower Projects" and ANSI/ANS-2.8-1992 to estimate the temporal distribution of snowmelt during a cool-season PMP event. The licensee estimated the 100-year snowmelt rates for each 1,000-ft. increment in topographic elevation at hourly time steps. Meteorological time series data (precipitation, temperature, dew point, and wind speed) were then obtained from that storm among eight storms used in the estimation of the site-specific cool-season PMP, which had the overall greatest observed average temperature, dew point, and wind speed. The hourly time series were created for a 120-hr period including the 72-hr PMP period. The data were temporally arranged in the same order as that of the PMP data set. The energy budget method described by the USACE (USACE EM1110-2-1406) was then used to estimate hourly snowmelt rates. Finally, the estimated temporally-varying snowmelt depths were added to the cool-season site-specific PMP depths (according to Calculation Package No. 32-9196314-000, "IPEC Probable Maximum Precipitation Calculation") to obtain the cool-season hyetograph. The staff concluded that the information provided by the licensee was sufficient to address this information need request.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
10	**Streams and Rivers: Infiltration Losses and Computation of PMF Discharges** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, the licensee stated that initial and constant loss rates for the HEC-HMS model were calibrated. FHRR Table 3.2-1 shows that the verified initial loss rates for all subbasins were set to zero. Table 3.2-1 of the FHRR also shows that the verified constant loss rates for the subbasins ranged from 0.03 to 0.17 in./hr. The cumulative precipitation losses over the 72-hr duration of the PMP storm, therefore, ranged from 2.16 to 12.24 in, which is a significant fraction (16 to 92%) of the combined water equivalent, 13.3 in., of the basin-specific, basin-average cool-season PMP and snowmelt. When discussing infiltration rates during the May 27-30, 2014, audit meeting (NRC, 2014), the licensee's subject matter expert explained that constant loss rates were initially based on minimum published infiltration rates for each hydrologic soil group which were changed during calibration. High infiltration rates can have a significant impact on flood characteristics. It is requested that the licensee provide a table describing the cumulative 72-hr average combined water equivalent of a cool-season PMP that takes into account snowmelt as well as infiltration losses for each subbasin area. It is also requested that the precipitation loss fraction during the PMP event be compared to other available PMF applications carried-out by other authorities in the Hudson River watershed. The licensee should also provide the constant loss rates used before calibration based on hydrologic soil groups for each subbasin referenced in the May 2014 audit meeting. In reference to the precipitation loss rates listed in Table 3.2-1, which were calibrated and validated to flood events much smaller than the PMF event, the FHRR text does not include a narrative describing the basis for their selection; it is requested that the justification for their selection be provided. Lastly, it is requested that the licensee provide any other information available that could support such high infiltration rates.	The licensee provided a draft response in the ERR in advance of the June 17, 2015, audit meeting (file name "Indian Point Info Needs Draft Responses Part 2 without 2, 3, 27, 28, 29," dated June 15, 2015). The licensee noted that the Manning's infiltration rate values selected for the HEC-HMS computer simulations were taken from Maidment's 1993 *Handbook of Hydrology*. Consistent with the staff's request, the licensee prepared tables containing the requested information and described how they applied that information to the computer simulations that formed the basis for the FHRR. The licensee specified the initially-estimated infiltration rate (constant or continuing loss rate) for each subbasin by calculating the area-weighted average of the minimum infiltration rates for the hydrologic soil types in each subbasin. The licensee reported that the IPEC area-average initial constant loss rate was 0.081 in./h. During validation of the model using floods events from October 1995, June 2006, and November 2006, the licensee estimated the constant loss rate to be 0.073 in./h. The staff concluded that the information provided by the licensee was sufficient to address this information need request. However, the staff used the information in the tables provided in the licensee's response to develop follow-on Information Need 10A.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
	This information need request is also related to Information Needs 19, 20, and 26.	
10A	**Streams and Rivers: Infiltration Losses and Computation of PMF Discharges** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. Table 4.1-1 of the FHRR (Revision 2) and updates to this table included in the licensee's response to Information Need 1 show that the current design basis for a PMF in the Hudson River at the reactor site is 12.7 ft. National Geodetic Vertical Datum of 1929 (NGVD29). This table also lists the current design basis for combined effects flooding to be 15.0 ft. NGVD29. The plant site grade is also 15.0 ft NGVD29. The reevaluated PMF stillwater elevation (without wind-wave effects) is reported as 14.6 ft. NGVD29, giving an available margin of 0.4 ft. The licensee provided infiltration losses for subbasins of the greater Hudson River watershed in Table 10.2 of its June 15, 2015, responses to information needs. Using the data in this table, the NRC staff independently estimated that the 72-hr losses range from 15.7 to 64.7% of 72-hr PMP plus coincident snowmelt. The staff also estimated that the watershed-average loss is 36.7%. The magnitude of the loss is a significantly high fraction of the precipitation plus coincident snowmelt, especially for an extreme event like the PMP and the fact that during winter, at least part of the watershed is likely to have frozen soils.	The licensee's response to this information need request was placed in the ERR and is dated December 21, 2015; in that response, the staff-recommended sensitivity analysis was not included. In reviewing that response, the staff noted the following regarding the licensee's modeling views concerning loss rates and potentially frozen soils: • *Frozen soils: The licensee stated that because 58% of the Hudson River watershed surface area has a minimum of 66% forest cover; these areas are likely to remain unfrozen during winter months (i.e., during a cool season PMP event). The licensee further stated that the assumptions used for the cool-season PMF calculations are not compatible with frozen soils (ripe snowpack indicating pre-warming and insulating properties of a snowpack).*

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
	Given the limited available margin (0.4 ft.) between the licensee's reevaluated PMF stillwater elevation and the current design basis, the staff recommended that the licensee perform a sensitivity analysis to evaluate the likely variation of PMF stillwater elevation at the IPEC site with lower loss rates that account for extreme precipitation events and potentially frozen soils.	• *Loss rates: The licensee stated that about 83% of the Hudson River watershed surface area has soils belonging to Hydrologic Soil Group (HSG) A, B, or C. According to Calculation Package 32-9196315-000, out of 19 subbasins of the IPEC watershed, 6 subbasins have constant loss rates of 0.05 in/hr or less (effectively group HSG D). Soils classified as group HSG D constitute about 42.4% of the IPEC watershed surface area. Thus, there appeared to be a discrepancy in the area percentages reported in the information need response (83%, above) and that obtained from Calculation Package 32-9196315-000 (i.e., 100% – 42.4% = 57.6%).* During the February 11, 2016, audit meeting, the staff requested clarification concerning the highlighted discrepancy. The licensee uploaded a revised response to the ERR on February 24, 2016. In its amended response, the licensee clarified that it used NRCS soil classification data to obtain the area of each subbasin for each soil class, then summed the subbasin data to obtain a total of 1.3 million acres classified as group HSG D, or less than 17% of the 8-million-acre total Hudson River watershed surface area and hence the remaining 83% of the watershed having been classified as having either HSA A, B, or C soil groups. The response also

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		clarified that subbasin loss rates were assigned after the HEC-HMS model calibration and verification process was completed, thus loss rates should not be used to determine the specific NRCS soil classification(s). The staff concluded that the information provided by the licensee was sufficient to address this information need request.
11	**Streams and Rivers: HEC-RAS Setup and Calibration** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, the licensee stated that the HEC-RAS model was calibrated by uniformly adjusting Manning's n values of the main channel until peak WSEs at US Geological Survey (USGS) Gage Station 01376304 were "... generally within one foot of the peak observed historical data ...." Calibration of hydraulic parameters can impact flood characteristics near the IPEC site. It is also requested that the licensee provide justification that a uniform Manning's roughness coefficient value applied over the entire model reach is a reasonable assumption. In this regard, it is requested that the licensee explain whether this one-foot difference is conservative (i.e., above or below the historical value), and whether any filtering (e.g., moving average or box smoothing) was performed. For example, were the trends compared with the higher harmonics removed? The licensee should provide time-series comparison plots, if available, and some quantification of error associated with the analysis.	The licensee provided a draft response to this information need request in the ERR in advance of the June 17, 2015, audit meeting (file name "Indian Point Info Needs Draft Responses Part 2 without 2, 3, 27, 28, 29," dated June 15, 2015). In its response, the licensee noted that during the calibration of the HEC-RAS model, they observed a model behavior that was hydraulically counter-intuitive – i.e., the WSEs predicted by the computer simulation increased with decreasing valves of the Manning's roughness coefficient. The licensee expressed the opinion that this modeling behavior was caused by the tidal influence in the model reach (specifically a terminal boundary condition at the Manhattan Battery location). Thus, when lower values of the Manning's roughness coefficient are applied to their model, tidal flow influences occurring at the Manhattan Battery location would extend upstream, effectively creating a backwater effect, and in doing so lead to an increase in flow depth near the IPEC site. Although this type of behavior might be true

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		for nominal flow conditions within the HEC-RAS computer model, the staff observed that the same model behavior, of varying Manning's roughness coefficient values during calibration runs, would also be valid during PMF discharges, which are several times larger than the discharges used during model calibration. (The staff noted that the literature tends to support the licensee's interpretation of the modeling results relative to tidal influences.) In response to the second part of this information need request, the licensee prepared a table containing the observed WSEs for two calibration events and modeled peak WSEs corresponding to three different Manning's n values. The licensee described how they applied that information to the computer simulations that formed the basis for the FHRR. The staff concluded that the information provided by the licensee in the ERR was sufficient to address the information need request. However, the staff used the information in the table in the licensee's response to develop follow-on Information Need 11A.
11A	**Streams and Rivers: HEC-RAS Setup and Calibration** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. Table 4.1-1 of the FHRR (Revision 2) and updates to this table included in the licensee's response to Information Need 1 show that the current design basis for a PMF in the Hudson River at the reactor site is 12.7 ft. NGVD29. This table also lists the current design basis for combined effects flooding to be 15.0 ft. NGVD29. The plant site grade is also 15.0 ft. NGVD29. The reevaluated PMF stillwater	The licensee submitted a response to this information need request to the ERR on December 21, 2015; however, the response did not include the staff-recommended sensitivity analysis. Alternatively, the licensee cited a few references from the literature to support an argument that the lower Manning's n values obtained during

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	elevation (without wind-wave effects) is reported as 14.6 ft. NGVD29, giving an available margin of 0.4 ft. In its June 15, 2015, responses to information needs, the licensee stated that its HEC-RAS calibration process was counter-intuitive because lower values of Manning's roughness coefficient resulted in higher model-predicted stillwater elevations at the IPEC site. The staff performed a sensitivity test to determine if the counter-intuitive behavior of the water-surface elevation to Manning's roughness coefficient values holds for cool-season PMF discharges. The staff's results, using the licensee's HEC-RAS model and only altering the Manning's roughness coefficient value, suggest that the predicted stillwater elevation at the IPEC site is highly sensitive to changes in Manning's roughness coefficient values. Additionally, the PNL staff found that for the cool-season PMF discharge, the HEC-RAS predictions show the expected behavior with Manning's roughness coefficient (higher values of Manning's roughness coefficient lead to higher predicted stillwater elevations). The staff also observed that a small change in Manning's roughness coefficient resulted in the model-predicted stillwater elevation to exceed the current design basis for combined effects flooding, 15.0 ft. NGVD29. Given the small available margin (0.4 ft) between the licensee's reevaluated PMF stillwater elevation and the current design basis, the staff requested that a sensitivity analysis be carried out to evaluate the likely variation of PMF stillwater elevation at the IPEC site for the range of literature-recommended Manning's roughness coefficient values for natural streams. In particular, it was requested that the licensee explain why varying the values of Manning's roughness coefficient during calibration runs would be valid during PMF discharges, which are several times larger than the discharges used during calibration. The staff also requested that the licensee provide a parametric sensitivity to support its reasoning.	model calibration were appropriate. The licensee stated that the Manning's n value of 0.022 obtained during model calibration provided a better match with observed flood discharges. The licensee also noted that the PMF discharge is largely contained by fjord-like geometry (i.e., high valley walls) of the Hudson River. In connection with its independent evaluation of the FHRR results, the staff performed a sensitivity analysis using the licensee's HEC-RAS computer model. That sensitivity analysis indicated that at PMF discharge levels, the WSE increased as the magnitude of the Manning's n value increased; these results were contrary to those reported by the licensee during its calibration runs. During a February 11, 2016, audit telephone call, the licensee agreed to perform the requested sensitivity analysis. Following the completion of those sensitivity runs, the licensee provided an updated response to Information Need 11A to the ERR dated February 24, 2016. In that response, the licensee described additional HEC-RAS computer simulations that it had performed based on a Manning's n value that had been increased over a range of 10 to 20%. The licensee reported that the corresponding WSEs now being estimated given a larger Manning's value were 14 to 23% higher than that originally reported in the FHRR. The WSE behavior observed by the licensee

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		qualitatively agreed with the staff's sensitivity analysis. Using a Manning's n value of 0.022 that was obtained from earlier HEC-RAS computer simulations, the licensee's calibrated HEC-RAS computer model predicted a stillwater elevation of 14.6 ft. NGVD29 at the reactor site. When taking into account the tidal influence at the downstream Manhattan Battery location, the computer simulations are likely to show lower Manning's n values and higher stillwater elevations near the IPEC site (i.e., the lower value of Manning's n would favor tidal waters to move farther upstream in the Hudson River thereby resulting in higher stillwater elevations upstream). Based on this reasoning, the staff concluded that the licensee's use of a Manning's n value of 0.022 in the tidally-influenced alternative PMF scenarios (ANSI/ANS-2.8-1992 Section 9.2.2.2 Alternatives II and III) was reasonable.[2] The staff noted that this determination is based in large measure on the fact that the licensee-estimated storm surge-influenced flooding scenario currently bounds the PMF resulting from a precipitation and/or snowmelt event combination occurring within the Hudson River drainage area.

[2] A copy of the licensee's preferred Alternative II HEC-RAS computer model was not made available to the staff. Alternatively, a sensitivity analysis was performed by the staff using the PMF HEC-RAS computer model with the downstream boundary condition changed to reflect NRC's estimate of the antecedent tidal level at the Manhattan Battery location.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		The staff concluded that the information provided by the licensee was sufficient to address this information need request.
15	**Streams and Rivers: Downstream Boundary Condition for the HEC-RAS Model** Evaluation of the effects of flooding of streams and rivers on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, the FHRR does not describe the downstream boundary condition used for the HEC-RAS model to evaluate this hazard. The formulation of the downstream boundary condition (at the Manhattan Battery) could impact flood characteristics at the IPEC site. For tidally-influenced downstream boundary conditions, the HEC-RAS manual recommends using a temporal weighting factor (theta) as close to 0.6 as possible. It was requested that the licensee describe how the downstream boundary condition for the stream/river flood analysis was formulated using HEC-RAS, and how it reflects the 10-percent exceedance high tide as recommended in NUREG/CR-7046, Appendix H. For the PMF calculation, for example, it was requested that the licensee explain whether a historical time series or predicted time series of tidal elevations was used at the downstream boundary of HEC-RAS. The licensee was asked to describe the time period considered and how did peak tide correlate with travel time to the IPEC site of the inflow hydrograph. The licensee was also asked to explain how tidal asymmetry was handled by the HEC-RAS model and whether there were any stability problems. The licensee was asked to describe the value of theta used and whether other adjustments were made to avoid reductions in the accuracy associated any theta values greater than 0.6. Lastly, the staff requested that the licensee provide a description of any error or warning messages obtained from the HEC-RAS model when it was executed.	The licensee's response to this information need request was in the file entitled "Indian Point Info Needs Draft Responses Part 2 without 2,3,27,28,29", and dated June 15, 2015. During the June 17, 2015, audit meeting, the licensee noted that it had relied on tidal records taken in the vicinity of the Manhattan Battery to estimate the downstream boundary condition for the Hudson River HEC-RAS computer model. The upstream and downstream model limits, and the respective boundary conditions selected for the FHRR analysis, were initially described in the Sections 2.1.1 and 6.1.1 of Calculation Package No. 32-9196316-000, entitled "IPEC Probable Maximum Flood on Hudson River – Hydraulics Calculation." The staff reviewed that calculation package. The licensee also noted that it had selected a 10-percent exceedance high tide for the downstream boundary condition at the Manhattan Battery location based on the recommendations of Appendix H to NUREG/CR-7046. The licensee also stated that the 10-perecent exceedance high tide downstream boundary condition was specified as a constant WSE value, and was not treated as a varying tide level. The licensee stated that its use of theta value of 1.0 is appropriate according to the HEC-RAS *User's Manual*. The licensee also

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		performed a sensitivity analysis by setting the theta value to 0.6 in. the HEC-RAS computer model. The licensee's sensitivity analysis showed minimal change in the maximum estimated WSE at the IPEC site. The licensee also provided a listing of HEC-RAS model warning messages and noted that no error messages were produced by the model during the computer simulation. The staff reviewed these warning messages and determined that they were not germane to the computational stability of the model. The staff concluded that the information provided by the licensee was sufficient to address the information need request.
16 (~~CEII~~)	**Dam Failures: Debris Loads** Evaluation of the effects of dam failures on WSEs at the IPEC site is requested in the 50.54(f) letter. In connection with that evaluation, the licensee stated that debris load was evaluated but was unclear whether this was evaluated as debris impact on SSCs at IPEC, or with respect to the dam breach. The staff requested that the licensee provide clarification on this point, as NUREG/CR-7046 discusses debris loads relative to SSCs, but japan lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2013-01 recommends that they also be with respect to effects on dams. It was also requested that the licensee provide a description of how debris flow was treated in the dam failure evaluation.	During the June 4, 2015, audit meeting, the licensee noted that the debris load portion of the dam failure analysis had been completed in April 2013 prior to the issuance of NRC interim guidance JLD-ISG-2013-01 (in July 2013). The licensee also expressed that view that its analysis was, nevertheless, consistent with the staff's interim guidance and within the available water level margin at the site (i.e., the [redacted] difference between the [[redacted]] critical PMF WSE for SSCs within the powerblock and the [redacted] WSE associated with the dam failure scenario). The licensee also reported that it had conducted an analysis involving the forced failure of the [[redacted]]; that analysis produced an estimated WSE of [redacted] at the IPEC site which is less than the finished grade of the reactor site.

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		Following the audit meeting, the licensee submitted a supplemental response to this information need dated June 8, 2015 (filename "Indian Point Info Needs Responses 6-4-15 Part 1 PMP"). Later, during an October 26, 2015, telephone conference with the licensee there was further discussion of this particular information need request. During that discussion, reference was made to Calculation Package No. 32-9213356-000, "Combined Effect Floods – Coastal Processes for Indian Point Energy Center", which included the details of a calculation of debris load impacts on SSCs at the site for the controlling flood effects which were higher than the WSEs attributed to dam failure. The licensee's supplemental response included the following points: • *At the maximum WSE resulting from dam failure, waterborne debris would not reach or exceed site grade owing to a low bulkhead that rises slightly above the site grade and therefore would prevent any flood waters from significantly impacting any SSCs.* • *Dam failure would not occur because all of the upstream impoundments considered in the dam failure calculations have significant freeboard and would not overtop during a PMF event; the controlling dam failure*

INFO NEED[1]	INFORMATION NEED DESCRIPTION	RESPONSE SUMMARY
		scenario was a forced failure of the [redacted] within the watershed. Upon review of this information, the NRC staff noted that current guidance includes consideration of operational failures as well as the potential for flood debris to block spillways or interfere with dam gates or other mechanical equipment. While dams upstream of the IPEC site might not fail because of adequate freeboards during the watershed-scale PMF event, the possibility exists that individual dams could fail during a sub-basin-scale PMF event, possibly in concert with debris loading effects. However, under this alternative scenario, flood discharge within the Hudson River is be expected to be significantly less than that during a watershed-scale PMF event. Moreover, it is also unlikely that there would be multiple (simultaneous) upstream dams failures during PMP/PMF events limited to a select few sub-basins. The staff determined, based on engineering judgment and the consideration of downstream wave attenuation effects, that the licensee's omission of debris effects causing failures of individual upstream dams is not likely to affect the most severe dam breach flooding scenario at the IPEC site. The staff concluded that the information provided by the licensee was sufficient to address the information need request.

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SUBJECT: NUCLEAR REGULATORY COMMISSION REPORT FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC.'S FLOOD HAZARD REEVALUATION REPORT SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 AND 3 DATED May 31, 2018

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