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ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261 / RENEWED LICENSE NO. DPR-23

Subject: Submittal of Revision to Flooding Hazard Reevaluation Report to Provide a Revised Site Specific Local Intense Precipitation Storm for H. B. Robinson Steam Electric Plant, Unit No. 2

References:

1. NRC Letter to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, *Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,* dated March 12, 2012, Angencywide Documents Access and Management System (ADAMS) Accession No. ML 12053A340

2. Duke Energy Letter, H. B. Robinson Steam Electric Plant, Unit No. 2, "Flood Hazard Reevaluation Report, Response to NRC 10 CFR 50.54(f) Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1, 2.3 and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, Dated March 12, 2012," Dated March 12, 2014 ADAMS Accession No. ML14086A384

3. NRC Letter, *H. B. Robinson Steam Electric Plant, Unit 2 -Request For Additional Information Regarding Flood Hazard Reevaluation Report (TAC NO. MF3586),* Dated June 18, 2014, ADAMS Accession No. ML 14168A050

4. Duke Energy Letter, Response to NRC Request for Additional Information Regarding H. B. Robinson Steam Electric Plant, Unit No. 2 Flood Hazard Reevaluation Report, dated July 9, 2014, which was withheld under 10 CFR 2.390 due to inclusion of Security-Related Information

5. NRC E-mail, *H. B. Robinson Steam Electric Plant, Unit 2 -Request For Additional Information Regarding Flood Hazard Reevaluation Report,* Dated March 4, 2015, ADAMS Accession No. ML 15065A085

6. Duke Energy Letter, Response to NRC Request for Additional Information Regarding H. B. Robinson Steam Electric Plant, Unit No. 2 Flood Hazard Reevaluation Report, dated May 26, 2015

Ladies and Gentlemen:

By letter dated March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 2 of Reference 1 requested that each licensee perform a reevaluation of external flooding sources and report the results in accordance with the NRC's prioritization plan. The due date established for the H. B. Robinson Steam Electric Plant, Unit No.2, was March 12, 2014. Enclosure 1 to Reference 2 contained the required Duke Energy Flooding Hazard Reevaluation Report (FHRR) for H. B. Robinson Steam Electric Plant, Unit No. 2.

By Reference 3 the NRC Requested Additional Information (RAIs) regarding the H. B. Robinson Flood Hazard Reevaluation Report. Reference 4 provided the Duke Energy responses to the NRC's RAIs for H. B. Robinson.

By Reference 5 the NRC Requested Additional Information regarding the H. B. Robinson Flood Hazard Reevaluation Report. Reference 6 provided the Duke Energy responses to the NRC's RAIs for H. B. Robinson.

As part of the Reference 6 response Duke Energy stated that, "Although Duke Energy is providing responses to the NRC RAIs for the previously submitted FHRR, it is Duke Energy's intent to submit a new site-specific storm analysis as it relates to the Local Intense Precipitation (LIP) section of the FHRR, for H. B. Robinson Steam Electric Plant, Unit No. 2 during the third quarter of 2015.

The purpose of this letter is to provide the new site-specific storm analysis as it relates to the Local Intense Precipitation (LIP) section of the FHRR, for H. B. Robinson Steam Electric Plant, Unit No. 2. The new flooding information is attached to this letter as Enclosure 1 of the H. B. Robinson FHRR with changes annotated with revision bars in the margin. The original H. B. Robinson FHRR was submitted to the NRC by letter dated March 12, 2014, ADAMS Accession No. ML14086A384.

This letter contains no new regulatory commitments.

Should you have any questions regarding this submittal, please contact Mr. Richard Hightower, Manager, Nuclear Regulatory Affairs at (843) 857-1329.

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

Executed on August 29, 2015.

Sincerely,

R Michael Glover

R. Michael Glover
Site Vice President

RMG/shc

Enclosure: Revised Flooding Hazard Reevaluation Report for H. B. Robinson Steam Electric Plant, Unit No. 2

cc: Ms. M. C. Barillas, NRC Project Manager, NRR
Mr. K. M. Ellis, NRC Sr. Resident Inspector
Mr. V. M. McCree, NRC Region II Administrator
Mr. V. E. Hall, NRC Senior Project Manager, JLD-NRR

ENCLOSURE 1

REVISED FLOOD HAZARD REEVALUATION REPORT

FOR

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

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1. EXECUTIVE SUMMARY

This report summarizes the results of the flood hazard reevaluations performed at H. B. Robinson Steam Electric Plant, Unit No. 2 (HBRSEP) in response to the March 12, 2012 NRC 10 CFR 50.54(f) Request for Information, Item 2.1. The flood hazard reevaluation was completed using current regulatory guidance and methodologies used for early site permits and combined license applications. For each flood hazard, the reevaluated flood elevations were compared to the design basis flood hazard level to determine whether it was bounded.

To improve the accuracy of the Local Intense Precipitation (LIP) Flood analysis, HBRSEP has performed a revised LIP analyses to: improve accountability for roof drainage, incorporate new rainfall input as a site-specific storm as opposed to rainfall data from HMR 51/52 as part of the original analysis, and update the LIP flood models with recent site layout configuration changes. In addition, this enclosure addresses Duke Energy's response to NRC's Request for Additional Information (RAI) 2 concerning roof drainage dated May 26, 2015.

This revised FHRR evaluation differs from the 2014 evaluation with the primary difference being the Local Intense Precipitation (LIP) event used in the evaluations and incorporation of site configuration changes.

There were several instances where the expanded flood caused higher elevations than the site's Current Licensing Basis (CLB) flood level. Therefore, an Integrated Assessment (if required) will be completed and a report submitted to the NRC. As stated in the NRC letter dated May 26, 2015, the staff is deferring, until further notice, the date for submitting the Integrated Assessment Reports (if required). The NRC expects to provide additional clarification and schedule information as the staff develops and implements the closure plan for the NTTF Recommendation 2.1 reviews. In the meantime, HBRSEP has implemented the requisite interim actions.

2. SITE INFORMATION

The plant site elevation is 225 ft Mean Sea Level (MSL), MSL is equivalent to National Geodetic Vertical Datum of 1929 (NGVD29). The main surface water feature in the site vicinity is Lake Robinson, created by the impoundment of Black Creek at the Lake Robinson Dam for industrial cooling purposes. Robinson Lake normal pool elevation is 220 feet MSL.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

Low-level outlet valves used for normal controlled releases in the spillway structure were assumed to be unavailable for use during the evaluated flooding conditions.

2.1 CURRENT DESIGN BASIS FLOOD HAZARD

Design basis flood hazards were determined by reviewing the CLB. This includes docketed and currently effective written commitments for ensuring compliance with NRC requirements, and design basis information documented in the plant Updated Final Safety Analysis Report (UFSAR).

2.1.1 Local Intense Precipitation

Local intense precipitation was not considered applicable in the CLB.

2.1.2 Flooding in Streams and Rivers

The flood hazard determination was based on peak flows into the lake calculated for two hypothetical storms. A design unit hydrograph for the drainage area above the dam was developed from examination of nearby gauging station records that yielded several well defined hydrographs. Two different peak flows were calculated using the design unit hydrograph. No credit was taken for the shape of the drainage area in reducing the rainfall in these calculations, and maximum antecedent moisture conditions were assumed in estimating infiltration and retention. The first peak flow condition was based on a July 1916 storm transposed from Asheville, NC to the Black Creek drainage area, which yielded a peak discharge into the lake of 23,000 cubic feet per second (cfs). The second peak flow determined resulted from the Probable Maximum Precipitation (PMP) for the area, which was taken from the charts prepared by the Hydrometeorological Section of the Weather Bureau. This peak flow yielded a 39,000 cfs discharge into the lake. The two peak flows are bounded by the design basis capacity of the Tainter gates of 40,000 cfs, thus, ensuring the lake level would not exceed 222 ft MSL.

2.1.3 Storm Surge

Storm surge was not considered applicable in the CLB.

2.1.4 Seiche

Seiche was not considered applicable in the CLB.

2.1.5 Tsunami

Tsunami was not considered applicable in the CLB.

2.1.6 Ice-Induced Flooding

Ice-induced flooding was not considered applicable in the CLB.

2.1.7 Channel Migration or Diversion

Flooding due to channel migration or diversion was not considered applicable in the CLB.

2.1.8 Combined Effects Floods

A combined effects flood was not considered applicable in the CLB.

2.1.9 Dam Breaches and Failures

Dam breaches and failures were not considered applicable in the CLB.

2.2 CURRENT LICENSING BASIS FLOOD PROTECTION AND MITIGATION FEATURES

The Lake Robinson Dam Tainter gates are credited flood protection features in the HBRSEP licensing basis. The function of the Tainter gates is to discharge the design basis flood waters to prevent the lake from exceeding 222 ft MSL. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) Personnel utilize a lake level gauge at the intake structure and two United States Geological Survey (USGS) gauge stations to ascertain lake level and head flow in order to determine appropriate positioning of the Tainter gates. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) The flood protection and mitigation features are not associated with a unique mode of operation of the plant. In accordance with the CLB, site flooding will not occur since the site grade is above the maximum lake level which can be maintained by the dam and appurtenant structures.

During the flooding walkdowns performed in support of Request for Information Item 2.3, it was confirmed that the Tainter gates' material condition and functionality met the acceptance criteria, there is adequate time available for the gate operation personnel to properly position the gates during a flooding event considering weather conditions, and credited operator actions are feasible.

2.3 FLOOD RELATED CHANGES SINCE LICENSING ISSUANCE

The local watershed condition on the HBRSEP site has changed slightly. The site has added temporary/portable buildings, permanent buildings, paved parking lots, earthen berms and vehicle (Jersey) barriers since the original license was issued. A new drainage channel and a retention pond have also been constructed.

There have been no significant changes to the watersheds of the Black Creek and its tributaries since license issuance.

3. SUMMARY OF FLOOD HAZARD REEVALUATION

3.1 SITE SPECIFIC LOCAL INTENSE PRECIPITATION (LIP)

The effects of the site-specific LIP were evaluated. For the assessment of flood hazards at safety-related buildings, the Hierarchical Hazard Assessment (HHA) process, as described in NUREG/CR-7046 (Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America) was followed. It is conservatively assumed that there are no precipitation losses on-site during the entire PMP event and runoff process, and all catch basins, pipelines, small culverts, inlets, pumps, siphons and other drainage systems are not functioning. However, raising the jersey barriers was taken into account to reflect current site configuration. The local PMP could be caused by tropical storm or frontal precipitation. It is conservatively assumed that the storm occurs without warning. It is also assumed that topography will not change during the event due to sediment erosion/accretion.

3.1.1 Methodology / Analyses / Computations

A two-dimensional hydrodynamic model, FLO-2D Pro Version, was used to calculate the flow depth and velocity due to the local PMP. The model computational domain encompasses the entire HBRSEP site, the high land on the west and northwest, and part of Lake Robinson on the east. The FLO-2D model uses the finite volume method to solve the dynamic wave momentum equations.

FLO-2D uses a grid system to calculate the flow field to solve the equations. The computational method for overland flow involves calculating the discharge across each of the boundaries in eight potential flow directions. The full dynamic wave equation is a second order non-linear partial differential equation. To solve this non-linear equation for velocity at each grid element, an initial estimate of velocity is obtained from the corresponding diffusive wave equation using the average water surface slope. Manning's equation is applied to compute the friction slope. The estimated velocity is then plugged back in the dynamic wave equation to calculate the non-linear solution for velocity by applying the Newton-Raphson iteration method. After obtaining the velocity, the discharge across the grid element boundary is computed by multiplying the velocity by the cross sectional flow area. After the discharge is determined for all eight directions, the net change of flow volume is calculated. This change in volume is used to calculate the change in depth for each grid.

Modeling runs were performed where the site building roofs are represented as topography as per ANSI/ANS 2.8 (1992), where water falling on the roofs drains to the site ground (i.e. without assuming water is stored on roofs). Additionally, the turbine building and storage tank area obstructions were accounted for in the FLO-2D model by applying an Area Reduction Factor (ARF) and Width Reduction Factor (WRF).

Newly constructed buildings were added to the FLO-2D model based on the most recent aerial imagery and site configuration drawings. The existing ground elevation of FLO-2D grid cells representing building footprints were elevated to reflect the roof tops. Newly placed jersey barrier segments and onsite flood barrier surrounding the diesel generator were added to the FLO-2D model as levee features. The height of the raised jersey barriers in the FLO-2D model was set at 38 inches (3.17 feet) based on a typical height of 32 inches and a 6-inch gap between the bottom of the jersey barriers and the ground, non-raised barriers remained at a typical height of 32 inches. The purpose of raising the jersey barriers was to reduce the flow restriction caused by the barriers.

The local PMP calculation relies on a hydrologic analysis as shown in Section 3.2 for the downstream boundary condition. For the Lake Robinson watershed, the analysis showed that the flood from the watershed PMP took more than 40 hours to raise the water elevation to 225 ft NGVD29 in Lake Robinson. The local flood would have receded before that occurred. Therefore the downstream condition will not affect the outflow boundary condition at the lake shoreline for FLO-2D model.

HMR 51/52 LIP Calculation

The 1-hour, 1-square mile PMP values were used for the FHRR computation. Hydrometeorological Report (HMR) 52 recommended that no increase in PMP values be applied for areas smaller than 1 square mile. The HBRSEP site is approximately 0.3 square miles. The contributing watershed is approximately 0.55 square miles. The FLO-2D grid mesh covers about 1.25 square miles area which encloses the contributing watershed completely. The FLO-2D model automatically determines the flow direction based on the ground elevation. Runoff outside of the contributing watershed is diverted toward offsite locations. The effective contributing area for the computational domain in the model is approximately 0.55 square miles. Therefore, the 1-hour, 1-square mile PMP was applied to the entire HBRSEP contributing watershed. The rainfall amounts for the HMR 51/52 PMP are listed in Table 1. The 1-hour, 1-square mile PMP amount is 19.02 inches. The 5-, 15- and 30-minute rainfall amounts were determined by multiplying the 1-hour rainfall by ratios obtained from Figures 36 through 38 of HMR 52. Values of each increment of PMP are listed in Table 1. The 6-hour PMP (HMR 51) of 30.21 inches is also included in the same table in order to generate the 6-hour hyetograph for the computation.

Site-Specific LIP Calculation

The site-specific analyses is an update to the original FHRR LIP calculation using data from Hydrometeorological Report 51 (HMR) and HMR 52 reported in Table 1. In this analysis, the site specific LIP event is defined as the 1-hour, 1-mi^2 probable maximum precipitation (PMP).

The site-specific analyses of storms considers the unique characteristics of the HBRSEP site and updates the storm database with more than 40 years of storm data not reported in the HMRs analyses. After the maximization and transposition factors were calculated for each storm, the results were applied to the maximum 1- and 6-hour value for each storm to calculate the maximized 1- and 6-hour 1-mi^2 value. These maximized and transpositioned rainfall events produced site-specific rainfall depth values that were less than those provided in HMR-52 as shown by comparison presented in Table 1.

Table 1. Precipitation Amount for Local Site-Specific PMP

Event Duration	Rainfall Depths (inches) (Area Size 1-mi2)		Percent Difference
	Site-specific	HMR-51/52	
5-minute	3.8	6.2	38%
15-minute	6.1	9.7	38%
30-minute	8.7	14.1	38%
1-hour	11.8	19.0	38%
6-hour	29.2	30.2*	3.3%

*Area Size 10-mi2

A front-loaded PMP hyetograph was selected similar to the 6-hr PMP hyetograph presented in NUREG/CR-7046 to analyze the contribution of off-site flow across the site. The PMP has a greater intensity at the beginning of the hyetograph. The PMP rainfall hyetograph conservatively peaks during the first five-minute interval, as shown in Figure 1A, where the majority of the rainfall occurs within the first hour and levels out to a minimal rainfall increment after the first hour of the 6-hour storm duration.

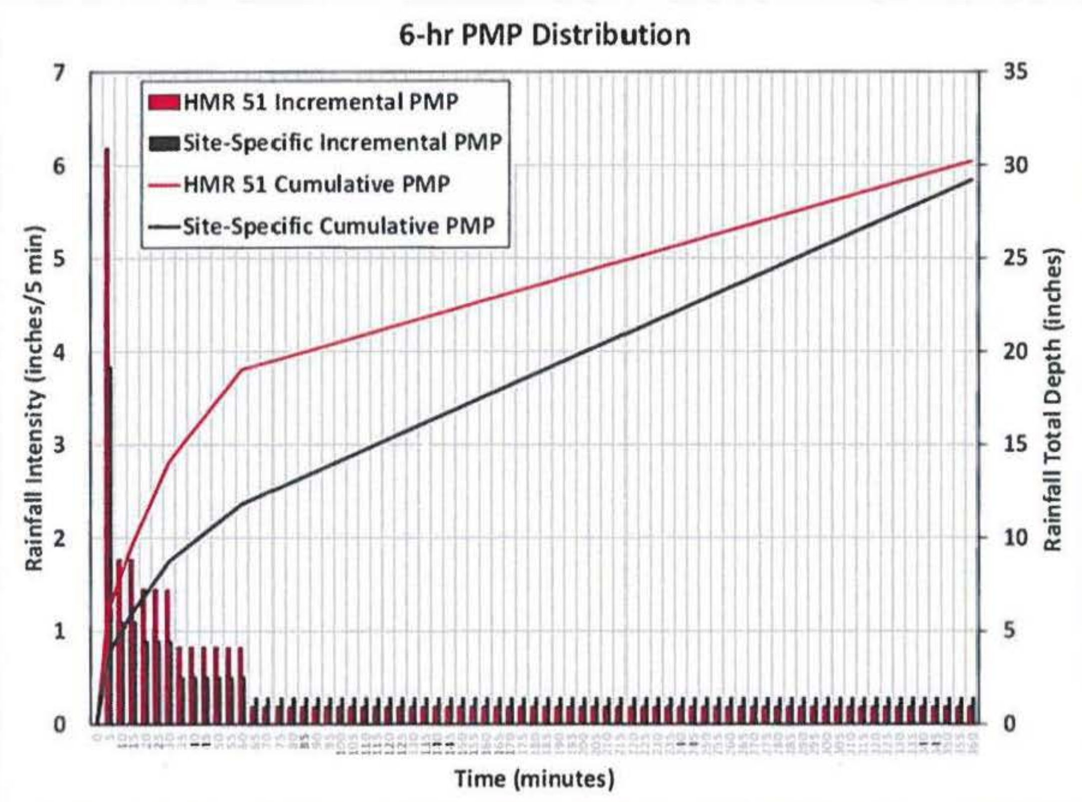

Figure 1A: Site-Specific Early Peak 6-Hour Storm Hyetograph

To determine the impact of the site-specific Local Intense Precipitation (LIP) on the roofs of the Containment Building, Auxiliary Building / Control Room, and the Turbine Building, the total volume of water stored or ponding on the roof was compared to the design live load. The site-specific LIP event is considered to have no adverse effect on the roofs of the investigated buildings.

3.1.2 Results / Conclusions

The flood elevations, velocities and impact forces at safety-related SSCs under the site-specific PMP condition and revised site configuration (i.e. raising jersey barriers) are summarized in Table 2. These flood elevations and resultant static loads represent the water levels and static pressures at the peak flood condition. The maximum velocities and resultant impact loads represent the peak flow speed condition of flood flow on the site. Note that the impact load is from flow velocity. Debris is not expected to influence impact loads due to the low velocities, low flow depths and the presence of site barriers which would intercept offsite debris before it could enter the powerblock area.

As shown in Table 2, maximum flood levels are higher than the finished floor elevations at most buildings on the list. The site elevation is 225 ft NGVD29 for the HBRSEP site as reported in the UFSAR.

As seen in Table 2, the potential of erosion from high velocity flow is low at the site because the maximum velocity is lower than the speed threshold for earth channel erosion (4 ft/sec for coarse sand earth channel). The maximum impact force and pressure are less than the concrete strength 3,000 pound per square inch (psi) (or 432,000 lb/ft^2) at each building. The potential for buildings to be damaged by flood force is therefore minimal.

Table 2. Summary of Site-Specific LIP Results for FLO-2D Model at Key Buildings on HBRSEP Site

Location	Finished Floor Elevation ft NGVD29	Maximum Flow Elevation ft NGVD29	Maximum Velocity ft/s	Max. Resultant Impact Load lb/ft	Max. Resultant Static Load lb/ft	Finished Floor vs Max Flood Elevation ft
Fab Shop	230.15	231.32	1.09	6.11	134.37	1.17
Fuel Building	226.13	228.95	0.86	9.20	247.40	2.82
Fuel Handling Building	226.13	229.08	0.84	9.97	272.36	2.95
Environmental and Radiation Control Building	226.38	230.04	1.54	7.03	2.72	3.66
Turbine Building: Turbine Generator and Condensers	226.00	228.79	2.09	30.11	242.52	2.79
Condensate Polishing System	226.36	228.83	0.65	3.89	188.54	2.47
Contaminated Equipment Storage	226.12	229.10	0.55	2.17	137.78	2.98
Outage Management Building	234.06	235.27	0.93	13.72	45.21	1.21
Spent Fuel Dry Storage Area	240.17	241.14	0.50	0.71	40.26	0.97
Auxiliary C Building	225.97	228.76	0.64	4.79	191.42	2.79

Location	Finished Floor Elevation ft NGVD29	Maximum Flow Elevation ft NGVD29	Maximum Velocity ft/s	Max. Resultant Impact Load lb/ft	Max. Resultant Static Load lb/ft	Finished Floor vs Max Flood Elevation ft
Radwaste Building	226.13	228.73	0.42	4.18	147.85	2.60
Reactor Auxiliary Building	226.13	228.79	1.17	11.89	221.03	2.66
Work Control Building	226.65	229.10	1.52	12.50	241.76	2.45
Unit 2 Containment Building	226.13	229.06	0.58	14.69	247.66	2.93
Access Building	226.13	229.12	0.53	3.41	162.86	2.99
Diesel	226.00	228.88	2.42	39.96	234.61	2.88
AFW Pump	226.00	228.62	2.13	29.04	213.93	2.62
SDAFW Pump	226.00	228.79	1.56	29.46	242.96	2.79
Visitor Center parking lot	254.00	255.17	0.21	0.19	0.39	1.17
Flex Building	243.00	244.26	0.16	0.64	18.27	1.26
Near Barrier SE – PA side (135105)	225.97	228.24	1.34	9.69	160.91	2.27
Near Barrier SE -Switchyard side (135104)	225.97	228.11	0.92	4.50	143.42	2.14

Location	Finished Floor Elevation ft NGVD29	Maximum Flow Elevation ft NGVD29	Maximum Velocity ft/s	Max. Resultant Impact Load lb/ft	Max. Resultant Static Load lb/ft	Finished Floor vs Max Flood Elevation ft
Near Barrier SW - PA side (129680)	226.00	228.86	0.12	0.10	254.37	2.86
Near Barrier SW-Switchyard side (129678)	226.00	228.41	2.63	43.09	181.54	2.41

3.2 FLOODING IN STREAMS AND RIVERS DUE TO PROBABLE MAXIMUM PRECIPITATION (PMP)

Lake Robinson is a cooling water reservoir for HBRSEP and is fed by Black Creek and its tributaries. This section is to determine the effect of flooding in rivers and streams near the HBRSEP from the Probable Maximum Flood (PMF) induced by Probable Maximum Precipitation (PMP) in Lake Robinson and its watershed.

The PMF has been defined as an estimate of the hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible at a particular location. The PMF represents an estimated upper bound on the maximum runoff potential for a given watershed.

A comprehensive HEC-GeoHMS and HEC-HMS hydrologic model of the Lake Robinson Watershed was prepared. The model was developed using Economic and Social Research Institute (ESRI) ArcMap Geographic Information System (GIS) mapping and the U.S Army Corps of Engineers (USACE)'s HEC-GeoHMS.

The Natural Resources Conservation Service (NRCS), formally known as the Soil Conservation Service (SCS), Curve Number (CN) methodology was utilized to calculate runoff hydrographs from the 28 watershed sub-basins. Sub-basin sizes, Curve Numbers (CN), land use classifications, and sub-basin times of concentration (T_C) were estimated for the 28 sub-basins.

The hydrologic model of the Lake Robinson Watershed was expanded to include the USGS stream flow from the gauge station located immediately downstream of Lake Robinson dam.

Sub-basin hydrographs were routed through the watershed channels and combined with hydrographs from tributary sub-basins. The upstream ponds and dams are small and have little storage capacity. Therefore, the limited upstream storage was not included in the model, but potential attenuation was captured via calibration of initial abstraction. All upstream reservoirs and ponds are assumed full at the beginning of the postulated PMP event and will not attenuate the peak or volume during any flooding (i.e., inflow = outflow). Reservoir storage and spillway discharge characteristics for Lake Robinson Dam were obtained from as-built drawings and reports provided by HBRSEP. The Muskingum-Cunge methodology was used to model channel routing. Non-linearity adjustments were made according to NUREG/CR-7046 guidance.

3.2.1 **Hydrologic and Hydraulic Study**

3.2.1.1 **Hydrologic Methodology / Analysis / Computation**

A comprehensive HEC-GeoHMS and HEC-HMS hydrologic model was utilized to calculate runoff generated by the PMF. Watershed-related input parameters needed for the HEC-HMS model include initial rainfall losses, rainfall infiltration losses, drainage area size, rainfall-runoff lag times, and data for hydrograph routing through the watershed and channels.

Initial rainfall losses (abstraction) to account for surface wetting of vegetation and soil and filling of local surface depressions were adjusted using Hurricane Frances 2004 data.

Initial rainfall infiltration losses were estimated using the NRCS (formerly SCS) Curve Number methodology for which the CN is the parameter used to define rainfall infiltration losses. CN values for each sub-basin were derived based on soil types and land uses in the watershed.

The drainage area of the Lake Robinson Dam drainage basin is divided into 28 sub-basins. The watershed sub-basins were delineated and the enclosed areas were calculated using HEC Geo-HMS. The sub-basin areal sizes were then input into the HEC-HMS model for the hydrologic simulation. In selecting sub-basins for the analyses, special attention was given to potential coincident peaks, dams, flow observation points (USGS gages), and other critical elements (e.g., slope and land use pattern) which could influence the watershed responses during a flood event.

Rainfall-runoff lag times were calculated from estimates of sub-basin time of concentration (T_C). T_C is defined as the time it takes storm water runoff to travel from the hydraulically most distant point of the watershed to an outlet point within the watershed. A T_C value was determined for each sub-basin using the method in Natural Resources Conservation Society (formerly SCS) Technical Release No. 55 (TR-55). Runoff from each sub-basin was divided into the sheet flow segment (non-concentrated runoff from the most distant point), the shallow concentrated flow segment, and the channel flow.

The Muskingum-Cunge routing procedure was used for the hydrologic routing of sub-basin hydrographs and combinations of hydrographs throughout the watershed channels. This routing procedure is a sub-routine in the HEC-HMS model that is designated by the user and only requires input of the channel geometry. South Carolina State LiDAR based 8-point cross-sections were generated using ArcGIS tools for the channels. Routing was included in the hydrologic modeling to account for transient channel storage attenuation and travel lag times between flow concentration points.

Probable Maximum Precipitation (PMP) & Development of the Probable Maximum Flood (PMF)

The PMP estimates for the Lake Robinson Watershed above the main dam of the Lake Robinson Reservoir, South Carolina were determined using the criteria and step-by-step instructions given in HMR 51 and HMR 52. The data in HMR 51 and HMR 52 indicates that the PMP event for the Lake Robinson Watershed would result from a tropical storm event (hurricane) that would be a predicted severe weather event.

The drainage area of the Lake Robinson Dam drainage basin is 171.5 square miles; the location of the centroid of the basin is approximately 34.5826°N, 80.2137°W. Using HMR 52 as a guide, the PMP for the Lake Robinson Dam drainage basin was developed.

The PMF storm was developed by accounting for the antecedent rainfall that precedes the PMP storm based on American National Standards Institute (ANSI/ANS)-2.8-1992, Determining Design Basis Flooding at Power Reactor Sites, guidelines and adjusted for non-linearity based upon NUREG/CR-7046. The PMF storm that was used as the rainfall input in the hydrologic modeling has the following components:

(1) An antecedent 72-hours storm that is comprised of the lesser of 500-year (14.1 in) or 40% of the PMP (16.1 in),

(2) Immediately followed by a 72-hours dry period,

(3) Immediately followed by the full 72-hours PMP.

The 500-year rainfall depth over 72-hours is 14.1 inches and it is lower than 40% of the PMP and selected for PMF storm antecedent condition.

Parameters needed to route flood hydrographs through the Lake Robinson Reservoir and Dam spillway include reservoir elevation-storage relationships, spillway elevation-discharge characteristics, and initial reservoir storage at the beginning of the storm event.

The elevation-storage relationship for Lake Robinson Reservoir was developed based on the bathymetric survey for Lake Robinson. The lake has a storage capacity of 27,560 acre-feet (AF) below the normal pool elevation of 220.0 feet NGVD29 and maximum storage capacity of 51,861 AF below the embankment crest elevation of 230.0 feet NGVD29.

Water elevation in the Lake Robinson Reservoir is controlled by two [redacted] Tainter gates. The elevation-discharge relationships were developed based on the gate operational procedure.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

For the PMF analysis, the gate operational rule was applied, and the initial reservoir storage elevation at the beginning of the storm event was assumed to be at the plant operation pool elevation, 221.5 feet NGVD29, a historically high reservoir level.

For the PMP assessment of the HBRSEP site final PMF simulation with nonlinearity effects was selected and applied to the hydraulic model routing. The PMF scenario is the watershed model simulation that uses the watershed parameters with corrections to unit hydrographs, the Muskingum-Cunge routing procedure for the hydrologic routing of sub-basin hydrographs and combinations of hydrographs throughout the watershed channels and 216 hours PMF storm.

3.2.1.2 **Hydraulic Methodology / Analysis / Computation**

The hydraulic analysis completed for this study was based on HEC-RAS. HEC-RAS is a one-dimensional model that can perform unsteady flow routing through an open channel system that may also include culverts, bridges, levees, tributaries, storage areas, and traversing dams. Unsteady flow analyses deals with flow conditions that vary temporally and spatially.

Lake Robinson and contributing river segments show that the flow is mostly one-dimensional, constrained by natural narrow valleys with steep side slopes and very little possibility of a two-dimensional flow condition. Application of a one-dimensional HEC-RAS model for Lake Robinson is appropriate.

For the PMF flood wave routing, an unsteady HEC-RAS simulation was conducted for a 9.5 mile segment of Black Creek, extending approximately 8 miles upstream and 1.5 miles downstream of the Lake Robinson Dam. Selection of this 9.5 mile segment provides the model with the capability to capture the backwater effects from downstream and the impacts from upstream bridges more accurately.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

The input breach parameters for HEC-RAS model were developed based on field assessment and physically based earth dam erosion model- BREACH.

The applicability of these parameters was also validated with empirical equations. (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

3.2.2 **Results / Conclusions**

Under the analyzed beyond design basis PMF condition, the HEC-RAS model hydraulic simulations show that the Lake Robinson water surface elevation is (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) NGVD29 for with and without dam breach simulations at HBRSEP, respectively. Both simulation results show that the analyzed PMF event (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) as compared to the site grade elevation of 225.0 feet NGVD29.

Debris from the upstream watershed will not translate to the site due to the low velocities in the lake and the constricted crossing of State Road S-13-346 near the north end of the lake.

The estimated PMF elevations at Lake Robinson Dam with and without dam breach resulting from the HEC-RAS simulations are shown in Figure 1.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

[redacted]

Flood Elevation (Feet, NGVD29)	Start Time from PMF Storm	Start Time from PMP (HH:MM:SS)	End Time from PMF Storm (No Breach Condition)	End Time from PMF Storm (Breach Condition)	Duration -No Breach Condition (Minutes)	Duration-Breach Condition (Minutes)
(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted]						

RNP Site Elevation - 225 (ft, NGVD29)

**PMF Storm (72HR 500YR+ 72 HR DRY PERIOD + 72 HR PMP) Begin Time - 31DEC2012 2400*

Figure 1: Estimated PMF Elevations at Lake Robinson Dam with and without Dam Breach by HEC-RAS Simulations

(Note that PMF values include adjustment for non-linearity)

3.3 STORM SURGE

3.3.1 Approach / Methodology

The Probable Maximum Hurricane (PMH) was developed according to the methodology and data provided in "Meteorological Criteria for Standard Project Hurricane and Probable Maximum Hurricane Windfields, Gulf and East Coasts of the United States", referred to hereafter as NWS 23. Because the project site is not at the immediate coast, the storm strength was reduced using the approach of Kaplan & DeMaria. Due to the north-to-south orientation of Lake Robinson and the location of the study site at the southern end of the lake, it was assumed that a wind blowing north to south would result in the Probable Maximum Storm Surge (PMSS).

3.3.2 Computations Discussion

The storm surge was calculated using PMH wind speeds determined from NWS-23, inland reduction calculations from Kaplan and DeMaria, topographic data from South Carolina Department of Natural Resources, and bathymetric data. The inputs were:

depth d = 16.20 feet
fetch F = 4.6 miles
wind speed U = 119.3 mph
angle $\sigma = 0$

Applying these to the Zuider Zee equation yields:
surge S = 2.89 feet = 224.39 feet NGVD29 = 223.47 feet NAVD88

The wave conditions were calculated using the force of gravity, the wind speed, and the lake geometry:

gravity g = 9.81 m/s^2
fetch X = 1,268 m
wind speed U_{10} = 119.3 mph = 53.33 m/s

Applying the calculations in the Coastal Engineering Manual yields:

wave height H_{m0} = 1.36 m = 4.47 feet
wave period T_p = 2.53 seconds

The wave runup and overtopping were calculated from the wave parameters, bathymetric data, and the LiDAR data from South Carolina Department of Natural Resources:

freeboard R_c = 0.492 m = 1.61 feet
slope $\tan(\alpha)$ = 0.382
wave height H_{m0} = 1.36 m = 4.47 feet
wave period T_p = 2.53 seconds

Applying these to the Coastal Engineering Manual's equations from Ahrens for runup, and van der Meer & Janssen for overtopping yields:

runup $R_{2\%}$ = 2.26 m = 7.41 feet = 231.80 feet NGVD29 = 230.87 feet NAVD88
flux per unit width q = 0.0821 m^3/s per meter of crest width = 0.884 ft^3/s per foot of crest width

Note that the surge elevation is at 224.39 feet NGVD29 which is below the site grade 225 ft NGVD29. The wave runup may splash at the shoreline near the site. The flow rate is relatively small and will only affect the area along the shoreline. It will not generate any flood for the interior area of the HBRSEP site. Water will not enter critical structures at the shoreline so long as they are above the runup elevation or are sufficiently enclosed.

3.4 SEICHE

The static wind-induced water setup at the south end of the lake $\Delta\eta$ = 1.43 m (~ 4.69 ft) is the initial seiche amplitude in Lake Robinson along the north-south direction. The potential amplitude of the lake seiche in the east-west direction is 0.24 m (~ 0.79 ft) near the Robinson Nuclear Plant site. According to the UFSAR for the Robinson Nuclear Plant, the HBRSEP site grade is at 225 ft (~ 68.58 m) NGVD29. When the still lake water level is at the maximum allowable water elevation 221.5 ft (~ 67.51 m), the water level could rise to 67.51 m + 1.43 m = 68.94 m (~ 226.2 ft) due to wind setup in the north-south direction, which is higher than the HBRSEP site grade (225 ft NGVD29); while the water level could rise to 67.51 m + 0.24 m = 67.75 m (~ 222.3 ft) due to wind setup in the east-west direction, which is lower than the HBRSEP site grade. The results indicate that the lake water level subject to wind-induced seiche in the north-south direction could exceed the site grade. The maximum flood elevation caused by seiche can reach the floor elevation at the shoreline location. Although, away from the shoreline, the water level will drop as the flow pushes toward the power block. The flood level is expected to be lower than the floor grade when it reaches the buildings. Hence the seiche will not cause any significant flood problem for the power block.

For the potential seiche caused by seismic activities in the HBRSEP area, the long periods of the fundamental mode seiche oscillations fall well outside of the period range where earthquake ground motions carry most energy, and it is thus unlikely that these modes will be generated in Lake Robinson. The particular circumstances that could lead to the occurrence of mild seiching are not likely to occur in Lake Robinson.

3.5 TSUNAMI

HBRSEP is located approximately 87 mi inland from the Atlantic coast, where tsunami hazards are relatively low, and 225 ft above sea level. Therefore, the HBRSEP Unit 2 site is not subjected to the effects of tsunami flooding.

3.6 ICE-INDUCED FLOODING

HBRSEP winters are mild with the cold weather usually lasting from late November to mid-March. However, only about one-third of the days in this period have minimum temperatures below freezing. Winters in the area are mild and there is no history of Lake Robinson freezing. Consequently, ice induced flooding is not considered a viable flood hazard.

3.7 CHANNEL MIGRATION OR DIVERSION

Channel migration or diversion is the lateral movement of a stream channel across its valley and floodplain due to bank erosion or avulsion. Bank erosion occurs when the channel flow is fast enough to scour the bank. Most of the bank erosion occurs at the outside of meander bends due to the centrifugal fluid dynamic forces exerted by the flow. It can cause the channel to migrate toward the outside of the bends. An erodible bank could be eroded rapidly during a high flood and results in a channel migration. Avulsion is when a river suddenly abandons the old channel and shifts to a new channel. It typically occurs at a meander or a highly active sediment transport river segment such as the river delta. During the avulsion process, the flow breaches the river bank and spills out onto a new course. The diversion of water could cause a flood event for low lying areas near the new river course.

Other types of channel migration include stream capture, which is a geomorphological phenomenon describing a stream that is diverted from its original course and flows down to the course of a neighboring stream. Stream capture could cause a flood problem if the neighboring stream is not large enough to carry the flows from both streams.

3.7.1 Approach / Methodology

This study evaluated the rates of lateral channel migration and channel diversion along the Black Creek (upstream of Lake Robinson Dam), to understand the effects of surface discharge variations and surface flooding resulting from channel migration and channel diversion on the Robinson Nuclear Power Plant site.

Bank erosion, which leads to channel migration and diversion, is a function of several variables: flow discharge, slope and alignment of the river, characteristics of bank material, height of the eroding bank, flow depth, stream bank vegetation, seismic activities, and ice expansion.

Seven data sources were established and evaluated for Black Creek for the channel migration and channel diversion calculation. These data sources are:

1. Aerial imageries, topographic maps, and satellite imageries spanned for more than 70 years from 1941 to 2013.
2. Soil characteristics for the channel, channel banks and the overbank areas.
3. Channel meandering.
4. Riparian vegetation cover.
5. Seismic activities.
6. Ice expansion.
7. Shear stress during the PMF event.

The seven data sources were supported by field reconnaissance and verifications. Stream centerlines of Black Creek and its major tributaries were digitized and the centerlines were overlaid. Examination and comparison of the digitized stream lines of Black Creek and its major tributaries did not reveal any evidence of natural channel migration or diversion.

Increases in peak flows can require a stream to enlarge its channel cross-sectional area in order to carry the higher depth flows. The type of bank material can influence a stream bank's vulnerability. Bedrock is highly resistant to erosion. Stream banks that consist of highly erodible gravels and sand are more susceptible to erosion. Most of the Black Creek and its major tributaries banks are underlain by soil with a slight to moderate hazard to water erosion, such as sandy loam, sandy clay loam, clay loam, silty clay loam, and silt loam. Banks underlain by soil with severe hazard to water erosion such as sand, silt, and gravel are more susceptible to bank erosion. This was found near Black Creek banks but in small and limited areas which is unlikely to create a basis for channel migration or diversion.

Riparian vegetation is an important factor in reducing the stream bank's susceptibility to erosion. Stream meander bends before and after a major flood without riparian vegetation were nearly five times as likely as vegetated bends to have undergone bank erosion. The vegetated banks detected by the aerial imageries, topographic maps, and field verification for Black Creek and its major tributaries are indicators of stream bank stability.

Black Creek and its major tributaries are characterized by long, straight reaches separated by short, steeper, sinuous reaches, that yields typically low average sinuosity, thus provides an indication of stream stability.

A seismic fault line and an inferred fault line cross Black Creek in two locations. Black Creek and some of its major tributaries were found to have a low potential for soil liquefaction and for the possible occurrence of a landslide blocking or limiting stream flow.

Ice expansion effects in Black Creek are expected to be limited (minor freezing) and are not expected to cause stream flow blocking that could lead to channel flooding. Therefore, channel migration or diversion during winter months is not a concern.

Shear stress distribution over cross-section in open channel is an important factor to assess channel resistance to bank erosion. The shear stress values in the reach of Black Creek upstream of Lake Robinson Dam during the PMF event were reviewed and compared to typical sheer stresses resisted by the soil and vegetation types found on the channel banks and the overbank areas of Black Creek. The sheer stresses are lower than the sheer stresses resisted by the soil and vegetation found on the banks and overbank areas of Black Creek except for four cross-sections which slightly exceeded the lower limit of the resisted shear stress. However, the location of these cross-sections is approximately 7.5 miles upstream of the Robinson Nuclear Power Plant site, and as a result it is unlikely to create a basis for channel migration or diversion that would cause flooding at the plant site.

3.7.2 Results / Conclusion

The above analysis indicates that Black Creek (upstream of Lake Robinson Dam) has a stable stream alignment with no conclusive evidence of lateral migration and diversion, bank erosion, or sediment bar deposition while maintaining its sinuosity and gradient.

Therefore, flooding risk to the Robinson Nuclear Power Plant site caused by river channel migration and channel diversion of Black Creek is low.

3.8 DAM BREACHES AND FAILURES

Two dam failure flooding scenarios were evaluated for HBRSEP. The first scenario, Scenario A, addresses failure of dams upstream of Lake Robinson and the subsequent flooding in rivers and streams and impact at HBRSEP. The second scenario, Scenario B, addresses the failure of the Lake Robinson Dam due to PMF.

3.8.1 Scenario A – Upstream Dam Breach and Failure

3.8.1.1 Approach / Methodology / Computation

The hydrologic model developed for the Probable Maximum Flood (PMF) simulation was used to simulate the runoff produced by the 500-year event at Lake Robinson Reservoir.

The 500-year watershed model simulation uses the calibrated and validated model parameters, Muskingum-Cunge routing procedure for the hydrologic routing of sub-basin hydrographs and combinations of hydrographs throughout the watershed channels and 500-year precipitation with SCS Type II distribution over 24 hours.

According to NRC ISG guidance the initial water surface elevation should be set as the 500-year flood event elevation, which is 221.36 feet NGVD29. However, to provide a more conservative approach, the maximum operational pool elevation of 221.5 feet, NGVD29, was used as the initial water surface elevation for the computations.

According to SCDHEC guidance, dams considered for its inventory were 25 feet or more in height or that had the capability of impounding 50 acre-foot of water or more (with water up to the top of the dam); additionally, dams smaller than this were also included in the inventory if it was judged their failure would cause appreciable property damage or any loss of life.

3.8.1.2 **Inconsequential Dams**

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted]

a. If Initial water surface elevation is based on 500-year flood event:

   500-year flood storage = 30145 acre-foot

   500-year flood elevation = 221.36 feet, NGVD29

   (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted]

b. If Initial water surface elevation is based on Maximum operational pool level:

   Maximum operational pool flood storage = 30364 acre-foot

   Maximum operational pool flood elevation = 221.5 feet, NGVD29

   (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted]

Following NRC ISG procedures, it was determined that all [redacted] additional SCDHEC dams and ponds were "Inconsequential" because they were not identified by the National Inventory of Dams (NID) database as a dam or potential water body based on their purpose of use, height, and volume and provide only [redacted] feet elevation increase for the most conservative option. These dams would have minimal or no adverse failure consequences beyond the dam owner's property.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

3.8.1.3 **Noncritical Dams**

All upstream NID dams, [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) were evaluated by the Volume Method as described in NRC ISG to identify their potential impact as "noncritical" or "critical" dams. According to NRC ISG guidance the initial water surface elevation should be set as the 500-year flood event elevation, which is 221.36 feet. However, to provide a more conservative approach, the maximum operational pool elevation of 221.5, was used as the initial water surface elevation. In addition, volume from each of the [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) was added and the resultant elevations were determined using elevation-storage relationship.

3.8.1.4 **Results / Conclusion**

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

[redacted]

3.8.2 **Scenario B – Lake Robinson Dam Breach**

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

[redacted]

3.8.2.1 **Approach / Methodology / Computation**

The HBRSEP dam breach calculations are performed based on the standard assumptions conforming to NUREG/CR-7046 and NTTF 2.1 requirements.

The analysis estimates the dam overtopping breach caused by the PMF using the BREACH model. The BREACH model is a physically based simulation model to predict the breach characteristics and the discharge hydrograph emanating from a breached earthen dam. The BREACH model includes a hydraulic simulation component which uses conservation of mass to determine reservoir elevation based on inflows and outflows through the spillway, dam overtopping, and the overtopping breach opening. However, the model uses a maximum of eight points to represent input relationships such as surface area-elevation of the reservoir, elevation discharge of the spillway, and inflow hydrograph. These relationships were simplified from their original high-resolution format to accommodate this model limitation. Therefore, the resulting peak flow timing, pool elevation, and peak flow magnitude are affected by the simplification. Because of the high accuracy of the HEC-RAS model in representing the above mentioned relationships, the breach characteristics including the elevation at which breach formation starts, breach progression curve, and final breach bottom elevation and width are used in the HEC-RAS model to estimate the maximum pool elevation and breach flow.

3.8.2.2 **Results / Conclusions**

The BREACH model results are transferred to the HEC-RAS Hydraulic model to route the full PMF inflow hydrograph through the reservoir using dam breach characteristics from this calculation. The HEC-RAS model determines the maximum reservoir elevation and dam outflow hydrograph.

The results show that the breach initiation starts at about the beginning of dam overtopping and continues for [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

3.9 COMBINED EFFECT FLOOD

3.9.1 **Approach / Methodology**

Combined-Effect floods are events considered reasonably likely to occur at the same time at a given location, and are used to develop an adequate design flood basis. Recommended combinations of events are discussed in ANSI/ANS 2.8 1992 Section 9.2, and also in NUREG/CR-7046 Appendix H. The HBRSEP Unit 2 site is bounded by Lake Robinson on the east and a railroad on the west. The 171.5 square mile Black Creek drainage basin feeds the Lake Robinson Reservoir and is subject to a PMF resulting from PMP over the watershed. A Probable Maximum Hurricane occurrence was also considered since the site is approximately 87 mi from the nearest coast. The Lake Robinson reservoir is subject to wind-generated setup and wave runup. The HBRSEP site could potentially be flooded by dam breaks upstream of Lake Robinson due to a seismic event. The plant site itself is subject to local intense precipitation. No other flood events such as tsunamis and channel migration have been identified as potential hazards at the site. Combined events applicable to the site are as follows.

3.9.1.1 **Floods Caused By Precipitation Events**

Three alternatives for combined precipitation events were analyzed.

(i) The wave runup induced by 2-year wind speed, combined with the PMF (w/ breach) on the reservoir. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

(ii) The wave runup induced by 2-year wind speed, combined with lesser of either one-half the PMF or a 500-year flood coincident with upstream dam failures. The maximum normal pool elevation is higher than the 500-year flood elevation and was used as a more conservative option. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

(iii) The PMH-induced PMSS combined with the maximum controlled lake level. For the PMSS event, the maximum wave runup level on the embankment near the HBRSEP site is 231.80 ft NGVD29. This elevation is higher than the HBRSEP site grade of 225 ft NGVD29.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

[redacted]

3.9.1.2 **Floods Caused by Seismic Dam Failure Events**

ANSI/ANS 2.8-1992 Section 9.2.1.2 gives two alternatives for calculating overall PMF due to dam failure. ANSI/ANS 2.8-1992 recommends using the higher result of the two alternative combinations as the design basis for seismic dam failure floods:

Alternative I for dam failure events requires a computation for dam failure that coincides with the 25-year recurrence peak flood. However, Alternative II has a higher flood potential because both the one-half PMP and the 500-year recurrence rainfalls are larger than the 25-year recurrence rainfall. Thus, only Alternative II was calculated because of the larger rainfall, which produces a higher flood as recommended by ANSI/ANS-2.8-1992.

Alternative II also applies to the flood caused by dam failure. The 2-year maximum 1-hr, over-water wind speed was taken to be 50 mph. This wind speed was adjusted for fetch lengths and was oriented on any critical fetch that would produce maximum wave runup at or near any safety-related structure at the peak water level of the PMF.

The flood due to the 500-year 24-hour rainfall coincident with dam failures upstream of Lake Robinson was determined. The 500-year flood elevation is 221.36 ft NGVD29. To provide a conservative approach, the maximum normal pool elevation of 221.50 ft NGVD29 was used instead of the 500-year elevation. The peak flood elevation for this event can be summarized as follows:

Maximum Normal Pool Elevation: 221.50 ft NGVD29

Flood depth increase caused by dam failure [redacted] ft NGVD29 (b)(3):16 U.S.C. § 824o-1(d), (b)

Peak water level including maximum normal pool elevation and dam failure:

(b)(3):16 U.S.C. § 824o-1(d), (b) [redacted] ft NGVD29

The wave caused by the 2-year recurrence wind can be calculated as follows:

2-year recurrence wind: 50 mph

Adjusted wind speed for duration of t = 4945 sec: 48.96 mph (21.89 m/s)

Wind setup caused by 2-year wind: 0.46 ft

Wave height caused by 2-year wind: 3.3 ft

Wave period caused by 2-year wind: 2.7 sec

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

[redacted]

Therefore, the peak flood elevation for the scenario of 500-year flood coincident with dam failure and 2-year wind waves is given by (note maximum normal pool starting elevation is used for additional conservatism):

> Peak flood elevation = maximum normal pool with dam failure + 2-year wind setup + wave runup
>
> (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) [redacted]

3.9.1.3 **Floods Along the Shores of Enclosed Bodies of Water**

For shore locations of an enclosed water body such as the HBRSEP site, PMH-induced PMSS includes the following alternatives for combination (ANS 2.8-1992 Section 9.2.3.1):

a) Probable Maximum Surge and seiche with wind-wave activity
b) 100-year or maximum controlled level in the water body, whichever is less

The PMH-induced PMSS on Lake Robinson has been evaluated using methods in the Shore Protection Manual, Second Edition. The maximum controlled water level for Lake Robinson is 221.50 ft NGVD29 per the HBRSEP Lake Robinson Spillway Equipment Operational Manual. The peak flood elevation for the PMH-induced surge and wave runup is the sum of the lake elevation (221.50 ft), PMH PMSS (2.89 ft) and wave runup (7.41 ft) for a total of 231.80 ft NGVD29.

The 100-year flood was calculated using the HEC-HMS model with basin data and the 100-year recurrence rainfall from NOAA Atlas 14. The calculated 100-year flood elevation is 221.15 ft NGVD29 which is less than the maximum controlled level.

For the PMSS event, the maximum wave runup level on the embankment near the HBRSEP site is 231.80 ft NGVD29. This elevation is higher than the HBRSEP site grade of 225 ft NGVD29.

3.9.2 **Results**

The Combined-Effect flood results are shown in Table 3.

Table 3. Combined Effects Flood

Floods Caused by Precipitation Events	**Still water level (NGVD29)**	**Wind setup**	**Wave runup**	**Combined-Effect max. water level (NGVD29)**
(i) PMF with 2-year wind caused wave runup coincident with dam breach	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) ft	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) ft	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) ft	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) ft
(ii) 500-year flood coincident with upstream dam failures and 2-year wind	ft	ft	ft	ft
(iii) PMSS event, the maximum wave runup	221.50 ft	2.89 ft	7.41 ft	231.80 ft
Floods Caused by Seismic Dam Failures	**Still water level (NGVD29)**	**2-year wind setup**	**Wave runup**	**Combined-Effect max. water level (NGVD29)**
Maximum normal pool with dam failure	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)			

4. COMPARISON WITH CURRENT DESIGN BASIS

For each flood hazard reevaluated, the result was compared to the CLB flood hazard and protection and mitigation features to determine whether the established site elevations were exceeded. The results are summarized and discussed in Table 4 below.

Table 4. Comparison of Flood Levels

Flood Hazard	Location	Finished Floor Elevation (FFE), ft NGVD29	Probable Maximum Flood, ft NGVD29	
			CLB	EVAL
Local Intense Precipitation	See Table 2			
Flooding in Streams and Rivers PMP	Lake Robinson 216-hour HEC-RAS w/o Robinson Dam Failure	N/A	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)	
	Lake Robinson 216-hour HEC-RAS w/ Robinson Dam Failure	N/A		
Dam Breaches and Failures	Lake Robinson from upstream Dams	N/A		
	Cooling Water Intake	N/A		
Storm Surge	Wind Setup (Surge) Along Shore	N/A	-	224.39
	Wave Runup Along Shore	N/A	-	231.8
Seiche	Lake Robinson Shoreline	N/A	-	226.2
Tsunami	Not an applicable Flood Hazard to this Plant Site.			
Ice Induced Flooding	Not an applicable Flood Hazard to this Plant Site.			
Channel Migration or Diversion	Not an applicable Flood Hazard to this Plant Site.			
Combined Effects	Floods caused by precipitation events	N/A	-	(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)
	Floods caused by seismic dam failure	N/A	-	
	Floods caused by storm surge events	N/A	-	231.8

4.1 LOCAL INTENSE PRECIPITATION

Local Intense Precipitation is not considered in HBRSEP's CLB. Therefore, the analyzed flood levels were compared to the finished floor elevations of the various buildings to determine if potential flooding of components could be impacted. The results of the evaluation indicate that the predicted flood levels will be above the floor elevation of several of the onsite buildings and, therefore, this mechanism will be considered in the integrated assessment.

4.2 FLOODING IN STREAMS AND RIVERS

[redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

This mechanism will be considered in the integrated assessment.

4.3 STORM SURGE

Local Storm Surge was not considered in HBRSEP's CLB. The surge elevation was evaluated to be at 224.39 ft NGVD29 which is below the site grade 225 ft NGVD29. The wave runup value of 231.80 ft NGVD29 is a hypothetical runup at ground level which may splash at the shoreline near the site. The flow rate is relatively small and will only affect the area along the shoreline. It will not generate any flood for the interior area of HBRSEP site. Water will not enter critical structures at the shoreline as long as they are above the runup elevation or are sufficiently enclosed.

4.4 SEICHE

Seiche was not considered in HBRSEP's CLB. The reevaluated values indicate that the lake water level subject to wind-induced seiche in the north-south direction could exceed the site grade; however, the floor grade of each building is one foot above the ground at 226 ft NGVD29 or higher. The maximum flood elevation caused by seiche, 226.2 ft NGVD29, may reach the floor elevation at the shoreline location; however, away from the shoreline, the water level will drop as the flow pushes toward the power block. The flood level will be lower than the floor grade when it reaches the buildings. Hence the seiche will not cause any significant flood problem for the power block.

For the evaluated potential seiche caused by seismic activities in the HBRSEP area, the long periods of the fundamental mode seiche oscillations are well outside of the period range where earthquake ground motions carry most energy, and it is unlikely that these modes will be generated in the Lake Robinson.

4.5 TSUNAMI

Flooding from tsunami was not considered in HBRSEP's CLB and was screened out of the analysis based on the plant's inland location.

4.6 ICE-INDUCED FLOODING

Ice-Induced Flooding was not considered in HBRSEP's CLB and was screened out of the analysis based on the historically mild winter temperatures at the site.

4.7 CHANNEL MIGRATION OR DIVERSION

Flooding from channel migration or diversion was not considered in HBRSEP's CLB. Based on the current and historical characteristics of the Black Creek tributary, the evaluation concluded that the expected flooding risk to the site is minimal.

4.8 DAM BREACHES AND FAILURES

Dam breaches or failures were not considered in HBRSEP's CLB. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F) This level is below the HBRSEP site grade (225 ft NGVD29) and, therefore, will not affect any SSCs important to safety.

The evaluation of the Lake Robinson dam for PMF conditions assessed that the overtopping of the dam could result in the dam being breached. [redacted] (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

4.9 COMBINED EFFECT FLOODS

Combined effect floods were not considered in HBRSEP's CLB. Three instances were evaluated: floods caused by precipitation events, floods caused by seismic dam failure events and floods along the shores of enclosed bodies of water.

For the combined effects associated with precipitation events, the peak water level included the sum of the PMF flood level, wind setup and ½ wave heights, and was determined to be [redacted] ft NGVD29. This elevation is higher than the HBRSEP's site grade of 225 ft NGVD29 and will be considered in the integrated assessment. (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

For floods caused by seismic dam failure including the 500-year event (221.36 ft), for conservatism the maximum normal pool elevation of 221.50 ft was used coincident with 2-year wind waves, the peak flood elevation was [redacted] ft NGVD29. This elevation is also higher than HBRSEP's site grade of 225 ft NGVD29 and will be considered in the integrated assessment. (b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

For floods along the shores of enclosed bodies of water for the PMH-induced Probable Maximum Storm Surge event, the maximum wave runup level on the embankment near the HBRSEP site is predicted to be 231.80 ft NGVD29, which is 6.8 ft above the HBRSEP site grade of 225 ft NGVD29.

5. INTERIM ACTIONS

Duke Energy has determined that some flood levels exceed the Current Licensing Basis (CLB). Of the flood hazard reevaluations performed for Robinson Nuclear Plant (HBRSEP), two events were selected as a basis for developing interim actions. The Local Intense Precipitation (LIP) event is a rainfall event that causes on-site flooding and is conservatively assumed to occur without warning for developing interim actions. The probable maximum flood (PMF) event causes the highest on-site flood levels.

5.1 EVALUATED EVENTS FOR SITE FLOODING

5.1.1 Local Intense Precipitation (LIP) Event

The site-specific LIP event is described in Section 3.1. As the storm is conservatively assumed to occur without warning, no interim manual actions are credited prior to the storm. Peak flood levels occur approximately six hour into the event, and flooding occurs across the entire power block area. Rain falls continuously for six hours and water starts to recede after the rain ends.

5.1.2 Probable Maximum Flood (PMF) Event

The PMF event is described in Section 3.2. This event is assumed to occur with sufficient advanced warning that enables a safe plant shutdown. The entire storm event consists of an antecedent storm of 500-year probability that lasts for 72 hr, a dry period of 72 hr, and a 72-hr Probable Maximum Precipitation (PMP) event. Water flow from the antecedent storm is within the HBRSEP spillway design basis, and no site flooding occurs during the antecedent storm and the following dry period.

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

5.2 IMPACTS OF THE EVENTS

(b)(3):16 U.S.C. § 824o-1(d), (b)(4), (b)(7)(F)

5.3 EVENT RESPONSE

Interim actions have been developed in response to the events. The interim actions do not adversely affect any existing site structures, systems or components. Procedures have been prepared and training performed for the interim actions.

5.3.1 Core Cooling

HBRSEP will maintain core cooling by supplying Auxiliary Feedwater (AFW) to the Steam Generators (SGs) for decay heat removal consistent with existing plant emergency procedures. Valve alignment would be performed locally per procedure. In addition, HBRSEP will preserve or re-establish the capability to add water to the RCS for inventory control and reactivity control with boration.

Additional actions to achieve core cooling related to each specific flooding event are detailed in Sections 5.4 and 5.5.

5.3.2 Spent Fuel Pool Cooling

Loss of AC power will result in a loss of power to the Spent Fuel Pool (SFP) Cooling pumps. An existing procedure is in place to deploy a portable pump to deliver water to the SFP prior to uncovering the top of the fuel.

5.3.3 Containment Integrity

As long as water is supplied to the SGs and the RCS is borated, containment integrity will be maintained for a minimum of two days. After two days, the Emergency Response Organization (ERO) will take any additional actions needed.

5.4 INTERIM ACTIONS RELATED TO THE LIP EVENT

5.4.1 Steam Generator Cooling

Feedwater flow must be provided to the SGs within 61 min of the reactor trip due to flooding to provide adequate decay heat removal. Steam generator cooling will be provided from the "C" AFW pump. The diesel generator that powers the "C" AFW pump, is protected from the LIP event. The "C" AFW pump is supplied by the Condensate Storage Tank. This tank may be re-filled with the "C" Deepwell pump powered by its installed diesel generator. The LIP event does not affect the "C" Deepwell pump or its associated diesel generator.

Manual actions consist of starting the "C" AFW pump and its diesel to provide AFW for SG cooling during the LIP event per procedure. The diesel may be started remotely from the "C" AFW pump.

5.4.2 RCS Inventory and Boration

HBRSEP has the capability to add borated water to the RCS using station procedures developed based on the guidance provided in Westinghouse WCAP-17601P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering, and Babcock & Wilcox NSSS Designs," Revision 0, August 2012.

To supply a source of borated water, dry boric acid will be mixed in a portable tank. This tank will be filled using a portable pump currently stored on-site. The borated solution will be injected into the RCS using a new high pressure, portable diesel-driven pump. HBRSEP will relocate this portable equipment near the Refueling Water Storage Tank (RWST) after flood levels have receded. It is not necessary to pre-stage the equipment as there is sufficient time to initiate boration with the portable equipment following the reactor trip. All required equipment will be stored on-site in an area that will maintain the equipment available following a LIP event.

5.4.3 **Spent Fuel Pool Cooling**

Existing procedures will be utilized to fill the SFP after the LIP event. The necessary equipment does not need to be pre-staged for this event as the flood level will have sufficiently receded before cooling water must be delivered to the SFP.

5.5 INTERIM ACTIONS RELATED TO THE PMF EVENT

The trigger for this interim action is notification of a severe storm system approaching that has the potential for significant rainfall. Response to the notification will be to utilize the Event Response and Notification procedure.

Additionally, lake elevation may also trigger plant response. The Tainter gates for the dam can control lake elevation and prevent flooding during the antecedent storm. An additional response for the PMF event was implemented such that if the gates are opened to meet the criteria in the plant's Emergency Notification Procedure, the Unit Threat Team will be activated.

5.5.1 **Steam Generator Cooling**

Procedures were revised to include guidance for the Unit Threat Team review of actions for a PMF event. If a known major storm is heading toward the plant, the conservative decision-making process of the Unit Threat Team will ensure a safe plant shutdown prior to site flooding that provides enough time for adequate core decay heat removal. Temporary equipment could then be utilized as needed. The plant's Extreme Damage Mitigation Guidelines (EDMGs) have been revised to address pre-staging a new pump above the expected flood elevation to provide AFW to the SGs from the Condensate Storage Tank or an alternate source.

5.5.2 **RCS Inventory and Boration**

A safe shutdown 24 hours prior to the main flooding event will ensure that RCS boration will be accomplished. Thereafter, for RCS inventory control, a high pressure, portable diesel-driven pump will be available for use after the flood recedes.

5.5.3 **Spent Fuel Pool Cooling**

Existing guidance provided in the EDMGs will be utilized to fill the SFP. The necessary equipment will be available above the flood elevation to ensure it is unaffected by the PMF event.