L-MT-16-024

ENCLOSURE 2

FLOOD HAZARD REEVALUATION REPORT

IN RESPONSE TO THE 50.54(f) INFORMATION REQUEST REGARDING RECOMMENDATION 2.1: FLOODING OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT

for the

MONTICELLO NUCLEAR GENERATING PLANT
RENEWED LICENSE NO. DPR-22

(REDACTED VERSION)

39 pages follow

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Prepared by:

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Rev. 0

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Acronyms and Abbreviations

ACES	Automated Coastal Engineering System
ADAMS	Agencywide Documents Access and Management System
ANS	American Nuclear Society
ANSI	American National Standards Institute
APWA	American Public Works Association
B	Bounded
CDB	current design basis
CEM	Coastal Engineering Manual
CFR	Code of Federal Regulations
cfs	cubic (foot) feet per second
d/b/a	Doing Business As
DEM	Digital Elevation Model
EC	Engineering Change
EFT	Emergency Filtration Train
EM	Engineer Manual
FFE	finished floor elevation
FIS	Flood Insurance Study
FLEX	Diverse and Flexible Coping Strategies
ft	foot (feet)
ft^3	cubic foot (feet)
ft/s	feet per second
H	horizontal
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HHA	Hierarchical Hazard Assessment
HPCI	High-Pressure Coolant Injection
HMR	Hydrometeorological Report
hr	hour
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance
JLD	Japan Lessons-Learned Directorate
km^2	square kilometer(s)
LiDAR	Light Detection and Ranging
LIP	Local Intense Precipitation
m	meter(s)
mi^2	square mile(s)
MNGP	Monticello Nuclear Generating Plant

mph	miles per hour
MSL	mean sea level
N/A	not applicable
NAVD 88	North American Vertical Datum of 1988
NGDC	National Geophysical Data Center
NGP	Nuclear Generating Plant
NB	not bounded
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRC	United States Nuclear Regulatory Commission
NSPM	Northern States Power Company, a Minnesota corporation
NTTF	Near Term Task Force
NUREG	NRC technical report designation
NUREG/CR	NUREG contractor report
PMF	probable maximum flood
PMP	probable maximum precipitation
psf	pound(s) per square foot
RHR	Residual Heat Removal
SCS	Soil Conservation Service
SSCs	structures, systems, and components
TBA	Turbine Building Addition
TR	Technical Release
USACE	United States Army Corps of Engineers
USAR	Updated Safety Analysis Report
USGS	United States Geological Survey
V	vertical
WSE	water surface elevation
yr	year

1. Information Related to the Flood Hazard

1.1 Introduction

In response to the nuclear fuel damage at the Fukushima Dai-ichi power plant due to the March 11, 2011 earthquake and subsequent tsunami, the United States Nuclear Regulatory Commission (NRC) established the Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations, and to make recommendations to the Commission for its policy direction. The NTTF reported a set of recommendations that were intended to clarify and strengthen the regulatory framework for protection against natural phenomena.

On March 12, 2012, the NRC issued an information request pursuant to Title 10 of the Code of Federal Regulations (CFR), Section 50.54 (f) (Reference 3) which included six (6) enclosures:

1. [NTTF] Recommendation 2.1: Seismic
2. [NTTF] Recommendation 2.1: Flooding
3. [NTTF] Recommendation 2.3: Seismic
4. [NTTF] Recommendation 2.3: Flooding
5. [NTTF] Recommendation 9.3: Emergency Preparedness
6. Licensees and Holders of Construction Permits

In Enclosure 2 of Reference 3, the NRC requested that licensees reevaluate the flooding hazards at their sites against present-day regulatory guidance and methodologies being used for early site permits and combined license reviews.

1.2 Purpose

This report provides the information requested in the March 12, 50.54(f) letter; specifically, the information listed under the "Requested Information" section of Enclosure 2 of Reference 3, paragraph 1 ("a" through "e") for Monticello Nuclear Generating Plant (MNGP).

Evaluation of the eight flood-causing mechanisms and associated effects (when required), as well as the combined effect flood, identified in Attachment 1 to Enclosure 2 of the NRC information request (Reference 3) and the potential effects on the MNGP site is described in Section 2 of this report.

1.3 Method

This flooding hazard reevaluation followed the Hierarchical Hazard Assessment (HHA) approach, as described in NUREG/CR-7046, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (Reference 2) and its supporting reference documents.

The HHA approach consists of a series of stepwise, progressively more refined analyses to evaluate the hazard resulting from phenomena at a given nuclear power plant site to structures, systems, and components (SSCs) important to safety with the most conservative plausible assumptions consistent with the available data. The HHA starts with the most conservative, simplifying assumptions that maximize the hazards from the maximum probable event. If the assessed hazards result in an adverse effect or exposure to any safety-related SSC, a more site-specific hazard assessment is performed for the probable maximum event.

The steps typically involved to estimate flood hazard include the following:

1. Identify flood-causing phenomena or mechanisms by reviewing historical data and assessing the geohydrological, geoseismic, and structural failure phenomena in the vicinity of the site and region.
2. For each flood-causing phenomenon, develop a conservative estimate of the flood from the corresponding probable maximum event using conservative simplifying assumptions.
3. If any safety-related SSC is adversely affected by flood hazards, use site-specific data and/or more refined analyses to provide a more realistic condition and flood analysis, while ensuring that these conditions are consistent with those used by Federal agencies in similar design considerations. Repeat Step 2; if all safety-related SSCs are unaffected by the estimated flood, or if all site-specific data have been used, specify design bases for each using the most severe hazards from the set of floods corresponding to the flood-causing phenomena.

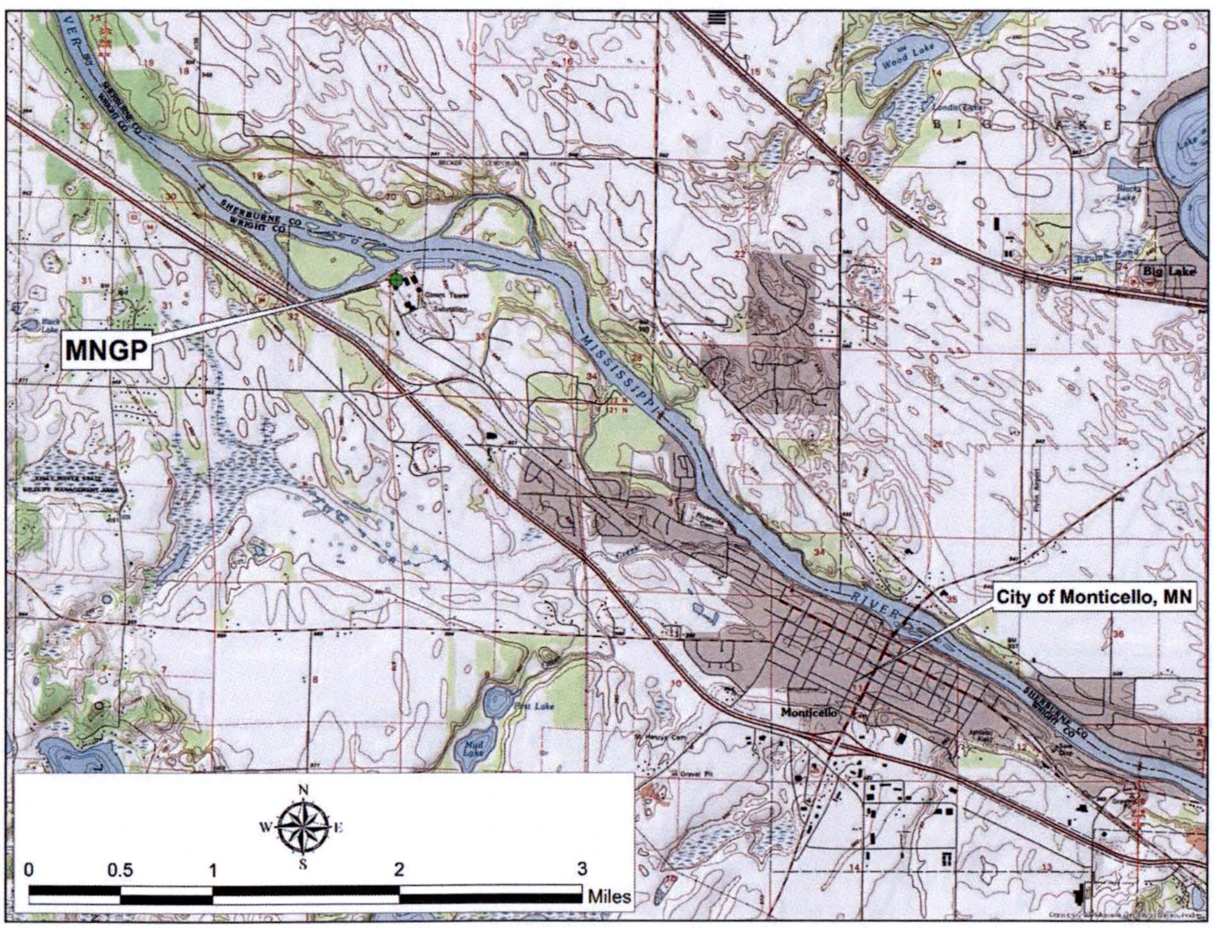
Section 2 of this report provides additional HHA detail for each of the flood-causing mechanisms evaluated.

1.4 Detailed Site Information

1.4.1 Elevation Values

Unless otherwise stated, all elevation values sited in this report are in feet above mean sea level (MSL), which is also referred to as National Geodetic Vertical Datum of 1929 (NGVD 1929).

Figure 1 – MNGP Site and Nearby Vicinity



1.4.2 Site Layout and Topography

The site is located within the city limits of the Monticello, Minnesota on the right bank of the Mississippi River and about 70 river miles upstream from Minneapolis-St. Paul. The plant site occupies an area of approximately 2,150 acres. The topography of the MNGP site is characterized by relatively level bluffs, which rise sharply above the river. Three distinct bluffs exist at the plant site at elevations 920, 930, and 940 ft. Bluffs located approximately a mile north and south of the site rise to 950 ft. Further to the north, the terrain is relatively level with numerous lakes and wooded areas. To the south, west, and east, the terrain is hilly and dotted with numerous small lakes (Reference 10).

The Mississippi River abuts the site to the north and northwest. The flow in the Mississippi River in the vicinity of the plant is unregulated and subject to large variations throughout the year. Normal river level is at elevation 905 ft and the maximum river flood stage was recorded in 1965 at elevation 916 ft. The 1,000-year projected river flood stage is at elevation 921 ft (Reference 10).

The natural grade of the power block is at elevation 930 ft with elevations of the majority of critical structure openings ranging from 931 ft to 935 ft (References 10 and 18). The MNGP site and the regional vicinity are shown in Figure 1.

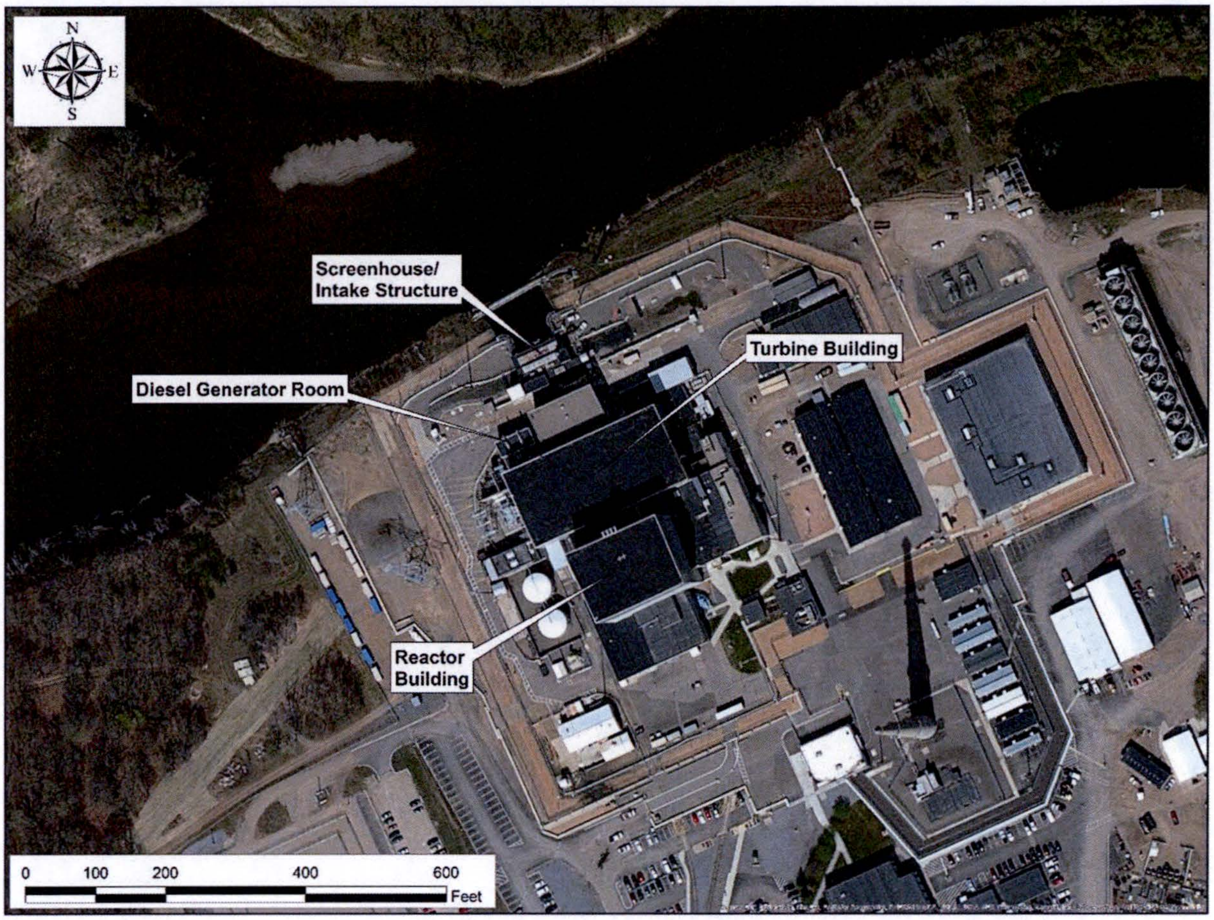
1.4.3 Elevation of Safety Related Structures, Systems and Components

Class I structures, which are vital to safe shutdown of the plant and removal of decay heat have been identified in the USAR (Reference 10), as following:

- Primary Containment (Drywell, Vents, Torus, and Penetrations)
- Reactor Building (up to Operating Floor – 1027-foot 8-inch)
- High Pressure Coolant Injection (HPCI) Building
- Plant Control and Cable Spreading Structure
- Spent Fuel Storage Pool
- Off-gas Stack
- Reactor Primary Vessel Biological Shield and Support Pedestal
- Standby Diesel Generator Building
- Diesel Fuel Oil Transfer House Containing Diesel Fuel Oil System
- Emergency Filtration Train (EFT) Building
- Intake Structure Pump Room Containing Emergency Service Water and Residual Heat Removal (RHR) Service Water Pumps and Connecting Pipe Tunnel
- Parts of Turbine Building Housing Class I Equipment
- Underground Duct Bank – 3rd Floor, EFT to Reactor Building.

Plant grade for Class I structures is at elevation 930 ft, except for the Intake Structure. These structures have been designed for a river flood stage up to this elevation. Certain components of the above mentioned Class I structures may be located below elevation 930 ft; however, flood protection features (e.g., steel plates, grout, or sandbags) are installed to close any openings below elevation 930 ft (Reference 10). The operating floor of the Intake Structure is located at elevation 919 ft with an opening between the Screenhouse and the Intake Structure at elevation 919.5 ft (References 10 and 18). The power block area is shown in Figure 2.

Figure 2 – MNGP Power Block Area



1.5 Current Design Basis Flood Elevations

The current design basis flood elevations for MNGP are described in the USAR (Reference 10) as well as the recent walkdown reports required as part of NRC's 10 CFR 50.54(f) letter (Reference 3).

The only flood causing mechanism quantified as part of the current design basis was "Flooding in Streams and Rivers." A summary of this flood causing mechanism and the corresponding flood hazard is provided in the following section. A brief discussion of "Ice Induced Flooding" is also provided.

1.5.1 Flooding in Streams and Rivers

The probable maximum flood (PMF) in the Mississippi River adjacent to the MNGP site was determined to be 364,900 cfs with a corresponding peak flood stage of 939.2 ft. A detailed description of the methodology, inputs, assumptions and results is provided in Appendix G of the USAR. The limiting flood resulted from a combination of meteorological conditions including snowmelt that could occur in the spring and could reach maximum river level in about 12 days. It was estimated that the flood elevation would remain above elevation 930 ft for approximately 11 days (Reference 10). From flow and stage hydrographs provided in Appendix G of the USAR, it can also be estimated that the flood stage would reach elevation 919 ft (Intake Structure operating floor) in less than 4 days and would remain above this elevation for approximately 20 days.

The PMF study included a watershed area of 13,900 square miles upstream of MNGP. The watershed is characterized by level to rolling prairie land interspersed with areas of glacial moraines. The average elevation of the watershed is approximately 1,200 ft. The main hydrologic characteristic of the watershed are the numerous lakes, which significantly influence the streamflow characteristics of the Mississippi River and its tributaries. The long-term mean annual runoff for the basin is approximately 5.0 inches (Reference 10).

The PMF at the MNGP site was determined by transposing actual storms to the watershed and maximizing the precipitation for potential moisture. The selected storms considered were the March 23-27, 1913 storm centered at Bellefontaine, Ohio (spring storm) and the August 28-31, 1941 storm centered at Hayward, Wisconsin (summer storm). The spring storm combined with a snowmelt occurring during the storm resulted in higher discharge than the summer storm. For the purpose of the PMF study, maximum snow water equivalent for a period between March 16 and March 31 having one percent probability was used. Methods developed by the USACE and described in EM 1110-2-1406 "Runoff from Snowmelt" were used to compute snowmelt (Reference 10).

Initial retention losses were assumed to be zero and infiltration losses were assumed to be 0.02 inches per hour during the snowmelt period and 0.03 inches per hour during the period following the beginning of rainfall (Reference 10).

The most critical sequence of event leading to a major flood in the watershed would be a combination of unusually heavy spring snowfall and low temperatures after a period of intermittent warm spells and sub-freezing temperatures forming an impervious ground surface followed by a period of extremely high temperatures and a major storm event. For the purposes of the design basis study, snow water equivalent having a one percent probability was assumed to cover the watershed at the beginning of the simulation. This was immediately followed by the maximum historical temperature sequence and after 5 days the probable maximum spring precipitation was initiated (Reference 10).

The watershed was divided into four major sub-basins and synthetic hydrographs were developed for each using the Snyder's method. Unit hydrograph peaks were increased by 25 percent and basin lag time decreased by one-sixth. Snowmelt and rainfall excess were applied to the unit hydrographs and the resulting hydrographs were determined for each sub-basin, which were then routed to the MNGP site using a computer model. The travel time for flood routing was based on the USACE recorded travel times for large floods. Baseflow of 5,000 cfs, based on long-term USGS records for the Elk River, Minnesota stream gage, was added to the routed flood hydrographs (Reference 10).

A stage-discharge curve at the MNGP site was developed using a computer model. The inputs for the computer model included channel and overbank cross-sections based on 2-ft and 10-ft topographic maps; Manning's n-values for left overbank, right overbank, and channel; discharges of various magnitudes; and starting water elevations. Average Manning's n-values were determined to be 0.032 for the main channel, 0.050 for the left overbank, and 0.045 for the right overbank. A higher value of 0.065 was used for the right overbank at MNGP and a value of 0.06 was used for the island immediately upstream of MNGP. The model was verified against the maximum flood of record (April 1965) for which records of high water marks exist at several points along the river (Reference 10).

Based on the results of the study described in the USAR, the limiting design basis flood for the MNGP site is the PMF of the Mississippi River of 364,900 cfs, with a peak river flood stage of 939.2 ft. Dam breaches and wind-wave runup were not considered in the current design basis evaluation.

1.5.2 Ice Induced Flooding

Appendix G of the USAR (Reference 10) briefly discusses backwater flooding caused by ice jams as one of the two types of flooding occurring the Mississippi River watershed. However, the ice induced flooding is not quantified and is not considered to result in flooding levels exceeding the precipitation-driven flooding levels.

1.6 Flood-Related Changes to the Licensing Basis and Flood Protection and Mitigation Changes since License Issuance

No changes to flood elevations have been made since the issuance of the original license.

Procedural changes and enhancements to flood protection were implemented following the completion of the Recommendation 2.3: Flooding Walkdowns, during which several deficiencies and observations were identified. These deficiencies and observations were documented in the flooding walkdown report (Reference 11). A summary of the changes is provided below:

- Enhancements to Procedure A.6 were implemented to streamline actions described in the procedure (Reference 12).
- Engineering Change (EC) 21937 was prepared to install permanent flood protection features on and around the Intake Structure and reduce the amount of field work required during a flooding event and ultimately improve response time (Reference 11). This included bin wall/earthen levee design changes (Reference 15) and design of debris barrier to protect the flood barrier from impact by debris floating in the flooded river (Reference 16).

1.7 Watershed and Local Changes

The watershed contributory to the Mississippi River upstream of MNGP is approximately 13,900 square miles (Reference 10). There have not been significant changes to the watershed since the last license renewal and the land use changes are relatively minimal. Local area changes have also been minimal since plant operation began at the MNGP site.

Changes consistent with most nuclear plant sites have been made at MNGP since operations began, including the addition of the following structures:

- Administration Buildings
- Independent Spent Fuel Storage Installation (ISFSI)
- Security Buildings
- Warehouses
- FLEX Equipment Storage Building
- Security barriers

The changes also included the bin wall sections adjacent to the Intake Structure, which are now permanently installed.

Location and configuration of current structures, as relevant, were inputs to the Local Intense Precipitation (LIP) calculations as related to the flooding impacts on SSCs.

1.8 *Licensing Basis Flood Protection and Mitigation Features*

Flood protection features utilized at MNGP in the event of the PMF include incorporated and temporary active and passive barriers. For flood protection below elevation 930 ft, installation of flood protection features (such as pumps and steel plates, grout, or sandbags to close openings up to elevation 930 ft) provides flood protection for Class I structures and Class II structures housing Class I equipment. Suitable steel flood protection plates are stored at the plant to ensure that they are readily accessible (Reference 10).

For flood protection above elevation 930 ft, a levee consisting of a bin wall and an earthen berm is constructed around Class I structures (excluding the Off-Gas Stack), Class II structures housing Class I equipment (excluding Off-Gas Storage Building), and Radwaste Building to protect them from the effects of a flood. The Off-Gas Stack is outside the boundary of the levee and is protected by sandbags. The Off-Gas Storage Building is excluded because the only areas that house Class I components are the Fan and Foyer Rooms for Stand-By Gas Treatment and the components are located at an elevation above the PMF. Additional flood protection features (such as steel plates, grout, or sandbags) to close openings may be used as a defense in depth measure when river levels are expected to exceed elevation 930 ft (Reference 10).

Procedure A.6, "Acts of Nature," (Section 5.0 – External Flooding) (Reference 12) outlines actions to be taken in the event flood waters are predicted to exceed elevation 918 ft. Should the projected river level exceed 918 ft, an orderly plant shutdown would be commenced to place the reactor in a cold shutdown condition (Reference 10).

Procedure 8300-02 (Reference 13) provides instruction for protection of MNGP from damage by floodwaters, including the construction of the bin wall/earthen levee and installation of the debris barrier to protect the bin wall and Intake Structure roof plates. The bin wall sections adjacent to the Intake Structure are permanently installed (Reference 15). The remaining bin wall/levee sections would be constructed if the river levels are forecast to exceed elevation 930 ft. The north-west portion of the levee and east and west temporary bin walls must be started prior to floodwaters reaching elevation 917 feet and remain ahead of the river. The remaining areas of the levee must be started prior to floodwaters reaching elevation 930 feet (Reference 12).

2. Flood Hazard Reevaluation

The flooding hazard reevaluation for each of the eight flood causing mechanisms and the combined effect flood, is described in the following subsections.

2.1 Local Intense Precipitation

The methodology and results presented in this section are based on the evaluation of the LIP event performed in Calculation 180999.51.1005 (Reference 18).

2.1.1 Methodology

The LIP is a measure of the extreme precipitation (high intensity/short duration) at a given location. NUREG/CR-7046 (Reference 2) specifies that the LIP should be equivalent to the 1-hr, 2.56-km^2 (1-mi^2) PMP at the plant site. For the LIP evaluation at the MNGP site, the storm duration was extended to 6 hours, as shown in Appendix B of NUREG/CR-7046. Case 3 assumptions in Appendix B of NUREG/CR-7046 were also applied. Case 3 assumes that the design of the site grade and the passive drainage channels are incapable of routing flow from the immediate plant site and, therefore, overland flow occurs over the entire plant site during the LIP event. Roof runoff was accounted for in the analysis and rooftops are not providing any storage. The LIP evaluation included an all-season storm event and a cool-season rain-on-snow storm event. The all-season event was determined to be the controlling event. Therefore, only the all-season event is discussed in this section.

Rainfall depths and temporal distribution for the LIP storm were developed using HMR 51 (Reference 24) and HMR 52 (Reference 25), respectively. The 1-hr 1-mi^2 rainfall depths and the corresponding percentages for the 5-, 15-, and 30-minute intervals were determined using the approach described in HMR 52. While HMR 52 does not specifically state that the time intervals be arranged in this order, with the typical west-east flow across North America, the type of storm set-up that would provide an LIP event at the MNGP site would likely be a mesoscale convective system (such as squall line for example). Using the conceptual model of this type of system, the initial precipitation is associated with the mature cells and a zone of convergence and as such will be very intense. The storm motion and nature of the system would then see a decrease in the precipitation after the initial burst as the rear trailing stratiform region with the cold pool moves over the area. This type of meteorological system fits with the front loaded distribution. The 6-hr 10-mi^2 rainfall depth is provided in HMR 51. The temporal distribution of the LIP storm used in the evaluation is provided in Table 1.

Table 1 – All-Season LIP Calculations and Cumulative Depth

Duration (minutes)	Area (mi^2)	Multiplier	Applied to	LIP (inches)
5	1	0.345	1-hr, 1-mi^2 PMP	5.78
15	1	0.55	1-hr, 1-mi^2 PMP	9.22
30	1	0.777	1-hr, 1-mi^2 PMP	13.02
60	1	0.71	6-hr, 10-mi^2 PMP	16.76
360	10	N/A	N/A	23.60

Runoff losses were ignored during the LIP event to maximize runoff per NUREG/CR-7046. As a result, infiltration (i.e., constant loss) was not considered and initial abstraction was set to zero.

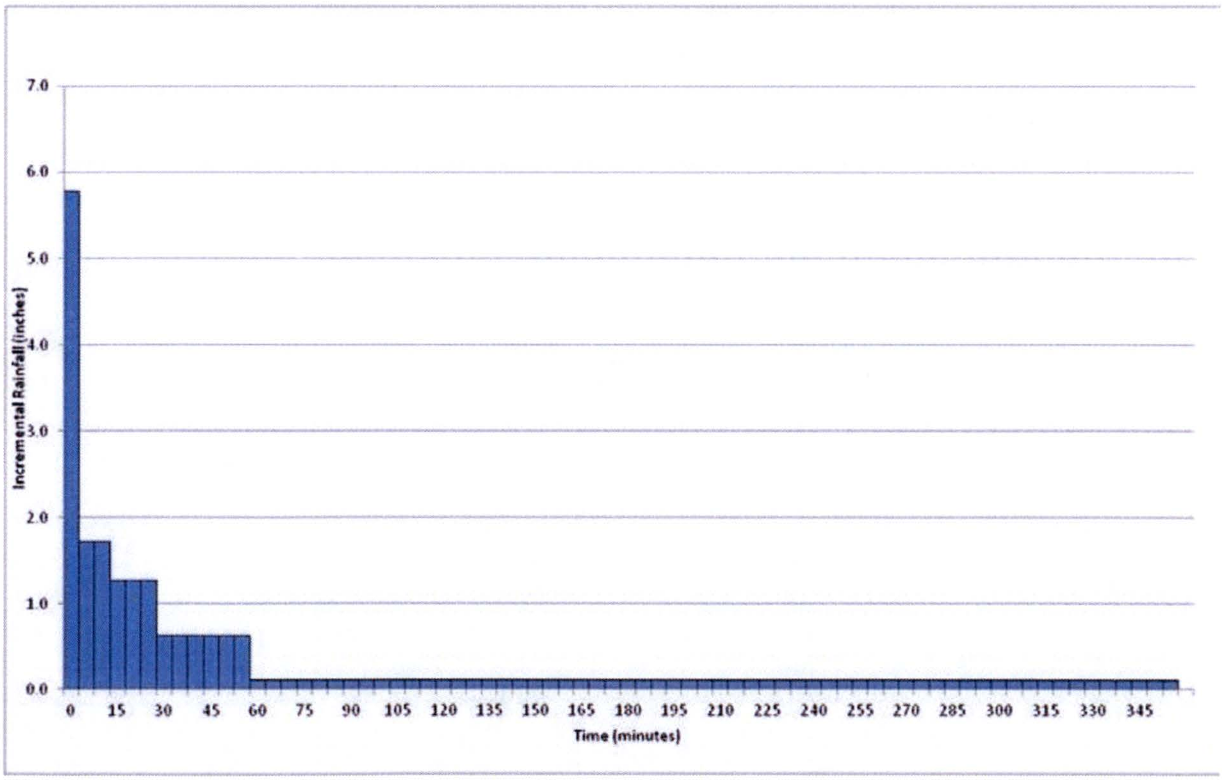
The Digital Elevation Model (DEM) was derived from bare earth LiDAR data combined with topographic survey data. For any buildings and structures not within the survey limits, a height of 10 feet is assumed for the shorter buildings and 100 feet for the tallest building. The top elevation of security barriers was defined by adding 3.3 feet (based on measurements) to the ground elevation reported by the LiDAR.

Manning's "n" roughness coefficients were based on land cover information and published guidance. For calculation of time of concentration for hydrologic calculation the Manning's n-values ranged from 0.011 to 0.4. The MNGP site is an industrial site with asphalt paving or gravel roads. Therefore, for on-site hydraulics a Manning's n-value of 0.02 was used to represent the roughness of the cross sections.

Travel times were calculated for each flow type (sheet flow, shallow concentrated flow, and channelized flow). The Technical Release 55 (TR-55) method (Reference 26) was used to determine the travel times for sheet flow and shallow concentrated flow. To determine the open channel flow time, the nomogram in American Public Works Association (APWA) 5600 (Figure 5602-3, Reference 28) representing typical hydraulic sections using Manning's equation, was used. To determine the time of concentration, the travel times for sheet flow, shallow concentrated flow and open channel flow were summed. The lag time for use in the HEC-HMS model was calculated as approximately 0.6 of the time of concentration (Part 630 Hydrology National Engineering Handbook, Reference 27).

The USACE HEC-HMS model was used to evaluate runoff from the LIP event and generate inflow hydrographs for hydraulic analysis. Inputs consisted of the all season LIP hyetographs, drainage area size, and lag time. The 6-hr LIP hyetograph is provided in Figure 3. The Soil Conservation Service (SCS) Unit Hydrograph method was used to transform precipitation into runoff.

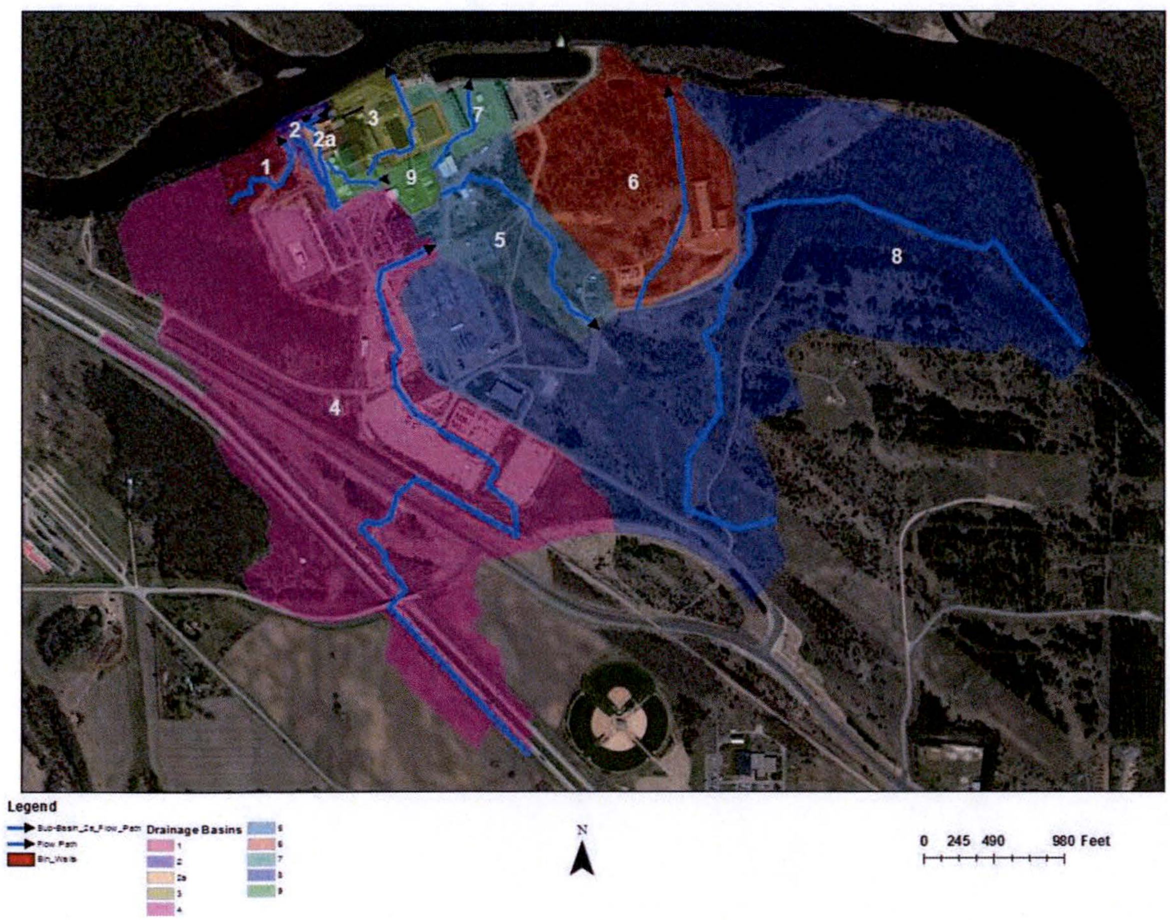
Figure 3 – Local Intense 6-Hr All-Season PMP Hyetograph



The drainage area of the MNGP site was divided in 10 sub-basins (Figure 4). Outputs from the HEC-HMS model are runoff hydrographs for each of the individual sub-basins areas.

An unsteady flow analysis was then performed using the USACE HEC-RAS model to evaluate dynamic hydraulic interactions between the different model components. Consistent with the NUREG/CR-7046 recommendations, it was assumed that all storm drains and roof drains are blocked. Based on the review of site conditions and site cover, it was concluded that all above-ground flow drainage paths would be available for conveyance and would not be blocked by debris. During the LIP event, precipitation that falls on the MNGP site flows away from the plant exiting either to the north into the Mississippi River or to the south through sections where concrete jersey barriers are not present. In areas where jersey barriers are present, they prevent outside runoff from flowing onto the site and limit the site runoff from flowing off-site. Where considerable gaps exist in between rows of jersey barriers, water is allowed to leave the site and off-site downstream boundary condition is taken into account in the on-site hydraulic models. In order to characterize the various flow paths at and around the site, seven hydraulic models were created. Three hydraulic models were necessary to hydraulically describe runoff in the off-site subbasins (sub-basins 1, 4, 5, 6, 7 and 8). Off-site basins were modeled to ensure that estimated flood levels would: a) not overtop protective jersey barriers; and b) would not impede onsite runoff. Additionally, four hydraulic models were necessary for characterizing the on-site runoff (runoff within the protective jersey barriers – sub-basins 2, 2a, 3, and 9). The downstream boundary condition was set to a known water level. Where the sub-basin discharges directly to the Mississippi River the downstream boundary condition was set to the 500-year water level in the Mississippi River, which is a conservative assumption. All models were run in the mixed flow regime, allowing for both supercritical and subcritical flows.

Figure 4 – LIP Drainage Areas and Directions of Flow



2.1.2 Results

The LIP evaluation determined the maximum water surface elevations at several critical door openings. The predicted flood elevations vary spatially throughout the site, as shown in Table 2. An interim evaluation (Reference 18) was also performed to assess the impacts of flood levels on the doors and to evaluate possible leakage through the doors. The results of this interim evaluation are presented in Sections 2.10.1 and 2.10.2.

Table 2 – LIP Evaluation Results

Opening Location	Opening Invert/ Sill Level (FFE)	Estimated Maximum WSE	Maximum Water Depth at Opening
	feet NGVD 29		feet
Intake Structure Door (Door 209) - Interior between Screenhouse and Intake Structure	919.50	920.62	1.12
West Roll-Up Door (Door 119) - Turbine Building Addition	931.25	931.41	0.16
East Roll-Up Door (Door 120) - Turbine Building Addition	931.25	931.53	0.28
Railcar Entry (Door 24) - Turbine Building	935.00	935.83	0.83
Railcar Entry (Doors 45 and 46) - Reactor Building	935.00	935.07	0.07
Emergency Diesel Generator - East 3-ft wide Man Door (Door 8)	931.00	931.41	0.41
Emergency Diesel Generator - West 3-ft wide Man Door (Door 7)	931.00	931.41	0.41
EFT Room (Door 341)	932.83	933.20	0.37
13.8 KV Room (Door 1)	931.00	933.09	2.09
Off Gas Stack (Door 193)	932.50	934.63	2.13
Fuel Oil Transfer Pump House (Door 483)	931.00	931.29	0.29

2.1.3 Conclusions

Based on the LIP evaluation for MNGP, the maximum depth of flooding varies spatially and ranges from 0.07 ft at the Railcar Entry to the Reactor Building to 2.13 ft at the Off Gas Stack. The LIP evaluation was not addressed as part of the current design basis and, therefore, the reevaluated flood hazard is considered not bounded.

Significant debris loading/transportation is not a safety hazard due to the relatively low velocity and depth of LIP flood waters in the vicinity of SSCs, in addition to the lack of natural debris sources within the on-site protected area.

Regarding uncertainty as per NUREG/CR-7046, note that the LIP methodology herein incorporates conservatism which is anticipated to bound potential uncertainties in the analysis. Specifically:

- Rainfall loss rates (i.e., depression storage, infiltration) were conservatively not considered.
- Roughness coefficients used in the hydraulic simulation are conservative.
- HMR 52 PMP depths were used in the LIP evaluation. These values are conservative compared to the site-specific LIP depths developed for MNGP in Calculation 180999.51.1008 (Reference 19).
- Stormwater drainage systems and features were assumed to be blocked.
- Rooftops were modeled as not providing any storage.

2.2 Flooding in Streams and Rivers

The PMF is considered to be the most severe, reasonably possible flood resulting from a PMP across the watershed (Reference 2).

The flows in the Mississippi River are affected by the presence of a large number of locks and dams. Some of these locks and dams were designed, constructed and are currently maintained by the USACE. To support Northern States Power Company, a Minnesota corporation (NSPM), d/b/a Xcel Energy, development of the flood hazard reevaluation associated with the assessment of flood hazards due to flooding in streams and rivers, including potential flooding due to dam failure, NSPM requested NRC assistance in obtaining information related to the USACE dams, including all completed and pending dam failure analyses. The assistance was requested on March 5, 2014 (Reference 14). The USACE performed this portion of the flood hazard reevaluation. The results of the USACE analysis were transmitted to NSPM on November 18, 2015. The transmittal included a public letter (Reference 8) and non-public enclosures. The non-public enclosures contained security-related information. The USACE analysis provided in that letter determined the controlling PMF discharge for MNGP. The analysis was performed in accordance with JLD-ISG-2013-01, "Guidance for Assessment of Flooding Hazards Due to Dam Failure," (Reference 4) and was based on the USACE knowledge of the river system. The following sections provide a summary of the USACE analysis.

Additionally, the effects of waves induced by 2-year wind speed applied along the critical direction were evaluated in Calculation 180999.51.1002 (Reference 22) and are provided in Section 2.2.2. This calculation was performed using the maximum water surface elevation determined by the USACE in their PMF analysis.

2.2.1 Maximum Stillwater Elevation

The information provided in this section is based on the results of the USACE PMF analysis transmitted to NSPM on November 18, 2015 (Reference 8), and the response to NSPM questions at the July 9, 2015 meeting with NRC and USACE (Reference 9).

2.2.1.1 Methodology

The USACE developed a HEC-HMS model of the Mississippi River watershed upstream of MNGP to evaluate the PMF discharges. The initial and constant loss rate method was used to model precipitation losses. Loss parameters adopted to simulate the PMF event in HEC-HMS were selected based upon model calibration and the results of other hydrologic studies in the region. The model was calibrated to three large, historic events (1957, 1965, and 2012) to replicate the conditions that would persist during the PMF event. The values derived via calibration are consistent with the initial and constant loss rates adopted for other studies performed by the USACE.

HMR 51 was used to determine the precipitation depth-duration-area relationships for the all-season PMP event. HMR 52 was used to optimize the PMP storm orientation and size. The principles in HMR 52 were

applied to determine the PMP rainfall hyetograph. To generate the spring PMP event, HMR 53 was used to determine the depth-duration-area relationships for a 10-mi^2 drainage area. The tables in "Probable Maximum Precipitation Estimates and Snowmelt Criteria for the Upper Mississippi River in Minnesota and the Fox-Wolf Rivers in Wisconsin" were used to translate this relationship to a wider range of drainage areas. The energy budget equations in USACE EM 1110-2-1406 were used to generate the snowmelt rates applied to model a 10-day melt prior to a spring rainfall event. The guidance in "Probable Maximum Precipitation Estimates and Snowmelt Criteria for the Upper Mississippi River in Minnesota and the Fox-Wolf Rivers in Wisconsin" was used to define the inputs to these equations and was used to define the 100-year Snow Water Equivalent (representative of the snowpack) prior to the melt.

Unsteady flow modeling using the USACE HEC-RAS computer program was implemented for developing the PMF stage/flow hydrographs at the MNGP site. The downstream boundary condition was set to a stage-discharge rating curve at a USGS stream gage (USGS Gage 05288500), which is at a substantial distance downstream from MNGP. The rating curve was extended to PMF magnitude events. The HEC-RAS model extends upstream to a point immediately downstream of St. Cloud Dam, in St. Cloud, Minnesota. As stated in Reference 9, The hydraulic model "was calibrated to the Anoka County and Sherburne County Flood Insurance Study (FIS) steady flow profiles for the 10-yr, 50-yr, 100-yr, and 500-yr events as well as published USGS rating curves at two locations. The model cross-sections were calibrated to water surface elevations within 0.5 ft of the 100-year FIS study water surface elevations and within 1.0 ft of the 500-yr flood water surface elevations, while ensuring that the 10-yr and 50-yr flood water surface elevations calibrated within a reasonable range." The primary parameters adjusted to achieve a better fit to the calibration data were Manning's n-values, which were consistent with the results of both the Anoka and Sherburne County FIS studies.

2.2.1.2 Results

The representative HEC-RAS cross-section for the MNGP site is located at River Station 900.5. The peak flow rate corresponding to the combined-effect PMF is [redacted] cfs. The peak stage resulting from the combined-effect PMF is [redacted] ft NAVD 88 [redacted] ft NGVD 29). The average right overbank velocity is [redacted] ft/s and the average channel velocity is [redacted] ft/s.

The combined-effect PMF flow and stage hydrographs for the governing precipitation driven discharge at the MNGP site are presented in Figure 5. [redacted]

Figure 5 – Probable Maximum Flood Flow and Stage Hydrographs at MNGP Site (River Station 900.5)

2.2.1.3 Conclusions

Based on the results of the PMF study performed by the USACE, the combined-effect PMF discharge of [redacted] cfs corresponding to peak stage of [redacted] ft NAVD 88 [redacted] ft NGVD 29) is bounded by the current design basis stillwater elevation of 939.2 ft.

2.2.2 Wind-Generated Waves

The methodology and results presented in this section are based on the evaluation of wave prediction and wave runup performed in Calculation 180999.51.1002 (Reference 22).

2.2.2.1 Methodology

Wave prediction and wave runup were calculated using the Automated Coastal Engineering System (ACES) model. The required inputs for the ACES model for wave prediction included wind speed and direction, depth, fetch, and wind duration. For wave runup, additional information about the structure was required, including the depth of water at the structure, structure slope and roughness.

Hourly wind data for the 10-m reference height were obtained from MNGP for years between 1991 and 2013, inclusive. Only years with at least 80 percent complete records were used in the analysis. Data for years 1991, 1993, 2000 through 2004, and 2006 through 2012 had sufficiently complete records to be used in the analysis. The analysis was performed using a two-parameter Weibull distribution to determine the wind-speed with a 2-year recurrence interval. The 2-year wind speed was determined to be 33.8 mph.

Fetch length was determined based on the extent of the PMF inundation limits, as obtained from the USACE PMF study. As recommended in the Coastal Engineering Manual (CEM) (Reference 29), a straight line fetch method was used since it provides a more conservative value than the effective fetch method. Fetch lines

were drawn in several directions (Figure 6) and average depth along the fetch line was calculated as a difference between the water surface elevation, as obtained from the USACE PMF study, and the terrain elevation. Based on the combination of fetch length and fetch average depth, wave prediction calculations were performed for fetch lines 4 and 5.

Figure 6 – Inundation Limits and Fetch Lines

[redacted]

It was conservatively assumed that the wind is oriented along the longest fetch. In accordance with the CEM, the final duration, which is the amount of time required for the waves to fully develop depending on the fetch length and wind speed, was calculated and used as input in the ACES model. The final durations for fetch lines 4 and 5 were 52 and 51 minutes, respectively.

The aforementioned inputs were then used by the wave prediction module in the ACES model to calculate the significant wave height for fetch lines 4 and 5. The wave runup on the levee system that protects MNGP from the current design basis flooding was calculated only for the larger of the predicted significant wave heights. Since the levee system consists of an earthen levee and bin walls with vertical walls, wave runup both on a sloped berm (1V:2.5H) and a vertical wall was calculated. For this evaluation, it was conservatively assumed that the levee system is located at the river bank because the ACES model does not have the ability to simulate runup on a berm that is removed from the shoreline, as in the case of the MNGP site. The ACES model output was also checked using hand calculations, which showed very similar results.

2.2.2.2 Results

The significant wave height for fetch lines 4 and 5 is predicted to be 1.65 ft and 1.61 ft, respectively.

The runup on the vertical bin wall and the sloped berm was calculated to be 1.9 ft and 1.3 ft, respectively. The corresponding water runup elevation for the vertical wall and the sloped berm is predicted to be [redacted] ft and [redacted] ft, respectively.

2.2.2.3 Conclusions

The maximum wave runup elevation during the PMF event was estimated to be [redacted] ft. Note that the elevation is [redacted] below the top elevation of the existing flood protection system

(bin walls/levee). While the current design basis did not specifically address wind-generated waves, this flood causing mechanism is bounded by the current design basis stillwater, elevation of 939.2 ft.

2.3 Dam Breaches and Failures

Based on the information transmitted to NSPM on November 18, 2015 (Reference 8), potential dam breaches and failures were considered in the USACE PMF analysis: "The information contained in the enclosures was developed in accordance with Japan Lessons-Learned Directorate (JLD) interim staff guidance (ISG) JLD-ISG-2013-01, "Interim Staff Guidance For Assessment of Flooding Hazards Due to Dam Failure," Revision 0, dated July 29, 2013 (ADAMS Accession No. ML13151A153), and on the USACE knowledge of the river system." Furthermore, the USACE stated in its response to NSPM questions at the July 9, 2015 meeting between NSPM, the NRC, and the USACE: "All the dams upstream of the Monticello and Prairie Island Nuclear Generating Plants (NGP) were screened out with regard to dam failures that could potentially impact the NGPs. The Dam Screen process was conducted in accordance to the current version of the JLD-ISG guidance" (Reference 9). Furthermore, the USACE stated that "All dams were screened out in terms of flood risk to the NGP regardless of failure mode" (Reference 9). Based on the information provided by NRC and USACE, it can be concluded that potential upstream dam breaches and failures regardless of failure mode do not increase the flood hazard at MNGP.

2.4 Storm Surge, including Wind-Wave Activity

The methodology and results presented in this section are based on the evaluation of storm surge performed in Evaluation 180999.50.2300-02 (Reference 20).

JLD-ISG-2012-06 (Reference 5), "Guidance for Performing a Tsunami, Surge or Seiche Hazard Assessment," Section 3, "Surge Hazard Assessment," states:

> *"All coastal nuclear power plant sites and nuclear power plant sites located adjacent to cooling ponds or reservoirs subject to potential hurricanes, windstorms, and squall lines must consider the potential for inundation from storm surge and wind-waves."*

As shown in Figure 1, MNGP is located on the Mississippi River and, therefore, not subject to a storm surge and wind-waves, as defined in the NRC guidance. Furthermore, an increase in water surface elevation on one bank of the river because of wind blowing across the river's water surface would be minor and negligible during non-flood conditions. The lowest elevation important to the plant is elevation 919 ft (Intake Structure operating floor) while the normal elevation for the Mississippi River at MNGP is 905 ft, which is approximately 14 ft lower. Therefore, flooding due to a storm surge is not applicable to the MNGP site (Reference 20).

2.5 Seiche

The methodology and results presented in this section are based on the evaluation of seiche performed in Evaluation 180999.50.2300-02 (Reference 20).

NUREG/CR-7046 (Reference 2), Section 3.6, defines a seiche as follows:

> *"A seiche is defined as an oscillation of the water surface in an enclosed or semi-enclosed body of water initiated by an external cause."*

As further described in Reference 2, seiches are considered for a lake or a reservoir.
Reference 5, "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment," Enclosure 1, Section 4, "Seiche Hazard Assessment," defines a seiche as follows:

> *"Seiche is an oscillatory wave generated in lakes, bays, or gulfs as a result of seismic or atmospheric disturbances and with a period ranging from a few minutes to a few hours."*

The MNGP site is located on the Mississippi River and not on a location susceptible to a seiche. Therefore, flooding due to a seiche is not applicable to the MNGP site (Reference 20).

2.6 Tsunami

The methodology and results presented in this section are based on the evaluation of tsunami performed in Evaluation 180999.50.2300-02 (Reference 20).

Reference 5, "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment," Enclosure 2, Section 3, "Tsunami Hazard Assessment," states:

> *"All coastal nuclear power plant sites (including sites adjacent to oceans, seas, lakes, rivers, and other inland bodies of water) must consider tsunami hazards."*

Reference 5 refers to NUREG/CR-6966, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America," (Reference 7) for performing a hierarchical hazard assessment to evaluate flooding potential due to a tsunami. Reference 7, Section 2, describes the hierarchical hazard assessment approach. The first step is to determine the potential that a tsunami may pose a hazard to the site based on a regional survey of historical records in the region and an evaluation of potential tsunami generation sources.

NOAA National Geophysical Data Center (NGDC) maintains a historical tsunami database which catalogs tsunami events. Reference 7, Section 4.1 refers to this database as the source for archived tsunami records in the United States. The data in the NGDC database was filtered to exclude invalid events. Based on this filtering, no tsunami events were identified in region of the MNGP site. Instances were identified of tsunami-like waves on the Mississippi River caused by the New Madrid earthquakes in 1811 and 1812, but this is several hundred miles downriver from the MNGP site.

The MNGP site is located in a relatively low seismic hazard area with a Design Basis Earthquake of 0.12g. The lowest elevation important to the plant is elevation 919 ft (Intake Structure operating floor) while the normal elevation for the Mississippi River at MNGP is 905 ft, which is approximately 14 ft lower.

Therefore, based on historical records of tsunami events and the absence of significant tsunami generation sources in the region, flooding due to a tsunami is not applicable to the MNGP site (Reference 20).

2.7 Ice Induced Flooding

The methodology and results presented in this section are based on the evaluation of ice induced flooding performed in Calculation 180999.51.1001 (Reference 21).

2.7.1 Methodology

Potential ice induced flooding can either be the result of failure of an upstream ice jam or increased water elevation due to backwater conditions from a downstream ice jam. Consistent with the HHA approach described in NUREG/CR-7046 the following method was used to determine the maximum flood heights from an upstream ice jam failure.

The most severe historical ice jam events on the Mississippi River in the vicinity of MNGP were determined using the Ice Jam Information Clearinghouse maintained by the USACE Cold Regions Research and Engineering Laboratory. Based on the information obtained from the Ice Jam Information Clearinghouse, two ice jam events caused a significant increase in the water surface elevation. The first was an ice jam of 15 ft in height about 1 mile upstream of Coon Rapids Dam holding approximately 10 ft of water on April 12, 1965. This location is approximately 35 miles downstream of the MNGP site. The second was an ice jam event at the same location in March 1984, with water levels just 1.3 ft below the 1965 record.

Ice jams were presumed to form at four locations – at the closest upstream bridge (Clearwater Bridge at Route 24, approximately 13 miles upstream of MNGP), at the islands just upstream of MNGP, at the MNGP site, and at the closest downstream bridge (Highway 25 Bridge). It should be noted that there is no record of an ice jam occurring at the MNGP site.

For locations at and upstream of MNGP, conducive for the formation of ice jams, a simplified/conservative approach was initially applied by adding the 10-ft water depth (equivalent to the increase resulting from an ice jam of record) directly to the winter base flow water surface elevation at the respective locations and directly transposing these elevations to the site (without attenuation). The 10-ft water depth was added to the winter base flow water surface elevation at the MNGP site, the islands upstream of the MNGP site, and the Clearwater Bridge upstream of the MNGP. The winter base flow water surface elevation was determined by modeling average flows during the month of April in HEC-RAS. Using average flow rates in April is a conservative approach relative to average flow rates during the winter. Furthermore, NUREG/CR-7046 (Reference 2) does not require that simultaneous precipitation-induced flood be considered as part of the ice induced flooding analysis.

If the resulting water surface elevation exceeded the Intake Structure operating floor elevation of 919 ft, a more detailed analysis was performed using the HEC-RAS model to account for attenuation of the ice jam break flood wave. The HEC-RAS model was also used to evaluate backwater condition from an ice jam downstream of MNGP (Highway 25 Bridge).

2.7.2 Results

Using the conservative approach, which did not include HEC-RAS modeling, the maximum flood elevation due to an ice jam at the MNGP site and at the islands just upstream of the MNGP site was determined to be 916.6 ft and 917.3 ft, respectively. This is below the elevation of 919 ft (Intake Structure operating floor); therefore, additional analysis was not warranted for these two cases. Due to its upstream location and distance from MNGP, the simplified ice jam elevation (winter baseflow plus 10 ft) upstream of the Clearwater Bridge is higher than the Intake Structure operating floor elevation of 919 ft. As such, the HEC-RAS model was used to evaluate the attenuation of the flood wave resulting from the breach of the ice jam. The resulting water surface elevation at the MNGP site is 912.7 ft. The HEC-RAS estimated backwater surface elevation at MNGP resulting from an ice jam at Highway 25 Bridge was determined to be 910.1 ft. A summary of the results is provided in Table 3.

Table 3 – Summary of Ice Induced Flooding Evaluation

Case	Water Surface Elevation at MNGP (ft)	Margin to Intake Structure at 919 ft (ft)
Ice jam at Highway 25 Bridge	910.1	8.9
Ice jam at MNGP	916.6	2.4
Ice jam at the islands upstream of MNGP	917.3*	1.7
Ice jam at Clearwater Bridge upstream of MNGP (Route 24)	912.7	6.3

** water surface elevation at the location of the ice jam, i.e. at the islands upstream of MNGP. Please note that the margin is based on a simplified analysis with significant conservatisms.*

2.7.3 Conclusions

The reevaluated flood hazard due to ice induced flooding was estimated to be 917.3 ft, which is below the lowest elevation critical to the plant (919 ft) and significantly below the plant grade (930 ft). Therefore, ice induced flooding does not impact any safety related SSCs and is completely bounded by the "Flooding in Streams and Rivers" mechanism.

2.8 Channel Migration or Diversion

The methodology and results presented in this section are based on the evaluation of channel migration or diversion effects performed in Evaluation 180999.50.2300-02 (Reference 20).

Natural channels may migrate or divert either away from or toward the site. The relevant event flooding is diversion of water towards the site. The location of the MNGP site is adjacent to the natural channel of the Mississippi River. A review of USGS 7.5-minute topographic maps from 1961 and 2013 show no change in the course of the Mississippi River channels in the site vicinity. The river channel in the area of the site does not include prominent bluffs or other features that could be susceptible to landslide which could potentially result in migration of the channel more directly towards the site. A review of national landslide hazards program information shows that the area in general is not susceptible to landslides and does not show any landslides of record. Based on the review of available data, there is no evidence of recent migration of the Mississippi River in the vicinity of the MNGP site and the possibility of a migration which would result in site flooding is considered extremely remote. Furthermore, the elevation of the lowest important structure to the plant is at 919 ft (Intake Structure operating floor) and the plant grade is at 930 ft. Normal water surface elevation in the Mississippi River at the site is 905 ft, which is approximately 14 ft below the critical elevation of the Intake Structure. Even in the highly unlikely event of channel diversion or migration, MNGP has a significant margin that would accommodate the potential increase in water surface elevation.

There are no man-made channels, canals, diversions, or permanent levees used for conveyance of water and flood protection located near the site.

Based on the above, channel migration or diversion is not considered an applicable flood hazard for the MNGP site.

2.9 Combined Effect Flood

Combined effect floods as described in ANSI/ANS-2.8-1992 (Reference 1) and Appendix H.1 *Floods Caused by Precipitation Events* of NUREG/CR-7046 (Reference 2) were considered as part of the flood hazard reevaluation. The relevant combinations of flooding mechanisms are discussed in the previous sections under the individual flood causing mechanisms.

2.10 Interim Evaluations

The following sections provide a description of interim evaluations that were performed as part of the flooding hazard reevaluation to assess the impact of increased flood levels at critical door openings. No interim actions were deemed necessary in response to the reevaluated flood hazard.

2.10.1 Evaluation of Internal Flooding during the LIP

As determined in Calculation 180999.51.1005 (Reference 18), the LIP flood levels exceed finished floor elevation at several critical openings. These critical door openings are either maintained closed or in some instances internal doors would prevent water from entering areas with safety-related SSCs. However, none of the critical door openings have been designed to be watertight and they can be classified into two categories:

1. Door openings with a visible gap between the bottom of the door and the door sill.
2. Door opening without a visible gap between the bottom of the door and the door sill.

For the first door category, an engineering analysis was performed to calculate possible peak flow rates, total estimated inflow volumes, and total estimate inflow time through each door opening using the stage hydrograph obtained from the HEC-RAS model and the standard orifice equation. The results of this

evaluation are presented in Table 4. Based on these results, the peak inflow rate and total estimated inflow volume were calculated at the Railcar Entry to the Turbine Building (Doors 45 and 46) at 6.9 cfs and 19,113 ft^3, respectively. The peak inflow rate and total estimated inflow volume were calculated at the Emergency Diesel Generator Building at 0.23 cfs and 99 ft^3, respectively. The calculated peak inflow rates and total estimated inflow volumes into both the Emergency Diesel Generator Building and the Turbine Building are less than the acceptance criteria. The maximum acceptable inflow rate into the Emergency Diesel Generator Building was determined to be less than 0.734 cfs. The maximum acceptable inflow volume into the Turbine Building was determined to be less than 140,874 ft^3.

Table 4 – Estimated Inflow Rates through Door Openings during the LIP Event

Opening Location	Opening Invert/ Sill Level (FFE)	Estimated Maximum WSE	Maximum Water Depth at Opening	Door Opening Width	Gap Height at Bottom of Door	Coefficient of Discharge	Peak Inflow Rate	Total Estimated Inflow Volume	Total Estimated Inflow Time
	feet NGVD 29		feet		inches		cfs	ft^3	minutes
Railcar Entry - Turbine Building (Door 24 - see note)	935.00	935.83	0.83	16.00	1.00	0.71	6.9	19,113	70
					0.25	0.70	1.7	4,733	70
Emergency Diesel Generator Building - East 3-ft wide Man Door (Door 8)	931.00	931.41	0.41	3.00	0.25	0.70	0.23	99	14
Emergency Diesel Generator Bldg - West 3-ft wide Man Door (Door 7)	931.00	931.41	0.41	3.00	0.25	0.70	0.23	99	14

Note – the average gap between the bottom of the door and the doorsill at the Railcar Entry to the Turbine Building is 1.0 inch. As a sensitivity analysis and for information purposes, inflow rate and inflow volume were calculated for a 0.25-inch gap.

For the second door category, a qualitative analysis was performed to evaluate the potential impact of in-leakage through the non-watertight doors. The description of the analysis for each respective door is provided below:

- **Intake Structure Door from the Screenhouse (Door 209)**

  The door is between the Intake Structure and the Screenhouse. The door is normally maintained closed. The door sill/invert is at elevation 919.5 ft and the Screenhouse floor is at elevation 919 ft. The bottom of the door opening is six inches above the floor of the Screenhouse. Therefore, water would need to pool to a depth of six inches in the Screenhouse before reaching the door sill. However, water entering the Screenhouse would drain back into the Intake, precluding it pooling and reaching the door sill. Therefore, leakage through this door is not expected.

- **Turbine Building Addition (TBA) Roll-Up Doors (Doors 119 and 120)**

  As the TBA roll-up doors can be either open or closed, the roll-up doors are not credited with precluding water ingress. In lieu of crediting the roll-up doors, the capability of internal Door 30 to preclude water ingress was evaluated. When closed, the roll-up doors would provide redundancy. A walkdown performed on March 28, 2016 did not identify any obvious gaps at Door 30 that would allow water ingress. However, the door is not designed as a watertight door and some minor amount of water leakage is possible. The Turbine Building can accommodate a large volume of water (140,874 cubic feet

per Reference 17). Due to the minor amount of anticipated water ingress, the relatively short time period of the LIP, and the available volume in the Turbine Building there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

- **Rail Car Entry to Reactor Building (Doors 45 and 46)**

Doors 45 and 46 are normally maintained closed. A walkdown performed on March 28, 2016 did not identify any obvious gaps at Doors 45 that would allow water ingress. Door 45 was closed, thus, it was not possible to observe Door 46 without entering the Reactor Building. However, these doors are not designed as watertight doors and some minor amount of water leakage is possible. The Reactor Building can accommodate a large volume of water (at least 300,000 gallons per Reference 17). Due to the minor amount of anticipated water ingress, the relatively short time period of the LIP, and the available volume in the Reactor Building there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

- **EFT Room Door (Door 341)**

Door 341 is normally maintained closed. A walkdown performed on March 28, 2016 did not identify any obvious gaps at Door 341 that would allow water ingress. However, the door is not designed as a watertight door and some minor amount of water leakage is possible. Water leakage past the EFT door would flow down the nearby stairway into the Administrative Building; which (based on the walkdown) can accommodate a relatively large volume of water. Due to the minor amount of anticipated water ingress, the relatively short time period of the LIP event, and the available volume in the Administrative Building there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

- **13.8 KV Room Door (Door 1)**

Door 1 is normally maintained closed. A walkdown of performed on March 28, 2016 did not identify any obvious gaps at Door 1 that would allow water ingress. However, the door is not designed as a watertight door and some minor amount of water leakage is possible. Leakage past Door 1 could possibly leak past other door(s) from the 13.8 KV Room into the Turbine Building. The Turbine Building can accommodate a large volume of water (140,874 cubic feet per Reference 17). Due to the minor amount of anticipated water ingress, the relatively short time period of the LIP event, and the available volume in the Turbine Building there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

- **Off Gas Stack Door (Door 193)**

Door 193 is maintained closed. A walkdown performed on March 28, 2016 did not identify any obvious gaps around the doors. However, the door is not designed as a watertight door and some minor amount of water leakage is possible. Leakage into the Off Gas Stack could pool and, if the level builds up sufficiently, could leak into the Reactor Building. The Reactor Building can accommodate a large volume of water (at least 300,000 gallons per Reference 17). Due to the minor amount of anticipated water ingress, the relatively short time period of the LIP event, and the available volume in the Reactor Building there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

- **Fuel Oil Transfer Pump House Door (Door 483)**

Door 483 is maintained closed. A walkdown performed on March 28, 2016 did not identify any obvious gaps at Door 483 that would allow water ingress. However, the door is not designed as a watertight door and some minor amount of water leakage is possible. Leakage into the Fuel Oil Transfer Pump House could pool in the building, which does not have a large available volume to accommodate leakage. Calculation 180999.51.1005 (Reference 18) indicates that the water elevation would be above 931 ft for a short period of time (less than 16 minutes at the nearby Emergency Diesel Generator Room doors). Due to the minor amount of anticipated water ingress and the relatively short time period that the water elevation would be above the door sill, there is reasonable assurance that this possible water leakage would not impact SSCs important to safety.

2.10.2 Structural Evaluation of Doors for LIP Loads

Consideration was also given to hydrodynamic and debris impacts during the LIP event. The maximum flood level predicted during the LIP event is 935.83 ft. The LIP event will not include any debris impact or any appreciable hydrodynamic effects due to the direction of all flow being away from the building.

As stated in the previous section, several critical door openings will be subjected to water loading without flood protection. An interim structural evaluation was performed in Calculation 180999.51.1010 (Reference 23) by comparing existing allowable pressure, differential pressure, or capacity qualifications for each door to resultant LIP loading. The results of the evaluation indicate that the existing allowable pressure, differential pressure, or capacity qualifications bound the resultant LIP loading. Therefore, no re-analysis of the critical door openings is necessary as part of the flood hazard reevaluation.

3. Comparison of Current Design Basis and Reevaluated Flood Hazard

3.1 Comparison of Flood Hazard Elevations

Table 5 provides a comparison of the current design basis and reevaluated flood hazard elevations and an assessment whether the reevaluated flood hazard elevation is bounded by the current design basis flood elevation.

Table 5 – Summary of Current Design Basis and Reevaluated Flood Hazard Elevations

Flood Causing Mechanism	Current Design Basis Flood Hazard Elevation	Flood Hazard Reevaluation Elevation	Current Design Basis Bounds Reevaluation Flood Hazard Elevation?
Local Intense Precipitation	Not specifically addressed in the USAR	935.83 ft	Not Bounded
Flooding in Streams and Rivers	939.2 ft	[redacted] ft	Bounded
Dam Breaches and Failures	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Storm Surge	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Seiche	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Tsunami	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Ice Induced Flooding	Not quantified in the USAR	917.3 ft	Bounded[2]
Channel Migration or Diversion	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Combined Effects Flood - PMF with wave runup	Not specifically addressed in the USAR	[redacted] ft	Bounded[3]

[1] These flood-causing mechanisms were not specifically addressed in the USAR; however, a screening level analysis showed that these mechanisms were not applicable and are completely bounded by other mechanisms. Since these mechanisms were screened out as part of the flood hazard reevaluation, they were also considered bounded by the current design basis.

[2] While the ice induced flooding hazard was not quantified in the USAR, the resultant flood elevation is below elevations that would impact SSCs important to safety. Furthermore, this hazard is fully bounded by the flooding in stream and rivers hazard.

[3] While the wave run-up flooding hazard was not specifically addressed in the USAR, the resultant wave runup elevation is fully bounded by the current design basis (CDB) stillwater elevation.

3.2 Comparison of Flood Parameters

The March 12, 2012, 50.54(f) letter (Reference 3) requested that an integrated assessment of the plant's response to the reevaluated flood hazard be performed if the reevaluated flood hazard elevation is not

bounded by the current design basis. If the reevaluated flood hazard elevation is not bounded, the NRC requested that the licensee define the applicable flood parameters and perform an integrated assessment. The applicable flood parameters include the following per JLD-ISG-2012-05 (Reference 6):

1. Flood height and associated effects
    a. Stillwater elevation;
    b. Wind waves and run-up effects;
    c. Hydrodynamic loading, including debris;
    d. Effects caused by sediment deposition and erosion (e.g., flow velocities, scour);
    e. Concurrent site conditions, including adverse weather conditions; and
    f. Groundwater ingress.
2. Flood event duration parameters
    a. Warning time (may include information from relevant forecasting methods (e.g., products from local, regional, or national weather forecasting centers) and ascension time of the flood hydrograph to a point (e.g. intermediate water surface elevations) triggering entry into flood procedures and actions by plant personnel);
    b. Period of site preparation (after entry into flood procedures and before flood waters reach site grade);
    c. Period of inundation; and
    d. Period of recession (when flood waters completely recede from site and plant is in safe and stable state that can be maintained).
3. Plant mode(s) of operation during the flood event duration
4. Other relevant plant-specific factors (e.g. waterborne projectiles)

Since the reevaluated flood hazard elevation for the LIP event is not bounded, the applicable flood parameters for this flood causing mechanism were defined and are provided in Table 6.

Table 6 – Local Intense Precipitation

	Flood Scenario Parameter	CDB Flood Hazard	Reevaluated Flood Hazard	Bounded (B) or Not Bounded (NB)
Flood Level and Associated Effects	1. Maximum Stillwater Elevation (ft)	LIP was not specifically addressed in the USAR	935.83	NB
	2. Maximum Wave Run-up Elevation (ft)		See Note 2	N/A
	3. Maximum Hydrodynamic/Debris Loading (psf)		See Note 3	N/A
	4. Effects of Sediment Deposition/Erosion		See Note 4	N/A
	5. Concurrent Site Conditions		See Note 5	N/A
	6. Effects on Groundwater		See Note 6	N/A
Flood Event Duration	7. Warning Time (hours)		See Note 7	N/A
	8. Period of Site Preparation (hours)		See Note 8	N/A
	9. Period of Inundation (hours)		~1.2 (see Note 9)	NB
	10. Period of Recession (hours)		~5.3 (see Note 10)	NB
Other	11. Plant Mode of Operations		See Note 11	N/A
	12. Other Factors		See Note 12	N/A

Additional notes, "N/A" justifications (why a particular parameter is judged not to affect the site), and explanations regarding the bounded/non-bounded determination.

1. None
2. Consideration of wind-generated wave action for the LIP event is not explicitly required in NUREG/CR-7046, ANSI/ANS-2.8-1992 or the 50.54(f) letter. Furthermore, wave runup is considered negligible due to limited flood depths and fetch.
3. Hydrodynamic loading was not considered plausible due to surface water flow direction is not towards the buildings. Debris impact loading was not considered plausible due to limited velocities and flood depths (Reference 18).
4. Due to limited velocities, and short duration of flooding (Reference 18), sediment deposition and erosion is not considered to have an effect on the LIP flood levels.
5. High winds and hail could coincide with the LIP event. In general, no manual actions are required to be performed outside. Personnel may be, however, exposed to the elements while moving between locations. Environmental conditions would be considered prior to personnel being directed to move between locations.
6. Due to relatively short duration of the LIP event (Reference 18), surcharge to groundwater is not considered.
7. Warning time is not credited in the flood protection strategy (since only permanent/passive measures are used for the LIP flood) and, therefore, was not considered as part of the analysis.
8. SSCs important to safety are protected by means of permanent/passive measures and, therefore, site preparation was not considered as part of the analysis.
9. The period of inundation varies throughout the site; however, at the critical door location with the highest water surface elevation, it was estimated that water level would remain above finished floor elevation for 70 minutes (Reference 18).
10. Once the flood waters recede below finished floor elevation, it would take approximately 5.3 hours for flood waters to completely recede from areas near the critical doors, which is approximately within 30 minutes after the end of the 6-hr storm LIP event (Reference 18).
11. There are no limitations on plant modes of operation prior to, or during, the LIP event.
12. There are no other factors, including waterborne projectiles, applicable to this flood causing mechanism.

4. References

1. American Nuclear Society, "Determining Design Basis Flooding at Power Reactor Sites," ANSI/ANS-2.8-1992, 1992.
2. U.S. Nuclear Regulatory Commission, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America," NUREG/CR-7046, November 2011, ADAMS Accession No. ML11321A195.
3. U.S. Nuclear Regulatory Commission, 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, March 12, 2012, ADAMS Accession No. ML12053A340.
4. U.S. Nuclear Regulatory Commission, "Guidance for Assessment of Flooding Hazard due to Dam Failures," JLD-ISG-2013-01, July 29, 2013, ADAMS Accession No. ML13151A153.
5. U.S. Nuclear Regulatory Commission, "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment," JLD-ISG-2012-06, January 4, 2013, ADAMS Accession No. ML12314A412.
6. U.S. Nuclear Regulatory Commission, "Guidance for Performing the Integrated Assessment for External Flooding," JLD-ISG-2012-05, November 30, 2012, ADAMS Accession No. ML12311A214.
7. U.S. Nuclear Regulatory Commission, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America," NUREG/CR-6966, March 2009, ADAMS Accession No. ML091590193.
8. U.S. Nuclear Regulatory Commission, "Monticello Nuclear Generating Plant – Transmittal of U.S. Army Corps of Engineers Flood Hazard Reevaluation Information (TAC No. MF3696)," November 18, 2015, ADAMS Accession Nos.: ML15296A365 (Package), ML15324A383 (PUBLIC Letter) and ML 15296A274 (NON PUBLIC Letter).
9. U.S. Nuclear Regulatory Commission, "Summary of July 9, 2015 closed meeting between representatives of the U.S. Army Corps of Engineers, U.S. Nuclear Regulatory Commission, and Northern States Power Company – Minnesota, to discuss flood analysis associated with Monticello Nuclear Generating Plant and Prairie Island Nuclear Generating Plant, Units 1 and 2 (TAC Nos. MF3696, MF3697, and MF3698)," October 2, 2015, ADAMS Accession No. ML15271A207.
10. NSPM, "Monticello Updated Safety Analysis Report," Revision 32.
11. NSPM, "Revision to MNGP Final Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.3 ft of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," July 31, 2013.
12. NSPM, Procedure A.6 "Acts of Nature," Rev. 53.
13. NSPM, Procedure 8300-02 "External Flooding Protection Implementation to Support A.6 Acts of Nature," Rev 7.
14. NSPM, "Request for NRC Assistance to Obtain Information on Dams from the U.S. Army Corps of Engineers (USACE)," March 5, 2014, ADAMS Accession No. ML14064A291.
15. NSPM, "External Flooding Implementation Timeline," Calculation 14-080, Rev 2.
16. NSPM, "Debris Barrier Design for Impact Protection of External Flood Barrier," ECN 23429.

17. NSPM, "Reactor Bldg, Turbine Building & Intake Structure Water Height – Internal Flooding," Calculation No. CA-07-021, Rev. 0.
18. Black & Veatch, "Local Intense PMP Hydrology and Hydraulics," Calculation 180999.51.1005, Rev. 2.
19. Black & Veatch, "Site Specific PMP and Ancillary Meteorological Analysis," Calculation 180999.51.1008, Rev. 1.
20. Black & Veatch, "MNGP Flood Scenario Evaluations," 180999.50.2300-02, Rev. 0.
21. Black & Veatch, "Ice Induced Flooding," Calculation 180999.51.1001, Rev. 1.
22. Black & Veatch, "MNGP Wave Prediction and Wave Runup," Calculation 180999.51.1002, Rev. 0.
23. Black & Veatch, "Evaluation of Structural Elements – Flood," Calculation 180999.51.1010, Rev. 0.
24. National Oceanic and Atmospheric Administration, "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 51, June 1978
25. National Oceanic and Atmospheric Administration, "Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian," Hydrometeorological Report No. 52, August 1952.
26. U.S. Department of Agriculture, "Urban Hydrology for Small Watersheds – Technical Release 55," June 1986.
27. U.S. Department of Agriculture, "Part 630 Hydrology National Engineering Handbook," September 1997.
28. Kansas City Metropolitan Chapter, American Public Works Association Standard Specifications & Design Criteria, Section 5600 Storm Drainage Systems & Facilities, February 16, 2011.
29. U.S. Army Corps of Engineers, "Coastal Engineering Manual," Engineer Manual 1110-2-1100. Part II Coastal Hydrodynamics, 2015 and Part VI Design of Coastal Project Elements, 2011.

Appendix 1

50.54(f) Letter – Requested Information Cross-Reference

This appendix provides a list of each item requested in Enclosure 2 of the *NRC Letter, 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 and the corresponding section(s) in the main body of the MNGP FHRR where the requested information is provided.

a. **Site information related to the flood hazard. Relevant SSCs important to safety and the UHS are included in the scope of this reevaluation, and pertinent data concerning these SSCs should be included. Other relevant site data includes the following:**

   i. **Detailed site information (both designed and as-built), including present-day site layout, elevation of pertinent SSCs important to safety, site topography, as well as pertinent spatial and temporal data sets:**

      Response:

      - See Section 1.4 for detailed site information.

   ii. **Current design basis flood elevations for all flood causing mechanisms:**

      Response:

      - See Section 1.5 which describes current design basis flood hazards.

   iii. **Flood-related changes to the licensing basis and any flood protection changes (including mitigation) since license issuance:**

      Response:

      - See Section 1.6 for description of flood-related changes to the licensing basis and any flood protection changes (including mitigation) since license issuance.

   iv. **Changes to watershed and local area since license issuance:**

      Response:

      - See Section 1.7 for any changes to watershed and local area since license issuance.

   v. **Current licensing basis flood protection and pertinent flood mitigation features at the site:**

      Response:

      - See Section 1.8 for current licensing basis flood protection and mitigation features.

   vi. **Additional site details, as necessary, to assess the flood hazard (i.e. bathymetry, walkdown results, etc.):**

      Response:

      - No additional information beyond the information provided in the above-mentioned sections was required to assess the flood hazard.
      - The walkdown reports are referenced, as relevant, in Sections 1.5 and 1.6.

b. **Evaluation of the flood hazard for each flood causing mechanism, based on present-day methodologies and regulatory guidance. Provide an analysis of each flood causing mechanism that may impact the site including local intense precipitation and site drainage, flooding in streams and rivers, dam breaches and failures, storm surge and seiche, tsunami, channel migration or diversion,**

and combined effects. Mechanisms that are not applicable at the site may be screened-out; however, a justification should be provided. Provide a basis for inputs and assumptions, methodologies and models used, including input and output files, and other pertinent data:

Response:

A description of the flood hazard reevaluation for each flood causing mechanism is provided in the FHRR as referenced below:

- Local Intense Precipitation (LIP) and Site Drainage: See Section 2.1;
- Flooding in Streams and Rivers: See Section 2.2;
- Dam Breaches and Failures: See Section 2.3;
- Storm Surge including Wind-Wave Activity: See Section 2.4;
- Seiche: See Section 2.5;
- Tsunami: See Section 2.6;
- Ice Induced Flooding: See Section 2.7;
- Channel Migration and Diversion: See Section 2.8;
- Combined Effects (including wind-waves and runup effects): See Section 2.9 - the relevant combinations of flooding mechanisms are discussed under the individual flood causing mechanisms;
- Other Associated Effects (i.e., hydrodynamic/debris loading, effects caused by sediment deposition and erosion, concurrent site conditions, and groundwater ingress): See Table 6. Note that other associated effects are only applicable to the LIP since LIP was the only non-bounded flood causing mechanism for MNGP;
- Flood Event Duration Parameters (i.e., warning time, period of site preparation, period of inundation, and period of recession): See Table 6. Note that flood duration parameters are only applicable to the LIP since LIP was the only non-bounded flood causing mechanism for MNGP.

c. **Comparison of current and reevaluated flood causing mechanisms at the site. Provide an assessment of the current design basis flood elevation to the reevaluated flood elevation for each flood causing mechanism. Include how the findings from Enclosure 4 of the 50.54(f) letter (i.e., Recommendation 2.3 flooding walkdowns) support this determination. If the current design basis flood bounds the reevaluated hazard for all flood causing mechanisms, include how this finding was determined.**

Response:

A comparison of the current design basis and reevaluated flood hazard elevations for each flood causing mechanism is provided in Section 3.1 and Table 5. It was determined that the current design basis flood bounds the reevaluated hazard for all applicable flood causing mechanisms, including combined-effects flooding, with the exception of the LIP flood hazard. The following provides additional detail for each reevaluated flood causing mechanism:

i. Local Intense Precipitation (LIP): Since the LIP flood hazard is not addressed in the current design basis, the reevaluated LIP hazard is considered to be non-bounded. See Section 2.1 for the LIP analysis and Section 3.2 and Table 6 for the LIP Flood Scenario Parameters.

ii. Flooding in Stream and Rivers: Based on the USACE analysis performed for the NRC, the current design basis bounds the reevaluated flood hazard. See Section 2.2 and Table 5.

iii. Dam Breaches and Failures: Based on the USACE analysis performed for the NRC, it was determined that potential upstream dam breaches and failures, regardless of failure mode, do not increase the flood hazard at MNGP. See Section 2.3 and Table 5.

iv. Storm surge, seiche and tsunami: These hazards were screened out as not applicable/not plausible at the MNGP site. See Sections 2.4, 2.5, and 2.6 and Table 5.

v. Ice Induced Flooding: The reevaluated ice-induced flooding hazard was determined to be fully bounded by the combined-effects flooding and, therefore, considered to be bounded. See Section 2.7 and Table 5.

vi. Channel Migration and Diversion: This hazard was found to not be applicable/not plausible at the MNGP site. See Section 2.8 and Table 5.

vii. Combined-Effect Flood: Based on the combination of the PMF (Section 2.2.1) and the wind-generated wave analysis (Section 2.2.2), the current design basis bounds the reevaluated flood hazard. See Table 5.

d. Interim evaluation and actions taken or planned to address any higher flooding hazards relative to the design basis, prior to completion of the integrated assessment described below, if necessary:

Response:

An interim evaluation was performed to assess the potential impact of the reevaluated LIP flood hazard on the plant. The result of the interim evaluation for the LIP is that there is no adverse impact to safety-related SSCs. See Section 2.10.

e. Additional actions beyond Requested Information item 1.d taken or planned to address flood hazards, if any:

Response:

None required.