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

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
UNITS 1 AND 2
RENEWED LICENSE NOS. DPR-42 & DPR-60

(REDACTED VERSION)

(37 pages to follow)

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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
AWA	Applied Weather Associates
B	bounded
CDB	current design basis
CEM	Coastal Engineering Manual
CFR	Code of Federal Regulations
cfs	cubic (foot)feet per second
CMMP	Channel Maintenance Management Plan
d/b/a	Doing Business As
DEM	Digital Elevation Model
EC	Engineering Change
EM	Engineer Manual
FFE	finished floor elevation
FLEX	Diverse and Flexible Coping Strategies
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
ft/s	feet per second
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HELB	High-Energy Line Break
HHA	Hierarchical Hazard Assessment
HMR	Hydrometeorological Report
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)
mph	miles per hour
MSIV	main steam isolation valve
MSL	mean sea level
N/A	not applicable
NAVD 88	North American Vertical Datum of 1988
NB	not bounded
NGDC	National Geophysical Data Center
NGP	Nuclear Generating Plant
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRC	United States Nuclear Regulatory Commission
NSP	Northern States Power
NSPM	Northern States Power Company, a Minnesota corporation
NTTF	Near Term Task Force
NUREG	NRC technical report designation
NUREG/CR	NUREG contractor report
PINGP	Prairie Island Nuclear Generating Station
PMF	probable maximum flood
PMP	probable maximum precipitation
psf	pound(s) per square foot
SCS	Soil Conservation Service
SSCs	structures, systems, and components
TR	Technical Release
USACE	United States Army Corps of Engineers
USAR	Updated Safety Analysis Report

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 Prairie Island Nuclear Generating Plant (PINGP), Units 1 and 2.

Evaluation of the eight flood-causing mechanisms and associated effects, 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 PINGP 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 (SSC) 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.

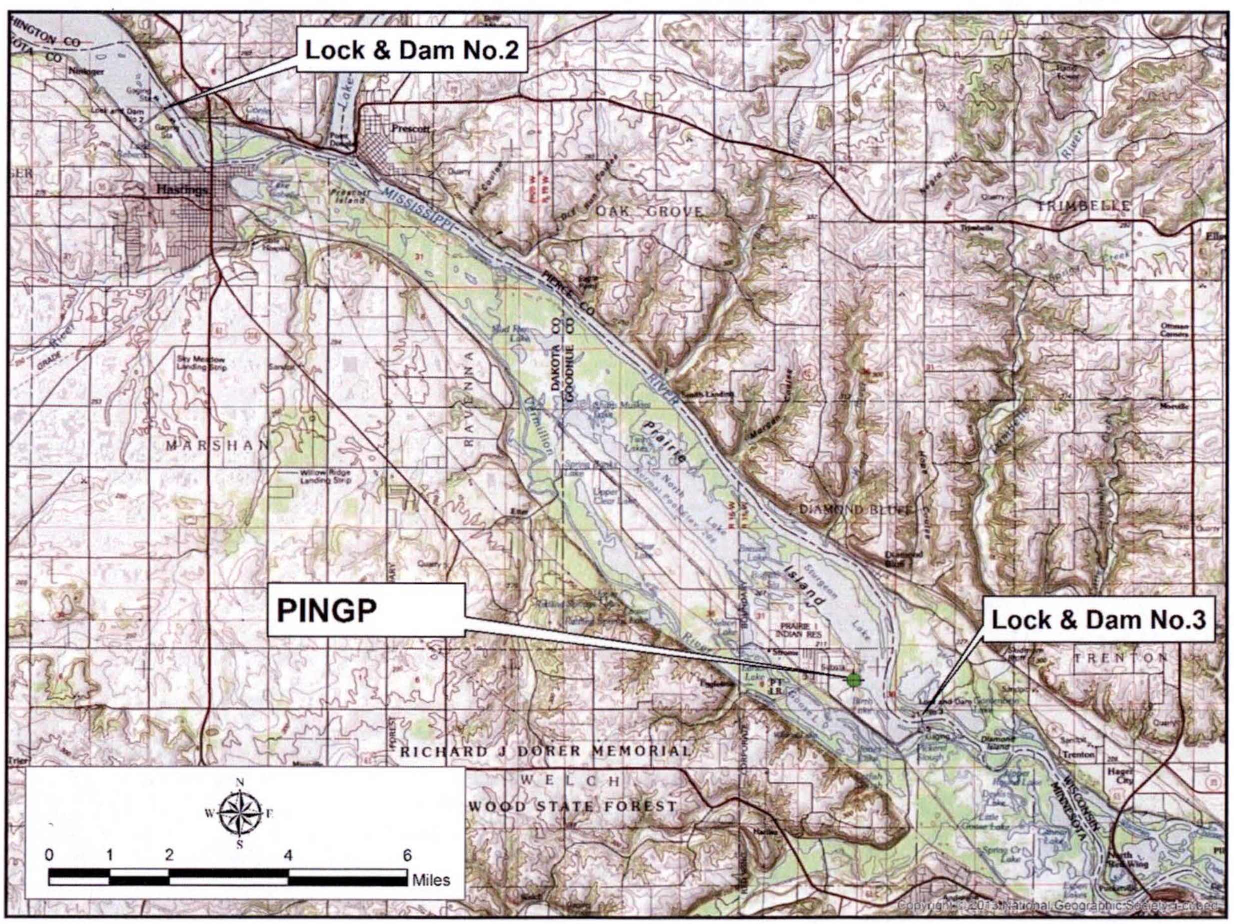
Section 2 of this report provides additional HHA detail for each of the flood-causing mechanisms evaluated.

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 – PINGP Site and Nearby Vicinity



1.4.2 Site Layout and Topography

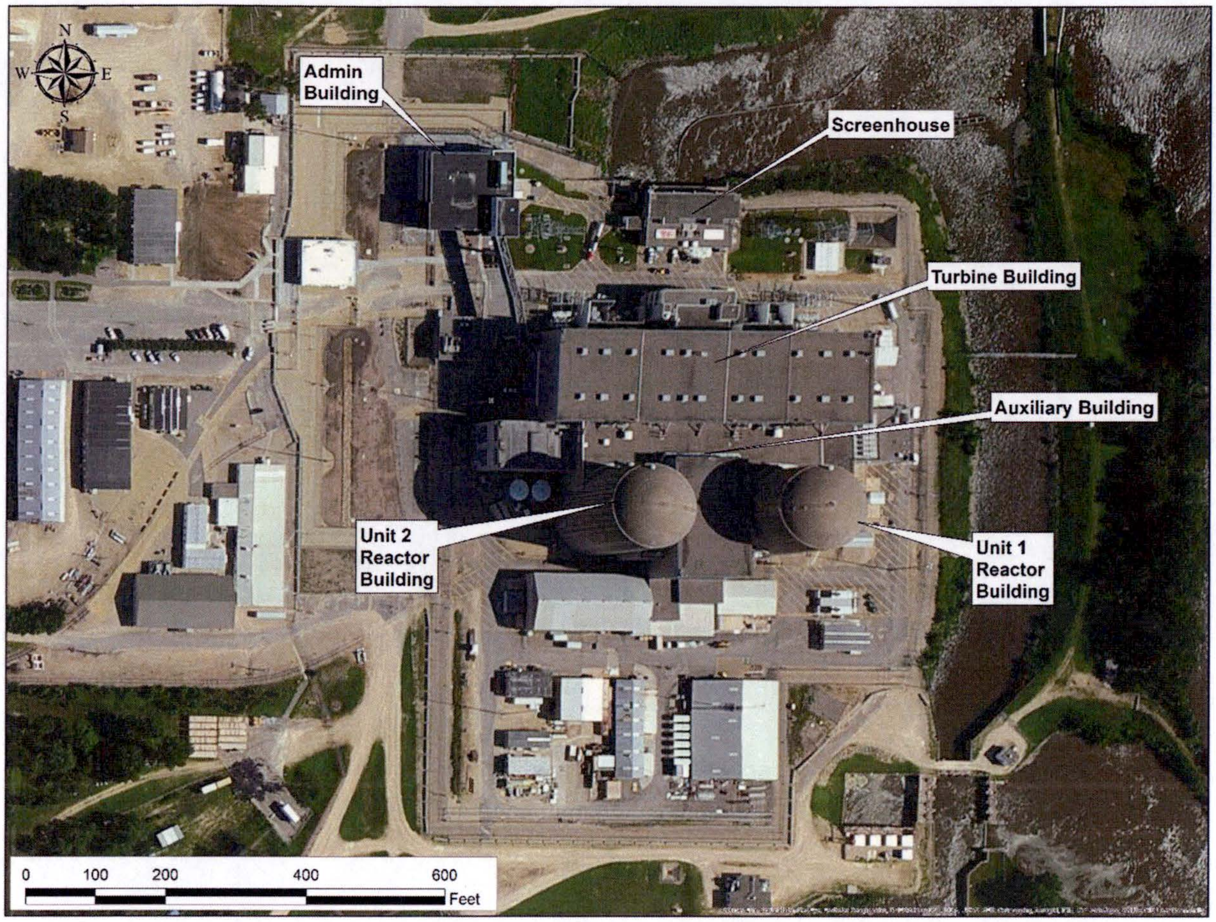
The PINGP site is located within the city limits of the City of Red Wing, Minnesota on the right (West) bank of the Mississippi River. Topography near the PINGP site is fairly level to slightly rolling ground ranging in elevation from 675 ft to 706 ft. The site surface slopes gradually toward the Mississippi River on the northeast and to the Vermillion River on the southwest. Normal river pool elevation is at 674.5 ft and the maximum reported flood elevation was recorded in 1965 at 687.7 ft. Steep bluffs parallel this stretch of the Mississippi River and rise to above a 1,000-ft elevation approximately one and a half miles northeast and southwest of the site. Northeast and southwest of these bluffs, the ground elevation ranges from 1,000 ft to 1,200 ft and is marked by many deeply eroded coulees. The plant grade surrounding the Power Block and Screenhouse varies between elevation 694.5 ft and 695 ft (Reference 10).

The principal surface waters in the vicinity of the site are the Mississippi River, Sturgeon Lake, the Vermillion River, and the Cannon River. The site and the regional vicinity are shown in Figure 1. The water level of the Mississippi River and Sturgeon Lake are controlled by Lock and Dam No. 3 which is located approximately one and a half miles downstream from the plant. The Vermillion River enters the main stream of the Mississippi River below the dam. The flow in the Mississippi River is for the most part unregulated (i.e., natural river flow is passed through the dam so as to maintain an unvarying upper pool level). The normal upper pool is at elevation 674.5 ft. This level may be lowered to elevation 672.5 ft at the dam to control pool elevation at Prescott to elevation 674.5 ft for a river flow of approximately 17,000 cfs. According to the U.S. Army Corps of Engineers (USACE), the 1965 flood, which is the highest on record, has a recurrence interval of 150 years. The peak elevation at Lock and Dam No. 3 during this flood was elevation 687.7 ft. It is estimated by the USACE that a flood having a 1,000-year recurrence interval would have a peak elevation of 691.8 ft. at Lock and Dam No. 3, and a discharge of about 335,000 cfs (Reference 10).

1.4.3 Elevation of Safety Related Structures, Systems and Components

The main powerhouse structures consist of the Reactor Buildings, the Auxiliary and Fuel Handling Building, the Turbine Building, the D5/D6 Diesel Generator Building, and the pump section of the Screenhouse. Plant grade for these structures is elevation 695 ft (Reference 10). The power block area is shown in Figure 2.

Figure 2 – PINGP Power Block Area



1.5 Current Design Basis Flood Elevations

The current design basis and related flood elevations for the PINGP are described in the USAR (Reference 10) as well as the recent walkdown reports (Reference 11) required as part of NRC's 10 CFR 50.54(f) letter (Reference 3).

The following flood scenarios were evaluated as part of the PINGP current design basis:

- Flooding in Streams and Rivers, including Wave Run-Up
- Upstream Dam Failure

A summary of the results for each of these flooding scenarios, as presented in the USAR, is provided in the following sections.

1.5.1 Flooding in Streams and Rivers

Appendix F of the USAR describes the study performed to determine the magnitude of the probable maximum flood of the Mississippi River in the vicinity of the PINGP site. A description of the methodology, inputs, assumptions and results are also provided in Appendix F of the USAR. The probable maximum discharge was determined to be 910,300 cfs with a corresponding peak elevation of 703.6 ft. The limiting flood resulted from meteorological conditions which 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 695 ft for approximately 13 days. From flow and stage hydrographs provided in Appendix F of the USAR it can also be estimated that the flood stage would reach plant grade in approximately 5.5 days. Wind generated waves would be of maximum height when the wind is from east to west in the direction of the circulating water intake canal. With a persistent wind speed of 45 mph the height of the significant wave would be less than 1.8 ft (crest to trough). The maximum one percent wave height, consistent with the highest significant wave, was estimated to be less than 3.1 ft. Maximum wave runup was assumed to be equal to the maximum one percent wave height resulting in the maximum water elevation of 706.7 ft (Reference 10).

1.5.2 Dam Breaches and Failures

Lock and Dam No. 2 is located 17 miles upstream of the plant site (Figure 1). The difference in normal pool elevations across the dam is 12.2 ft. Failure of the dam could result in a sudden release of water, temporarily producing the effect of a flood in the river channel downstream of the dam. The storage effect of the lower channel basin and the resulting loss of head in the upper reservoir will greatly attenuate flooding effects at the PINGP site (Reference 10).

There is no flood hazard resulting from a dam break at Lock and Dam No. 2. This conclusion was substantiated by determining stable water level elevations at Lock and Dam No. 3 resulting from sustained flow with the loss of 10 tainter gates at Lock and Dam No. 2. Sustained flow will maintain the upper pool elevation at Lock and Dam No. 3, and will provide the volume of water needed in the lower pool to produce the maximum pool level consistent with steady flow supplied through 10 spillway bays. The flow resulting from these postulated extreme conditions would produce a river elevation at 684.5 ft. in the lower pool at Lock and Dam No. 2 with a corresponding elevation in the upper pool at Lock and Dam No. 3 of 676.5 ft (Reference 10).

1.5.3 Summary

The limiting design basis flood for the PINGP site is the PMF of the Mississippi River, with a peak elevation of 703.6 ft and a wave run-up elevation of 706.7 ft.

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.

No changes to flood protection have been made since the issuance of the original license. During the flooding walkdown, a deficiency related to the operations of sump pumps was identified. As a result, a plan to provide portable sump pumps with power supplies that will be available during a loss-of-offsite power event was developed. In addition, procedure AB-4 (Reference 13) was revised to describe deployment of sump pumps (Reference 11).

1.7 Watershed and Local Changes

The watershed contributory to the Mississippi River upstream of the PINGP is approximately 45,000 square miles (Reference 10). The most significant changes to the watershed include expansion and development of the greater Minneapolis-St. Paul Metropolitan Area.

Local area changes have been minimal since plant operation began at the PINGP site and include the expansion of the local tribal community and businesses. These changes have improved local area roads and resulted in increased traffic.

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

- Administration Buildings
- Intake Screenhouse
- ISFSI
- Security Buildings
- Warehouses
- FLEX Equipment Storage Building
- Diesel Generator D3/D4 Building
- Diesel Generators D5 and D6 Building

Addition of security barriers and relocation of the security fence have also been made.

Location and configuration of current structures, as relevant, were inputs to the Local Intense Precipitation (LIP) calculations described in Section 2.1 as related to the flooding impacts on SSCs.

1.8 Licensing Basis Flood Protection and Mitigation Features

The main powerhouse structure consisting of the Reactor Buildings, the Auxiliary and Fuel Handling Building, the Turbine Building, the D5/D6 Diesel Generator Building, and the pump section of the Screenhouse structure are protected against the probable maximum flood elevation of 703.6 ft. The base slabs of these structures have been designed to resist the full hydrostatic head of the probable maximum flood. The top of the substructure and/or superstructure flood protection walls are at elevation 705 ft, and are designed to resist the probable maximum flood. These structures are also capable of withstanding the hydrostatic forces associated with the probable maximum flood and associated maximum wave run-up to elevation 706.7 ft. Some water leakage would occur whenever wave action exceeds elevation 705 ft on certain portions of the Turbine Building and Auxiliary Building walls. This leakage would occur through the joint between the top of the concrete wall and the bottom of the metal siding. This event would not compromise, or cause a loss of, any safety related function for two reasons. First, the leakage would represent a relatively small quantity of water which could be easily handled by plant sump pumps. Second, the leakage would occur at a great enough distance from safety related equipment that there would be no direct contact of the water with such equipment. All construction joints are keyed and provided with water stops. Penetrations through the foundation base slabs and flood protection walls below elevation 703.6 ft were held at a minimum. Necessary penetrations are closed prior to flooding with bulkheads stored on site. Hydrostatic pressures compress sealant materials along outside edges to assure a water tight fit on bulkhead closures (Reference 10).

The only safeguards related equipment located outside the structures mentioned above are the diesel fuel tanks and fuel storage vaults, pipes and control cables all of which are buried and are designed to resist hydrostatic forces as well as other effects associated with the probable maximum flood (Reference 10).

The PINGP is designed such that all areas critical to nuclear safety are protected against the effects of the probable maximum flood and associated maximum wave run-up. Plant operating procedures and emergency plans state the flood elevations at which plant protective measures must be taken. These procedures will require placing the unit in Mode 3, Hot Standby, when flood elevations exceed 692 ft at the plant site. Operating procedures also require the plant be placed in Mode 4, Hot Shutdown, with MSIVs closed based on HELB internal flooding analysis, which is more restrictive than the licensing requirement for the external flooding event described in the USAR (Reference 10). However, according to procedure AB-4 (Reference 13),

operators are directed to initiate a shutdown to Mode 5, Cold Shutdown, when the flood levels are predicted to exceed 692 ft. The actions in procedure AB-4 are based on a three-day flood forecast.

Long range advisory projections and short-term forecasts of river elevation and crest are supplied by the National Weather Service Office, Minnesota River District for gage stations on the Mississippi River and its major tributaries. Gage stations covered include Hastings and Red Wing, upstream and downstream from the PINGP site. Advisory and forecast reports are received directly in the Northern States Power (NSP) system dispatch center. The basis to readily interpret these projections for specific locations between gage stations is developed in cooperation with the USACE and National Oceanic and Atmospheric Administration (NOAA) (Reference 10).

NSP has had experience in using these advisories and forecasts to develop and use flood procedures for successful continued operation of many river-site plants subject to seasonal floods of varying degree (Reference 10).

Advance planning and preliminary arrangements for operation during floods would be based on the advisory reports of flood potential. Implementation of flood procedures would be based on the three-day forecast of river flood stage elevation and actual flood stage elevation at the plant site (Reference 10). According to procedure AB-4, "Flood," (Reference 13) the trigger for preparatory actions is when elevation 678 ft is to be exceeded based on a three-day flood forecast or when the actual river level at the plant site reaches 678 ft.

In the event that three-day forecasts project a crest in excess of those stated in the plant operating procedures (mainly procedure AB-4), bulkheads, which are stored onsite, will be installed to close all openings in the flood protection walls and sandbag barriers will be constructed around the substation control house. Normal operation would continue to a predicted flood elevation stated in the plant operating procedures (Reference 10).

The emergency and normal cooling water pumps are operable to a flood of elevation 695 ft with no additional protective measures required. When three-day forecasts project water elevation in excess of 692 ft, bulkhead closures are installed to allow cooling water system operation up to the maximum probable flood elevation. The cooling water pumps and their associated equipment are located in the Class I, Type I portion of the Screenhouse which is designed for the probable maximum flood (Reference 10).

2. Flood Hazard Reevaluation

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

2.1 Local Intense Precipitation

2.1.1 Methodology

The LIP evaluation was performed in Calculation 180461.51.1005 (Reference 15) using the assumptions of Case 3 in Appendix B of NUREG/CR-7046 (Reference 2). Case 3 assumes that the design of the site grade and the passive drainage channels are incapable of routing any flow from the immediate plant site; 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, as well as a cool-season rain-on-snow storm event. The all-season event was determined to be the controlling event. Therefore, only the all-season storm event analysis is discussed in this section.

Rainfall inputs used are based on a site-specific LIP study performed for the PINGP site by Applied Weather Associates (AWA) and documented in Calculation 180461.51.1011 (Reference 16). The all-season LIP values are provided in Table 1 and were developed for the 1-hour and 6-hour, 1-square-mile storm. This analysis followed the storm-based approach as used in the overall probable maximum precipitation (PMP) development and as described in HMR 51 (Reference 21) and HMR 52 (Reference 22).

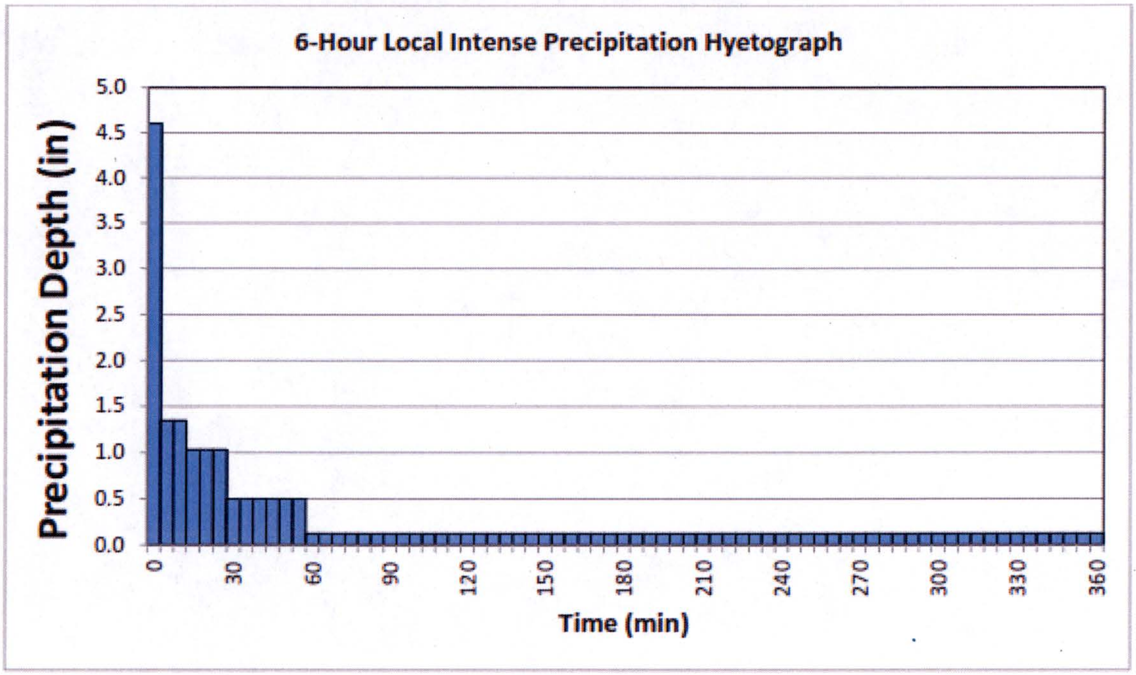
Table 1 – 1-Square-Mile All-Season LIP Values

Time (minutes)	Cumulative Depth (inches)
0	0.0
5	4.6
15	7.3
30	10.4
60	13.4
360	21.0

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. Rainfall was transformed directly into runoff within the hydrodynamic computer model discussed below.

The USACE HEC-HMS model was used to evaluate runoff from the LIP event and generate inflow hydrographs for hydraulic analysis. Inputs consist of the all season LIP hyetographs (1-hour and 6-hour), drainage area size, and lag time. The LIP hyetograph is provided in Figure 3. The Soil Conservation Service (SCS) Unit Hydrograph method was used to transform precipitation into runoff.

Figure 3 – LIP Precipitation Hyetographs



Outputs are runoff hydrographs for each of the drainage areas. An unsteady flow analysis was then performed using the USACE HEC-RAS model to evaluate dynamic hydraulic interactions between the different model components. The model consisted of 10 reaches and 18 storage areas. The schematic of the HEC-RAS model is presented in Figure 4. The reaches represent sections of the site that function as conveyance channels and storage areas represent areas where water can pond. In HEC-RAS, the geometry of the conveyance channels is represented as a series of cross sections along the channel alignment. Most drainage areas, especially those outside of the secured area are enclosed by roads, barriers or berms. These areas were modeled as storage areas (ponds) interconnected with lateral structures. Conceptually, the lateral structures represent the berms or road embankments and the storage areas the area within where water can pond. The lateral structures in the model allow water to move from one area to an adjacent one when the water level exceeds the top of the embankment; lateral structures also allow water to move from a storage area to a conveyance reach. The model allows water to move in either direction across the embankment depending on water surface differential.

The Digital Elevation Model (DEM) was derived from bare earth LiDAR data refined with survey and other data. The surveyed elevation data included ground point elevations, finished floor elevations, and building roof elevations. For any buildings and structures not within the survey limits, a height of 10 feet is assumed. The top elevation of security barriers was defined by adding 3.3 feet (based on measurements) to the ground elevation reported by the LiDAR. Small gaps in the jersey barriers were ignored in the hydraulic analysis. Generally, the jersey barriers would prevent water from draining out of the protected area rather than allowing water in. A few jersey barriers towards the north-west do prevent water from draining into the protected area; however, if those jersey barriers were not present, natural grade would convey that water towards the intake canal and away from the Screenhouse and Turbine Building.

Manning's "n" roughness coefficients were based on land cover information and published guidance. A Manning's n-value of 0.02 was assigned for the drainage paths as these consist mainly of paved roads with some areas along the sides of the roads covered with grass or gravel. This condition is similar to having a

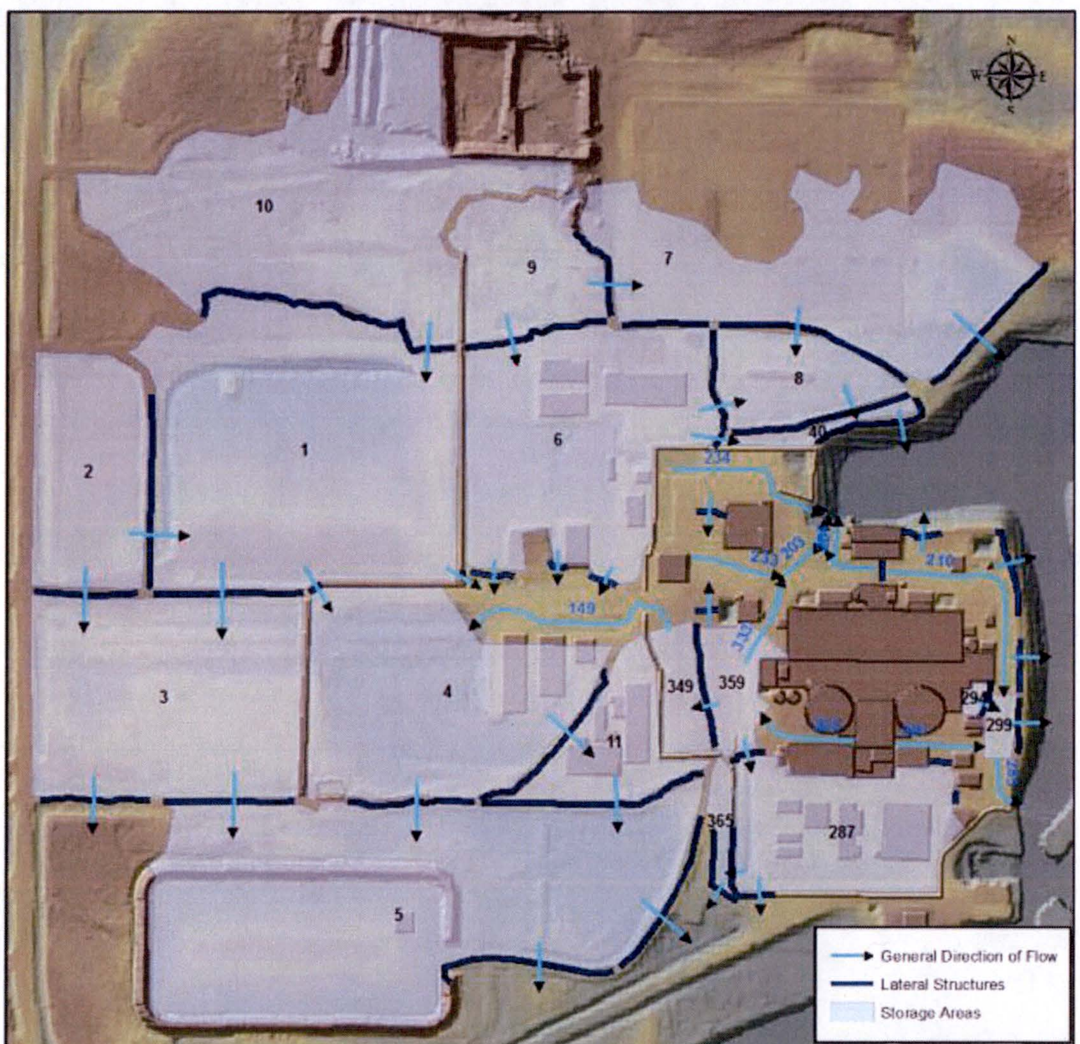
concrete bottom channel with sides of random stone in mortar per Table 5-6 of Open Channel Hydraulics (Reference 28). Therefore, for the on-site hydraulics, a Manning's "n" value of 0.02 was used to represent the roughness of the cross sections. This value represents a normal value from the range of accepted values for this type of material.

The time of concentration was conservatively assumed to be 6 minutes which is the minimum time of concentration used in Technical Release 55 (TR-55) (Reference 23). This value results in a lag time of 3.6 minutes. The lag time is generally accepted as approximately 0.6 of the time of concentration (Reference 24).

A constant weir coefficient of 2.65 was assumed for all lateral structures within the HEC-RAS model. Though weir coefficients vary as a function of the upstream head a constant value is deemed a good approximation. A weir coefficient of 2.65 is consistent with a broad crested weir under low head conditions which is typical within the structures model.

The 500-year water surface elevation in the Mississippi River was assumed as the downstream boundary condition in the HEC-RAS model for the storage areas and channel reaches that discharge into the intake and recycle canals. It is conservative to assume that the LIP would occur simultaneously to the 500-year flood.

Figure 4 – PINGP Drainage Areas in HEC-RAS



2.1.2 Results

The predicted flood elevations vary spatially throughout the PINGP site. Maximum predicted flood elevations in the vicinity of access doors into the structures are shown in Table 2. As indicated in Table 2, the maximum predicted flood water elevation could exceed the finished floor elevations at five of the 14 doors. Of these five doors, only Door 47 is not maintained as normally closed.

Table 2 – Local Intense Precipitation Flood Levels

Door/ Panel ID	Description	LIP Model Water Surface Elevation	Survey FFE* points	Modeled Maximum Depth Above FFE*	Margin
		feet NGVD 29		feet	
237	Screenhouse	694.82	694.90	-	0.08
257	Screenhouse	694.82	694.90	-	0.08
258	Screenhouse	694.82	694.90	-	0.08
238	Screenhouse	694.82	694.90	-	0.08
1	Old Administration Building	694.82	695.00	-	0.18
47	Turbine Building	695.17	694.90	0.27	-
46	Turbine Building	694.75	694.90	-	0.15
45	Turbine Building	694.81	694.90	-	0.09
44	Turbine Building/Service Building	694.76	694.90	-	0.14
73	Turbine Building	694.75	694.90	-	0.15
104	Auxiliary Building /Radioactive Waste Building	695.35	694.90 **	0.45	-
100	Auxiliary Building /Radioactive Waste Building	695.35	694.90 **	0.45	-
164	Auxiliary Building /Radioactive Waste Building	695.24	694.90	0.34	-
102	Auxiliary Building /Radioactive Waste Building	695.24	694.90	0.34	-

* FFE = Finished Floor Elevation

** No survey FFE point available at the door, closest FFE survey point was used

2.1.3 Conclusions

The LIP evaluation was not addressed as part of the current design basis and, therefore, the reevaluated flood hazard is considered not bounded. Based on the results presented in Calculation 180461.51.1005 (Reference 15), the following conclusions are reached:

- The maximum predicted flood water elevation could exceed the finished floor elevations at five of the 14 doors. However, four of the five doors are normally closed – Doors 100, 102, 104, and 164. The one open door is Door 47 ([redacted]).
- In the immediate vicinity of Door 47, the maximum water surface elevation predicted by the HEC-RAS model is 0.27 ft above the finished floor elevation.

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.
- 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 12). 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 PINGP. 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 180461.51.1002 (Reference 19) and are provided in Section 2.2.2. This calculation was performed using the maximum water surface elevation determined by 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, following the July 9, 2015 meeting with NRC and USACE (Reference 9).

2.2.1.1 Methodology

The USACE determined that the PMF hydrograph at Lock and Dam No. 3, which was developed as part of the PMF analysis for Lock and Dam No. 3, will be used to evaluate the PMF event at PINGP. The PMF analysis for Lock and Dam No. 3 was performed by USACE in 1985 and is based on a drainage area-discharge relationship developed to support evaluating extreme storm events at Lock and Dam sites throughout the USACE St. Paul District. This drainage area-discharge relationship was verified using the PMF analyses carried out for Lock and Dam Nos. 2 and 10, which are located upstream and downstream of PINGP, respectively. The Lock and Dam No. 3 PMF analysis is consistent with the PMF values adopted at the other sites within its vicinity and is representative of the USACE's currently accepted analysis for the Mississippi River Locks and Dams. Based on the information provided by USACE, all analyses were performed and reviewed in accordance with USACE protocol.

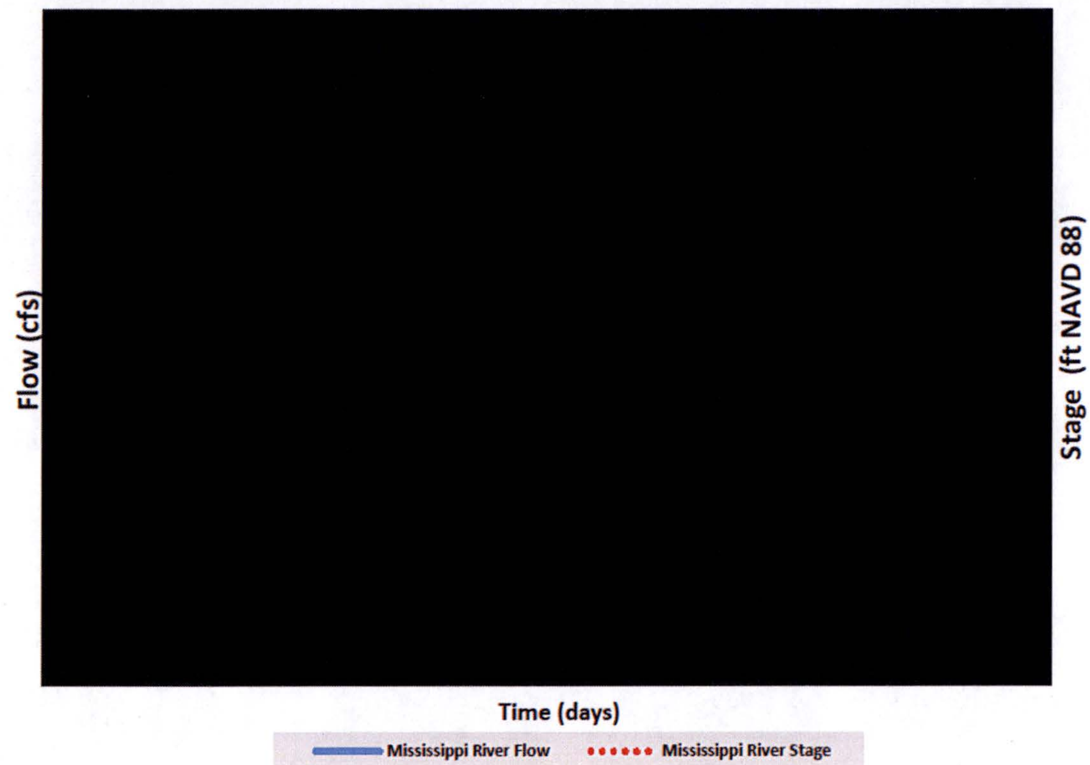
Unsteady flow modeling using the USACE HEC-RAS computer program was implemented for developing the PMF stage hydrographs at the PINGP site. The downstream boundary condition was set at Lock and Dam 4, which is at a substantial distance downstream from PINGP. The normal depth calculation based on the slope of the river bed downstream of Lock and Dam No. 4 was used for the boundary condition. The hydraulic model was calibrated to the 1965, 2001, and 2014 events using observed stage and flow hydrographs at the Lock and Dam locations and high watermark data for calibration to peak stages throughout the river reach. The parameters adjusted to achieve a better fit to the calibration data were Manning's n-values, ineffective flow limits, local inflows, and Lock and Dam gate and weir coefficients.

2.2.1.2 Results

The representative HEC-RAS cross-section for the PINGP site is located at River Station 798. The peak flow rate corresponding to the PMF (combined-effect flooding) is [redacted] cfs. The peak stage resulting from the 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 PINGP site are presented in Figure 5. The combined-effect PMF stage reaches plant grade in approximately [redacted] days where it remains for approximately [redacted] days. The combined-effect peak PMF stage is reached in [redacted] days from the onset of the rainfall event.

Figure 5 – Probable Maximum Flood Flow and Stage Hydrographs at PINGP Site (River Station 798)



2.2.1.3 Conclusions

Based on the results of the combined-effect PMF analysis performed by the USACE (Reference 8), 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 703.6 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 180461.51.1002 (Reference 19).

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.

2-minute average wind data from the 10-m reference height were obtained from the Red Wing Regional Airport, which is the closest station to the site with sufficient data available through the NOAA National Climatic Data Center website. The data were available for a period between 1993 and 2015 and were analyzed 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 35.55 mph.

Fetch length was determined based on the extent of the PMF inundation limits, as obtained from the USACE PMF analysis. As recommended in the Coastal Engineering Manual (CEM) (Reference 27), 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 analysis, and the terrain elevation. Based on the combination of fetch length and fetch average depth, wave prediction calculations were performed for fetch lines 1 and 7. These two lines represent the two longest fetches and the second and fourth highest average depths. It should be noted that the differences between average depths are minimal compared to the difference between the fetch lengths.

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 (Reference 27), 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 1 and 7 were 203 and 192 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 1 and 7. The wave runup on verticals walls of the PINGP structures was then calculated for the critical predicted significant wave height. However, waves break when the water depth becomes shallow. This is the case with the PINGP site, where the waves move over the shallower water on Prairie Island and start to break when reaching water depth of 4.2 ft. Therefore, the maximum wave height that could be sustained at water depth of [redacted] ft (at the structure toe) was determined and used in the wave runup calculations.

2.2.2.2 Results

The significant wave height for fetch lines 1 and 7 is predicted to be 3.25 ft and 3.21 ft, respectively. Since the waves will break prior to reaching the site, the maximum wave height that could be sustained at a water depth of [redacted] ft, assuming a breaking criteria of 0.78, is [redacted] ft.

The runup on the vertical walls of the PINGP structures was calculated to be 2.72 ft. The corresponding water runup elevation is predicted to be [redacted] ft.

2.2.2.3 Conclusions

The wave runup elevation during the PMF event was estimated to be [redacted] ft and is bounded by the current design basis wave runup elevation of 706.7 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 PINGP

2.4 Storm Surge, including Wind-Wave Activity

The methodology and results presented in this section are based on the evaluation of wave prediction and wave runup performed in Evaluation 180461.51.1000-01 (Reference 17).

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, PINGP is located on the Mississippi River near the outflow from Sturgeon Lake. 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. Due to the proximity to Sturgeon Lake, a possibility for a storm surge from the lake impacting the site was considered. Per NUREG/CR-7046 (Reference 2), Appendix H, Section H.4, the following combination was evaluated:

- Combination of
    - Probable maximum surge with wind-wave activity.
    - The lesser of the 100-year or the maximum controlled water level in the enclosed water body.

Per the Lock and Dam No. 3 Water Control Manual, the Mississippi River is considered to be no longer under control at a flow rate greater than 36,000 cfs and a corresponding water elevation of 674 ft at Lock and Dam No. 3 Pool (Reference 26). The PINGP is located just upstream of Lock and Dam No. 3 and, therefore, a maximum controlled water surface elevation at PINGP between 674 and 675 ft is considered reasonable. This is also consistent with the USAR normal pool water elevation of 674.5 ft. Thus, the maximum controlled water level for Sturgeon Lake is approximately 20 feet below plant grade elevation of 695 ft. As shown in Figure 1, Sturgeon Lake is a relatively small impoundment. The river bottom elevation in the vicinity of the PINGP site is approximately 660 ft (References 18 and 26). As such, when the Mississippi River is at the maximum controlled water surface elevation, the depth in the dredged channel is approximately 15 ft. The size of Sturgeon Lake combined with the relatively small depth in the river constrain any storm surge in the lake to a small number, significantly lower than 20 ft. This 20-ft difference between the river water elevation and plant grade precludes the site from being impacted by a potential storm surge from Sturgeon Lake.

Therefore, flooding due to a surge is not applicable to the PINGP site.

2.5 Seiche

The methodology and results presented in this section are based on the evaluation performed in Evaluation 180461.51.1000-01 (Reference 17).

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 PINGP 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 PINGP site (Reference 17).

2.6 Tsunami

The methodology and results presented in this section are based on the evaluation performed in Evaluation 180461.51.1000-01 (Reference 17).

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 PINGP 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 PINGP site.

The PINGP site is located in a relatively low seismic hazard area with a Design Basis Earthquake of 0.12g. Plant grade is elevation 695 ft and normal water elevation for the Mississippi River at the site is 674.5 ft, or approximately 20 ft below plant grade.

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 PINGP site (Reference 17).

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 180461.51.1001 (Reference 18).

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 or from backwater conditions from a downstream ice jam.

The most severe historical ice jam events on the Mississippi River in the vicinity of PINGP were determined using the Ice Jam Information Clearinghouse maintained by the USACE Cold Regions Research and Engineering Laboratory. The information from the Ice Jam Clearinghouse provides ice jam heights as either the height from the river invert (24 feet) or the height of flood water elevation behind the ice jam (7.2 feet).

The most likely location for an ice jam is either at the upstream Lock and Dam No. 2 or the downstream Lock and Dam No. 3. The relative locations for Lock and Dam Nos. 2 and 3 are shown in Figure 1. Lock and Dam No. 2 is located on the Mississippi River about 15 miles upstream of the PINGP site, just North of Hastings, Minnesota. Lock and Dam No. 3 is located on the Mississippi River about 1.3 miles downstream of the PINGP site.

The potential flooding due to an ice jam was determined for the following scenarios:

Scenario #1

- Add the maximum recorded ice jam height of 24 ft to the river invert elevation at Lock and Dam No. 2 and compare the resultant elevation to the PINGP plant grade elevation.
- Add the maximum recorded ice jam height of 24 ft to the river invert elevation at the PINGP site and compare the resultant elevation to the PINGP plant grade elevation.
- Add the maximum recorded ice jam height of 24 ft to the river invert elevation at Lock and Dam No. 3 and compare the resultant height to the PINGP plant grade elevation.

Scenario #2

- Add the maximum recorded increase in water surface elevation due to an ice jam of 7.2 ft to normal pool elevation at Lock and Dam No. 2 and compare the resultant elevation to the PINGP plant grade elevation.
- Attenuate the flood wave from the ice jam at Lock and Dam No. 2 to the PINGP site by applying a conservative reduction factor of 4/9 of the difference in water surface elevations behind the ice jam and the normal pool elevation at PINGP (References 28 and 29).
- Add the maximum recorded increase in water surface elevation due to an ice jam of 7.2 ft to normal pool elevation at Lock and Dam No. 3 and compare the resultant elevation to the PINGP plant grade elevation.

Furthermore, NUREG/CR-7046 (Reference 2) does not require that simultaneous precipitation-induced flood be considered as part of the ice induced flooding analysis.

2.7.2 Results

The results for the scenarios discussed above are summarized in Table 3. The conservative estimates of ice jam elevations at the closest upstream and downstream Locks and Dams are below the PINGP plant grade. Please note that the margin reported in Table 3 is based on a simplified analysis with significant conservatisms. Furthermore, the ice jam elevation at the PINGP site has a significant margin of 11 ft (Scenario 1) and 11.9 ft (Scenario 2).

Table 3 – Summary of Ice Induced Flooding Evaluation

Case	Water Surface Elevation (ft)	Margin to Plant Grade of 695 ft (ft)
Ice jam elevation at Lock and Dam No. 2 (Scenario 1)	686.2	8.8
Ice jam elevation at PINGP site (Scenario 1)	**684.0**	**11.0**
Ice jam elevation at Lock and Dam No. 3 (Scenario 1)	676.0	19.0
Ice jam elevation at Lock and Dam No. 2 (Scenario 2)	693.9	1.1
Ice jam elevation at PINGP site (Scenario 2)	**683.1**	**11.9**
Ice jam elevation at Lock and Dam No. 3 (Scenario 2)	681.7	13.3

2.7.3 Conclusions

The reevaluated flood hazard due to ice-induced flooding was estimated to be 684 ft, which is significantly below the plant grade. 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 180461.51.1000-01 (Reference 17).

Prairie Island is a low island terrace associated with the Mississippi River floodplain. It is separated from other parts of the lowland by the Vermillion River on the west, and by the Mississippi River on the east. Ground surface elevations range from approximately 675 to 706 feet. Most of Prairie Island is under cultivation. Other lowland areas near the site are forested or covered by swamp vegetation. The Mississippi River floodplain in this area is confined within a valley about three miles wide. Rocky bluffs and heavily forested slopes rise abruptly from both sides of the valley to a height of some 300 feet. The uplands immediately surrounding the valley reach elevations ranging from approximately 1,000 to 1,200 feet. They are deeply trenched by numerous streams emptying into the Mississippi River.

The bluff lines are established and composed of limestone. Significant bluff line failure is not expected, and failure of a bluff would be localized and not result in channel diversion towards the plant. Furthermore, a review of national landslide hazards program information showed that, in the vicinity of the plant, the areas along the Mississippi River are considered to have a low landslide incidence (less than 1.5% of area involved). On both sides of the river, there is a lower elevation land area between the bluff lines and the river. In general, the bluffs are closer on the east side of the river. On the east side, a railroad track runs on the lower land area between the bluff line and the river. A landslide failure of a bluff line would be substantially absorbed before reaching the river. Upstream and downstream of the plant the river is more than 1,000 feet wide. Thus, even if a localized area of a bluff were to slide there is substantial river surface area to attenuate a wave.

In addition, the Mississippi River channel is actively monitored and maintained by the USACE to preclude channel diversion or migration in accordance with the Channel Maintenance Management Plan (CMMP). The Mississippi River in the region of the PINGP site is used for both commerce and recreation and maintaining a navigable channel is a priority. The Mississippi River in the region of the PINGP site is controlled by the St. Paul District of the USACE, which is responsible for maintaining a navigable channel with a depth of at least 9 feet. The St. Paul District monitors channel conditions on a regular basis through the use of timely and accurate hydrographic surveys to ensure that dredging is performed when needed and unnecessary dredging is avoided. Dredging process is typically initiated when depths of less than 10.5 feet are observed encroaching into the navigable channel.

Since the USACE proactively controls and maintains the navigation channel of the Mississippi River in the PINGP region, channel diversion or migration is not considered an applicable flood hazard for the PINGP 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. 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 180461.51.1005 (Reference 15), the LIP flood levels exceed finished floor elevation at five critical doors of which only Door 47 [redacted]) is not maintained closed at all times. To determine the impact that the LIP event can have in terms of potential internal flooding to the Turbine Building, the amount of water that could enter through Door 47 was calculated. The flow rate into the building through Door 47 is determined using the standard weir equation and the depth of water in the vicinity of the door as a function of time. Using this approach, it was determined that 3700 ft^3 could enter the Unit 2 Turbine Building. The water would collect in the Condenser Pit and Sump. The floor space of the Unit 2 Condenser Pit is 8,993 ft^2 (Reference 14). Thus, the 3700 ft^3 of water will result in less than six inches of water on the pit floor, which will have no impact to safety related SSCs.

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 695.35 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. Furthermore, the flood levels are bounded by the PMF. Therefore, the existing flood walls will not be impacted by the LIP flood levels. However, there are five doors that will be subjected to water loading without flood protection that is only installed prior to the PMF event. Doors 47, 102, and 104 are designed to withstand 40 psf (due to wind), which bounds the pressure resulting from LIP flood level of 0.45 ft of 28.08 psf. The remaining two doors 100 and 164 are Overly Blast Doors that are designed to withstand a total static loading in the seated direction of 576 psf and the associated supporting structures are designed to withstand design basis flood levels. Therefore, no re-analysis of either set of doors is necessary as they are bounded (Reference 20).

3. Comparison of Current Design Basis and Reevaluated Flood Hazard

3.1 Comparison of Flood Hazard Elevations

Table 4 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 4 – 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	695.35 ft	Not Bounded
Flooding in Streams and Rivers	703.6 ft	[redacted] ft	Bounded
Dam Breaches and Failures	676.5 ft	Screened Out	Bounded
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 specifically addressed in the USAR	684.0 ft	Bounded[2]
Channel Migration or Diversion	Not specifically addressed in the USAR	Screened Out	Bounded[1]
Combined Effects Flood - PMF with wave runup	706.7 ft	[redacted] ft	Bounded

[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 specifically addressed in the USAR, the resultant flood elevation is well below elevations that would impact SSCs important to safety. Furthermore, this hazard is fully bounded by the flooding in stream and rivers hazard.

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 scenario parameters included 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 5.

Table 5 – 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 MSL)	LIP was not specifically addressed in the USAR	695.35	NB
	2. Maximum Wave Run-up Elevation (ft MSL)		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)		~1.1 (see Note 9)	NB
	10. Period of Recession (hours)		~5.4 (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, ANS-2.8 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 15).
4. Due to limited velocities, and short duration of flooding (Reference 15), 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 15), surcharge to groundwater is not considered. In addition, the PINGP is a wet site where the structures are designed for a flooded condition (Reference 10). Thus, an increase in groundwater elevation would not impact the site.
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 location with the highest flood depth, it was estimated that water level would remain above finished floor elevation for 66 minutes (Reference 15).
10. Once the flood waters recede below finished floor elevation, it would take approximately 5.4 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 15).
11. There are no limitations on plant modes of operation prior to, or during, the LIP event.
12. There are no other factors applicable to this flood causing mechanism.

4. References

1. American Nuclear Society, "Determining Design Basis Flooding at Power Reactor Sites," ANS/ANSI 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, "Prairie Island Nuclear Generating Plant, Units 1 and 2 – Transmittal of U.S. Army Corps of Engineers Flood Hazard Reevaluation Information (TAC Nos. MF3697 and MF369)," November 18, 2015, ADAMS Accession Nos.: ML15296A36 (Package), ML15324A371 (PUBLIC letter), and ML15296A349 (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, "Prairie Island Updated Safety Analysis Report," Revision 34P.
11. NSPM, "PINGP Final Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," November 26, 2012, ADAMS Accession No. ML12332A302.
12. 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.
13. NSPM, "Flood," Procedure AB-4, Rev. 50.
14. NSPM, "Turbine Building HELB Compartment Volumes," Calculation ENG-CS-168, Rev. 0.
15. Black & Veatch, "Local Intense PMP & Hydrology," Calculation 180461.51.1005, Rev. 0.
16. Black & Veatch, "Site Specific PMP and Ancillary Meteorological Analyses," Calculation 180461.51.1011, Rev. 2.

17. Black & Veatch, "PINGP Flood Scenario Evaluations," 180461.51.1000-01, Rev. 1.
18. Black & Veatch, "Ice Induced Flooding," Calculation 180461.51.1001, Rev. 2.
19. Black & Veatch, "PINGP Wave Prediction and Wave Runup," Calculation 180461.51.1002, Rev. 0.
20. Black & Veatch, "Evaluation of Structural Elements – Flood," Calculation 180461.51.1008, Rev. 0.
21. National Oceanic and Atmospheric Administration, "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 51, June 1978.
22. National Oceanic and Atmospheric Administration, "Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian," Hydrometeorological Report No. 52, August 1952.
23. U.S. Department of Agriculture, "Urban Hydrology for Small Watersheds – Technical Release 55," June 1986.
24. U.S. Department of Agriculture, "Part 630 Hydrology National Engineering Handbook," September 1997.
25. Federal Emergency Management Agency, "Flood Insurance Rate Map, Goodhue County, Minnesota, and Incorporated Areas – Map Number 27049C0045E," Effective Date September 25, 2009.
26. U.S. Army Corps of Engineers, St. Paul District, "Water Control Manual, Mississippi River Nine Foot Channel Navigation Project, Lock and Dam No. 3, Red Wing, Minnesota," August 2003.
27. 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.
28. Ven Te Chow, "Open Channel Hydraulics," 1959.
29. F.M. Henderson, "Open Channel flow," MacMillan Publishing Co., 1966.

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 PINGP 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 Failure: 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 5. Note that other associated effects are only applicable to the LIP since LIP was the only non-bounded flood causing mechanism for PINGP;
- Flood Event Duration Parameters (i.e., warning time, period of site preparation, period of inundation, and period of recession): See Table 5. Note that flood duration parameters are only applicable to the LIP since LIP was the only non-bounded flood causing mechanism for PINGP.

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 4. 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 5 for 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 4.

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 PINGP. See Section 2.3 and Table 4.

iv. Storm surge, seiche and tsunami: These hazards were screened out as not applicable/not plausible at the PINGP site. See Sections 2.4, 2.5, and 2.6 and Table 4.

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 4.

vi. Channel Migration and Diversion: This hazard was found to not be applicable/not plausible at the PINGP site. See Section 2.8 and Table 4.

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 4.

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:

<u>Response</u>:

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:

<u>Response</u>:

None required.