Rep 10

November 12, 1982

Docket No. 50-409
LS05-82-11-042

Mr. Frank Linder
General Manager
Dairyland Power Cooperative
2615 East Avenue South
LaCrosse, Wisconsin 54601

Dear Mr. Linder:

SUBJECT: SEP HYDROLOGY TOPICS II-3.A, II-3.B, II-3.B.1, AND II-3.C, LACROSSE BOILING WATER REACTOR (LACBWR)

Enclosure 1 is a copy of our final evaluation of SEP Hydrology Topics II-3.A, Hydrology Description; II-3.B, Flooding Potential and Protection Requirements; II-3.B.1, Capability of Operating Plants to Cope with Design Basis Flood Conditions; and II-3.C, Safety-Related Water Supply (Ultimate Heat Sink). These evaluations are based on the review of our contractor's Technical Evaluation Report which is provided as Enclosure 2. The technical evaluation report is based on your submittals of June 26, 1981, SEP Topics II-3.A and II-3.C and May 12, 1982, SEP Topics II-3.B and II-3.B.1. Appendix A to the evaluation is a discussion of the conservatisms involved in estimating a Probable Maximum Flood (PMF). Our conclusions regarding these topics are summarized as follows:

Topic II-3.A - Complete. No differences identified.

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Topic II-3.B - (1) The roofs of the 1A and 1B diesel buildings and the containment penetration building meet current criteria with respect to Probable Maximum Precipitation (PMP) induced loads. For the roofs of the turbine building, office building and cribhouse the PMP induced load exceeds the original design load. The structural analysis and conformance with current criteria will be determined in Topic III-7.B, (2) The LaCrosse site conforms with current criteria for local flooding from a locally intense PMP, (3) The Mississippi River PMF has been estimated to be 1,000,000 cfs which translates to a flood still-water elevation of 658 ft msl. An additional three feet should be added to this level to account for wind waves, and (4) Groundwater level should be assumed at grade elevation.

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Topic II-3.B.1 - The LACBWR plant does not meet current criteria for this topic. The licensee needs to develop emergency plans and technical specifications for site flooding and Mississippi River low water level, to complement the Emergency Service Water Supply System.

Topic II-3.C - The ultimate heat sink function can be loss due to flooding of the cribhouse or low Mississippi water level due to the catastrophic failure of Lock and Dam #9. While we agree the ESWSS could serve as an alternate water supply for the above conditions, the technical specifications would have to be revised to include limiting conditions of operations for these two scenarios.

This evaluation will be a basic input to the integrated assessment for your facility unless you identify changes needed to reflect the as-built conditions at your facility. This assessment may be revised in the future if your facility design is changed or if NRC criteria relating to this subject are modified before the integrated assessment is completed.

Sincerely,

Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
See next page

*SEE PREVIOUS TISSUE FOR ADDITIONAL CONCURRENCES.

OFFICE	SEPB:DL	SEPB:DL	SEPB:DL	SEPB:DL	ORB#5:PM	ORB#5:BC	
SURNAME	AWang:dk*	TMichaels*	CGrimes*	WRussell*	RDudley*	DCrutchfield	
DATE	10/28/82	10/28/82	11//82	11/4/82	11/10/82	11/12/82	

Topic II-3.B.1 - The LACBWR plant does not meet current criteria for this topic. The licensee needs to develop emergency plans and technical specifications for site flooding and Mississippi River low water level, to complement the Emergency Service Water Supply System.

The ultimate heat sink function can be loss due to flooding of the cribhouse or low Mississippi water level due to the catastrophic failure Lock and Dam #9. While we agree the ESWSS could serve as an alternate water supply for the above conditions, the technical specifications would have to be revised to include limiting conditions of operations for these two scenarios.

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Topic II-3.B.1 - The LACBWR plant does not meet current criteria for this topic. The licensee needs to develop emergency plans and technical specifications for site flooding and Mississippi River low water level, to complement the Emergency Service Water Supply System.

Topic II-3.C - The LACBWR plant does not meet current criteria for this topic. The ultimate heat sink function can be lost due to flooding or low Mississippi water level.

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DATE	10/28/82	10/28/82	11/ 7/82	11/ 8/82	10/ /82	10/ /82	10/28/82

Topic II-3.B.1 - The LACBWR plant does not meet current criteria for this topic. The licensee needs to develop emergency plans and technical specifications for site flooding, Mississippi River low water level, to complement the Emergency Service Water Supply System.

Topic II-3.C - The LACBWR plant does not meet current criteria for this topic. The ultimate heat sink function can be lost due to flooding or low Mississippi water level.

Topic III-3.B - Not applicable to the LACBWR plant and was deleted in our letter to DPC dated March 10, 1981.

This evaluation will be a basic input to the integrated assessment for your facility unless you identify changes needed to reflect the as-built conditions at your facility. This assessment may be revised in the future if your facility design is changed or if NRC criteria relating to this subject are modified before the integrated assessment is completed.

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HYDROLOGIC ENGINEERING SAFETY EVALUATION FOR SYSTEMATIC EVALUATION PROGRAM

Topic II-3.A, Hydrologic Description
Topic II-3.B, Flooding Potential and Protection Requirements
Topic II-3.B.1, Capability of Operating Plants to Cope with Design Basis Flood Condition
Topic II.3.C, Safety-Related Water Supply (Ultimate Heat Sink)

Plant Name: LaCrosse Boiling Water Reactor
Licensing Stage: Operating
Docket Numbers: 50-409

I. INTRODUCTION

The Systematic Evaluation Program (SEP) was established by the Nuclear Regulatory Commission (NRC) to evaluate the safety of 10 older nuclear power plants. The program evaluates the plants against current licensing criteria with respect to 137 selected topics.

The hydrologic topics provide:

- A brief description of the hydrologic features of the site and surrounding area, plant facilities and the design bases used for construction. Additionally both surface and ground water and their interfaces with plant safety-related buildings and systems are described.

- Design bases floods for the plant are developed, using current criteria, and compared to the design bases events used when the plant was built. Deviations and their safety significance are discussed. Acceptability of current features are noted where applicable.

- Where physical protection is used to prevent plant flooding, the design and design bases are reviewed and compared to current criteria. The variations, if any, and their safety significance with respect to structural and equipment distress are discussed.

- The design basis ground water level for hydrostatic loading is determined in accordance with current criteria and compared to the value used for design.

- Existing emergency plans or procedures and technical specifications related to flooding or safety-related water supply are reviewed and compared to current criteria. Deficiencies are noted and, where possible, acceptable fixes are recommended. Where emergency plans or technical specifications do not exist but are a potential solution to a problem, they are discussed and recommendations made, if appropriate.

- As reviewed here, the Ultimate Heat Sink (UHS) consists of water sources for the cooling water system, necessary retaining structures (e.g., a pond with its dam or a cooling tower supply basin), and the canals or conduits connecting the sources with (but not including) the cooling water system intake structures. The existing UHS is compared to current criteria with respect to available supply and maximum temperature, and if deficiencies exist, they are discussed and acceptable solutions recommended, if possible.

The information used to perform the reviews was gathered from the licensee's files, NRC files, other agencies, and the site visit. In some cases, detailed information was not available. In such cases, the staff and its consultants conservatively estimated these parameters required for analysis. For this evaluation the staff consultant was the Franklin Research Center.

II. REVIEW CRITERIA

Current licensing criteria for nuclear power plants, related to the SEP topics addressed in this report, were developed from the Code of Federal Regulations: 10 CFR Part 50, "Licensing of Production and Utilization Facilities," and General Design Criteria 2, 4, 5, and 44 of Appendix A, "General Design Criteria;" 10 CFR Part 100, "Reactor Site Criteria" and Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

The criteria which are applicable are (1) Standard Review Plans 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12, 2.4.14, 3.4.1, and 9.2.5 (Ref. 1); (2) Regulatory Guides 1.27, 1.59, 1.70, 1.102 and 1.127 (Ref. 2); and (3) American National Standards Institute (ANSI) Standard N170-1976 (Ref. 3).

III. RELATED SAFETY TOPICS AND INTERFACES

The effects of high surface water and ground water (pertaining to structural strength of building walls, loss of important equipment and its effect on the plant's ability to safely shut down, etc.) are outside the scope of the hydrologic evaluation. However, the levels of flood and ground water are determined in this evaluation and given to the structural and system reviewers for their use.

SEP interface topics are:

II-4.D - Stability of Slopes
II.4.E - Dam Integrity
II-4.F - Settlement of Foundations and Buried Equipment
III-1 - Classification of Structures, Components and Systems
III-3.A - Effects of High Water Level on Structures
III-3.B - Structural and Other Consequences of Failure of Underdrain System
III-3.C - Inservice Inspection of Water Control Structures
III-6 - Seismic Design Considerations
VII-3 - Systems Required for Safe Shutdown
VIII-2 - Onsite Emergency Power Systems - Diesel Generator
IX-3 - Station Service and Cooling Water Systems
XVI - Technical Specifications

IV. REVIEW GUIDELINES

The hydrologic issues identified in the Introduction are developed from design information for the nuclear power plant and from many sources containing hydrologic information for the site. Design bases (elevation of floods, depths of precipitation flooding, elevation of ground water and amounts of

available cooling water) are determined and their conformance with or degree of departure from the current criteria is assessed. The Standard Review Plans and Regulatory Guides identified in Section II direct a complete evaluation of all issues and suggest or reference appropriate technical evaluation methods.

Regulatory Guides 1.27, 1.59 and 1.102 have been specifically identified as needing consideration for backfit on operating reactors. These guides are used in determining whether the facility design complies with current criteria or has some equivalent alternatives acceptable to the staff. The acceptability or nonacceptability of any deviations identified in this evaluation and the need for further action will be judged during the integrated assessment for this facility.

V. TOPIC EVALUATION

The staff's consultant, Franklin Research Center (FRC), has reviewed available background information and made independent analyses necessary to prepare the report, "Technical Evaluation Report, Hydrological Considerations, LaCrosse Boiling Water Reactor" dated September 27, 1982, (TER-C5257-427). This work was performed under NRC Contract No. 03-79-118 and provides the assessment for Systematic Evaluation Program (SEP) Topics: II-3.A, Hydrologic Description; II-3.B, Flooding Potential and Protection Requirements; II-3.B.1, Capability of Operating Plants to Cope with Design Basis Flood Conditions and, II-3.C, Safetv-Related Water Supply (Ultimate Heat Sink (UHS)). The TER is appended to this SER as Enclosure 2.

The staff has reviewed the TER and generally concurs with the evaluations, conclusions and recommendations. The following summary evaluation describes significant features addressed, any staff differences of opinion with the TER and any independent staff judgments.

Topic II-3.A Hydrologic Description

This topic provides a brief description of hydrologic features, related plant facilities and design bases used for plant construction.

The LaCrosse Boiling Water Reactor (LACBWR) site is located on the left (east) bank of the Mississippi River. The site is potentially subject to flooding from large floods on the adjacent river or from local intense precipitation on the site area.

The ground elevation in the main plant area is 639.0 feet msl which is plant grade. Non-watertight openings in walls of Category I safety-related structures are at elevation 640.0 feet msl.

The surficial aquifer at the LaCrosse site is about 100-130 feet of glacio-fluvial deposits overlying bedrock. The material is essentially sand graded between fine and coarse. The upper 20 feet of the site is hydraulic fill of medium to coarse sand. The licensee has not provided any groundwater levels for the site area but has stated that the structures are designed for hydrostatic pressure and buoyancy effects of water to elevation 639.0 ft msl.(4) The staff does not know if this value was used in combination with seismic levels. The design bases used for plant construction are listed below.

- The design basis groundwater level is unknown.

- The design basis flood level for the main plant area was 639.0 ft msl.

- The design basis for local site flooding (rainfall and runoff on the plant and surrounding local drainage area) is unknown.

- The roofs of the turbine building, office building and cribhouse have a design basis live loading of 65 psf. The roofs for the containment penetration building, and 1A and 1B diesel buildings are designed for direct runoff (no water ponding).

- The licensee has a flood control program that was implemented in 1969 as a means of protecting the plant from intermediate floods on the Mississippi River.

Topic II-3.B Flooding Potential and Protection Requirements

The purpose of this topic is to identify the plant and site design basis flood level resulting from all potential flood sources external to the plant and site, using current NRC licensing criteria. This topic also includes the identification of the design basis groundwater levels for use in structural analyses.

Groundwater

For this site the maximum groundwater level is not a controlling design basis for hydrostatic loading and buoyancy effects. Since flood levels on the Mississippi River could exceed site grade, the PMF elevation of 658 ft msl would be the controlling design basis.

In order to meet current criteria, the plant must be shown to be capable of withstanding combined hydrostatic and seismic or other extreme environmental loadings. In lieu of further analyses, plant grade (639 ft msl) may be used as the groundwater elevation for combination with seismic or other extreme environmental loadings.

Probable Maximum Flood (PMF)

The licensee has not provided an estimate of the PMF for the LaCrosse site. Our contractor, FRC, has provided a conservative estimate of the PMF discharge (1,300,000 cfs) and stage (663 ft msl). The contractor used the method of enveloping isolines of PMF peak discharge presented in Regulatory Guide 1.59. This method is very conservative and may overpredict the PMF peak discharge by a considerable margin. There are other general guidelines acceptable to the technical community that suggest a relationship between the PMF and Standard Project Flood (SPF) which is the SPF equals about 40 to 60% of the PMF. The U.S. Army Corps of Engineers developed a SPF for the Mississippi River at LaCrosse, Wisconsin. The licensee converted this to a SPF at the LaCrosse site by using the respective drainage areas as the conversion parameter. This SPF peak discharge at the LaCross site is 386,000 cfs. Using the 40% guideline,

this would convert to a PMF discharge of about 965,000 cfs. It is the staff's judgment that 1,000,000 cfs is a reasonable approximation of the PMF for the LaCrosse site and should be used for purposes of the Systematic Evaluation Program.

Using our contractor's rating curve (Figure 5 of Appendix A), the PMF peak discharge of 1,000,000 cfs translates to a flood stillwater elevation at the site of 658 feet msl. An additional three feet for wind waves results in a maximum stage of 661 feet msl which is the level that the licensee should use as its design bases. For comparison, the SPF stage (including windwaves) at the site is elevation 644.2 ft msl.

We conclude that the Mississippi River PMF would cause flooding of the turbine building, cribhouse, office building and diesel generator rooms and that LACBWR does not meet current licensing criteria for flooding as specified in Regulatory Guides 1.59 and 1.102. Some safety related equipment which would be affected by flooding are: diesel generators (el 641), 125V batteries (el 654, turbine building), emergency buses (el 640, turbine building), and alternate core spray diesel pumps (el 641, cribhouse). The need and level of protection to be provided for these systems will be established during the integrated assessment. The ability of plant structures to withstand these water levels is being reviewed in Topic III-3.A.

Site Drainage - Local PMP

The Plant site was analyzed for its ability to drain during the local PMP. The 35-acre study area can produce an estimated peak discharge of 520 cfs from the localized storm. The plant area is sloped toward the Mississippi River and the runoff is conveyed to the river at a maximum depth of about six inches, which is less than the floor entrance level of all safety-related buildings. The local drainage configuration, therefore, protects the plant from localized PMP, and the site conforms to current criteria.

Roof Drainage

The roofs of safety-related structures at the LaCrosse plant were designed to withstand a live load of 65 psf The roofs of the 1A and 1B diesel buildings

and the containment penetration building drain freely (no parapets) thus there can be no appreciable live load due to local intense rainfall and these roofs will meet current NRC criteria with respect to PMP loading.

The roofs of the turbine building, the office building (which houses the control room) and the crib house all have parapets approximately 21 inches high. Each roof is equipped with roof drains but no scuppers to limit the depth of ponding. Thus, during a PMP, and assuming roof drains blocked, water could pond to the top of the parapets and produce a live load of 109 psf. If structural analyses (Topic III-7.B) show that the allowable stress in structural members is exceeded, then the structures will not meet current NRC licensing criteria. This potential problem can usually be corrected by either removing a portion of the parapet or installing scuppers to limit the depth of ponded water to less than the design basis.

Topic III-3.B.1 Capability of Operating Plants to Cope with Design Basis Flood Conditions

Protection against floods can be accomplished by implementing emergency procedures and technical specifications. This topic focuses on the adequacy and efficacy of the LACBWR flood emergency procedure to provide for safe shutdown and cooldown of the reactor during and after a severe river flood. Further, this topic addresses the need for other emergency plans and technical specifications to limit conditions of operation.

The attached TER provides detailed discussions of the licensee's flood emergency plan, potential problem areas and recommendations. We have reviewed and concur in our consultant's assessment. We consider the following to be significant potential problem areas:

- The staff would like an opportunity to review in detail the existing agreements with the U.S. Army Corps of Engineers and National Weather Service with respect to flood emergency planning and flood forecasts and warning time.

- The licensee needs to provide additional detailed information on the type and reliability of communication equipment to be used for flood emergencies.

- The licensee needs to provide a description of the warning times available as compared to time required to prepare the plant for floods up to and including the PMF.

- Regulatory Guides 1.59 and 1.102 require that all structures and systems required for plant shutdown be protected (hardened passive protection) to at least the SPF. Earth dikes constructed during the flood period do not meet this criteria.

- The licensee has not provided any details for the portable pumps and hoses (ESWSS) such as: intake (limiting suction head) and discharge capacities (capacity vs. plant requirements), elevation and location of intake and discharge points, fuel requirements and storage or supply facilities with due consideration of flood duration and limited mobility during floods.

- Pressurization of containment needs some additional discussion. All electrical power would probably be lost at some time during a large flood. The licensee needs to provide specific times or water elevations when pressurization will begin, discuss time required to pressurize containment, discuss the quality of the assumed 1% per day leakage rate and/or provisions to mitigate loss of pressure.

- The turbine building is relied on to provide a location for the ESWSS pumps when the containment is pressurized. The licensee needs to provide assurances that the turbine building can withstand flood loads and that access is available.

- The licensee needs to provide a formal flood emergency plan and appropriate technical specifications to cover the entire flood period.

The above comments assume that the integrated assessment finds that emergency plans, technical specifications and some hardened protection are acceptable methods to provide flood protection for the LACBWR.

The emergency plan in its present form does not meet current criteria specified in Regulatory Guides 1.59 and 1.102. Modifications necessary to make the plan acceptable to the staff will have to be addressed during the integrated assessment. A Technical Specification will be required to set the limiting conditions of operation and to establish time and elevation control points to be used in implementation of the plan.

Topic II-3.C Safety-Related Water Supply

This topic reviews the acceptability (supply and temperature) of water source(s) with respect to providing safety-related water during emergency shutdown and maintenance of safe shutdown. The normal safety-related water supply for the LACBWR is the Mississippi River. Water is withdrawn through the crib house which is located on the left (east) bank of the Mississippi River. The availability of this normal safety-related water supply may be lost as a result of flooding, low Mississippi River water level including loss of a downstream dam, or a seismic event that would damage the crib house and associated piping.

The licensee has designed and implemented (Amendment No. 24) an Emergency Service Water Supply System (ESWSS). This system and the associated technical specifications were developed specifically to mitigate the possible loss of the normal supply due to liquefaction during seismic events. This ESWSS could also serve as an alternate cooling water source during floods or low river level; however, the technical specifications may have to be revised to include limiting conditions of operations for these two scenarios.

In view of the foregoing, we conclude that the existing safety-related water supply from LACBWR does not meet current NRC criteria since the function may be lost due to flooding or low river water. This issue can probably be resolved by an acceptable flood emergency plan and appropriate technical specifications. These details should be resolved during the integrated assessment.

VI. CONCLUSIONS

Topic II-3.A

This topic is complete and acceptable.

Topic II-3.B

Groundwater

For this site the maximum groundwater level for hydrostatic loading and buoyancy effects is controlled by the Mississippi River. The stillwater PMF elevation of 658 ft msl would be the controlling design basis for an independent natural event.

Plant grade (elevation 639 ft msl) should be used as the groundwater elevation for combination with seismic or other extreme environmental loading.

Mississippi River Flooding

The current criteria design basis flood level for the Mississippi River PMF is elevation 658 ft msl plus 3 feet for wind waves. The need and level of protection for various safety related structures and systems will be established during the integrated assessment.

Site Drainage - Local PMP

Meets current NRC licensing criteria.

Roof Drainage

The roofs of the 1A and 1B diesel buildings and the containment penetration building meet current NRC criteria with respect to PMP induced loads.

The roofs of the turbine building, office building and cribhouse were designed for a live load of 65 psf. The PMP could produce a live load of 109 psf. Structural analyses and conformance with current NRC criteria are determined in Topic III-7.B.

Topic II-3.B.1 Capability of Operating Plants to Cope with Design Basis Flood Conditions

The LACBWR plant does not meet current NRC licensing criteria. The licensee needs to develop emergency plans and technical specifications for site flooding, to complement the Emergency Service Water Supply System.

Topic II-3.C Safety-Related Water Supply

The LACBWR plant does not meet current NRC licensing criteria. The ultimate heat sink function can be lost due to flooding or low Mississippi River water level.

VII. REFERENCES

1. Standard Review Plans, NUREG-0800 (formerly NUREG-75/087), U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation.

   a. 2.4.1 - Hydrologic Description
   b. 2.4.2 - Floods
   c. 2.4.3 - Probable Maximum Flood (PMF) on Streams and Rivers
   d. 2.4.4 - Potential Dam Failures
   e. 2.4.5 - Probable Maximum Surge and Seiche Flooding
   f. 2.4.6 - Probable Maximum Tsunami Flooding
   g. 2.4.7 - Ice Effects
   h. 2.4.8 - Cooling Water Canals and Reservoirs
   i. 2.4.9 - Channel Diversions
   j. 2.4.10 - Flooding Protection Requirements
   k. 2.4.11 - Low Water Considerations
   l. 2.4.12 - Groundwater
   m. 2.4.14 - Technical Specifications and Emergency Operation Requirements
   n. 3.4.1 - Flood Protection
   o. 9.2.5 - Ultimate Heat Sink

2. Regulatory Guides, U.S. Nuclear Regulatory Commission, Office of Standards Development.

a. 1.27 - Ultimate Heat Sink for Nuclear Power Plants
b. 1.59 - Design Basis Floods for Nuclear Power Plants
c. 1.70 - Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, NUREG-75/094
d. 1.102 - Flood Protection for Nuclear Power Plants
e. 1.127 - Inspection of Water Control Structures Associated with Nuclear Power Plants

3. American National Standard N170-1976, "Standards for Determining Design Basis Flooding at Power Reactor Sites," Published by the American Nuclear Society (ANS-2.8).

4. DPC Letter, LAC-8283, Leniler to Crutchfeld, dated May 23, 1982, SEP Topic III-3.A.

Generic
Conservatisms in a PMF Estimation

The purpose of this appendix is to present some of the conservatism involved in determining a Probable Maximum Flood.

Definitions

Probable Maximum Flood (PMF) - The PMF is defined as "the hypothetical flood (peak discharge, volume and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of Probable Maximum Precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snow melt."[1/]

Probable Maximum Precipitation (PMP) - The PMP is defined as "the estimated depth for a given duration, drainage area, and time of year for which there is virtually no risk of exceedance. The Probable Maximum Precipitation for a given duration and drainage area approaches and approximates the maximum which is physically possible within the limits of contemporary hydrometeorological knowledge and techniques."[1/]

Discussion

The following are elements involved in determination of the PMF:

1. The primary factor contributing to a PMF is the PMP. Estimates of PMP are generally obtained from National Weather Service reports of generalized PMP estimates for different regions of the country. In some cases where generalized PMP is not available or the generalized values are not pertinent to a specific site, site specific studies can be undertaken to develop site

[1/] Definitions from "Standards for Determining Design Basis Flooding at Power Reactor Sites", ANSI N170-1976, ANS-2.8.

specific PMP values. Criteria for the derivation of PMP estimates has been developed by the World Meteorological Organization and the Office of Hydrology, National Weather Service.

The significant conservatisms in generalized PMP estimates are: (1) only the most severe storms of record are considered; (2) the moisture content of these storms are adjusted to obtain the maximum percipitable water and (3) the process of enveloping or smoothing introduces additional conservatisms.

2. It is assumed that the storm producing rainfall is critically centered over the basin to produce maximum runoff.

3. An antecedent storm is assumed to have occurred 3 to 5 days before the PMF. This assumption minimizes rainfall losses and maximizes runoff in that it would saturate the soil and fill depression storage. Where storage reservoirs are involved, this assumption will generally insure that reservoirs are full at the start of the PMF. This then reduces attenuation due to storage and maximizes peak discharge.

4. The unit hydrograph coefficients are derived from storms of record in the basin whenever possible. Where storm data are not available, then conservative synthetic coefficients are derived to produce a maximum peak discharge for the basin. This can be a significant conservatism for open river floods. Where streams are controlled by reservoir storage, hydrograph coefficients are usually not a significant factor since they do not effect runoff volume.

5. For open river conditions, backwater computations are used to predict water surface elevations from peak discharge. Computed water surfaces are sensitive to the roughness coefficient (manning "n" value). These can be derived from historic storm data, but since roughness coefficients decrease with increasing stage or discharge, this approach would be conservative when used with the much larger PMF discharges. When these coefficients can not be derived, conservatively high values are assumed.

6. Where reservoirs and dams are involved, unsteady flow and routing models may be used to conservatively estimate reservoir elevations and elevations of downstream flood waves when dams fail. An important feature that may allow for conservatism in these models is spillway capacity. There are two broad classifications of overflow spillways generally used for dams; (1) a wide rectangular spillway which usually incorporates an ogee type weir and may be gated or ungated and (2) a vertical circular riser connected by a 90° elbow to a horizontal outlet conduit through the dam or abutment, generally referred to as a "Morning Glory" type of spillway.

   The capacity of the ungated wide rectangular spillways can be determined accurately. The gated structures may require conservatism if gate operability cannot be assured or if debris or ice is a potential problem. Generally where gate operability cannot be assured, one or more gates are assumed to be failed in the closed position. Similarly, if debris or ice accumulation is a potential problem, the staff assumes partial blockage and the associated reduced capacity.

The morning-glory type spillways can also experience blockage due to ice or debris accumulations. The large diameter spillways on large dams normally can pass large logs and other debris. However, there is no experience on the type and size of debris that can be generated during a flood as large as the PMF and therefore partial blockage for these spillways are assumed. These spillways can also experience large fluctuations in discharge capacity and associated vibrations and stresses if they are subjected to water levels significantly in excess of the design values.

7. When dams are overtopped and assumed to fail, an important factor is the size of the breach and the time required to fully erode the breached section. Since there is very little methodology available for predicting these factors, they are generally conservatively modeled. These conservative values would trend toward worst case observed values. The resulting downstream flood stages could be significantly higher than what would be predicted using average observed values.

The above discussion only addresses some of the more significant factors or the ones that can result in the largest differences in estimated PMF values.