RECENT NRC EXPERIENCE IN THE EVALUATION OF LOCAL INTENSE PRECIPITATION AT NUCLEAR POWER PLANTS

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Nuclear Energy Agency/Ontario Power Generation
Joint Workshop on Local Intense Precipitation and its Impact on Nuclear Installations
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Outline for Today's Presentation

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- NRC regulations and guidance bearing on external flood-causing mechanisms including local intense precipitation (LIP)
- Current design basis flood vs. 2012 flood hazard reevaluation results
- Site-specific probable maximum precipitation estimates
- Perry NPP License Amendment Request
- Proposed new SRP section on LIP
- Regulatory Guide 1.59 update (including LIP)
- Advance Act

Energy Reorganization Act of 1974

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- Separated the regulatory functions of the Atomic Energy Commission from its responsibilities
- Established NRC to regulate the commercial uses of nuclear materials
- Established the Energy Research and Development Administration to assume all other Atomic Energy Commission responsibilities

Hierarchy of NRC Licensing Tools

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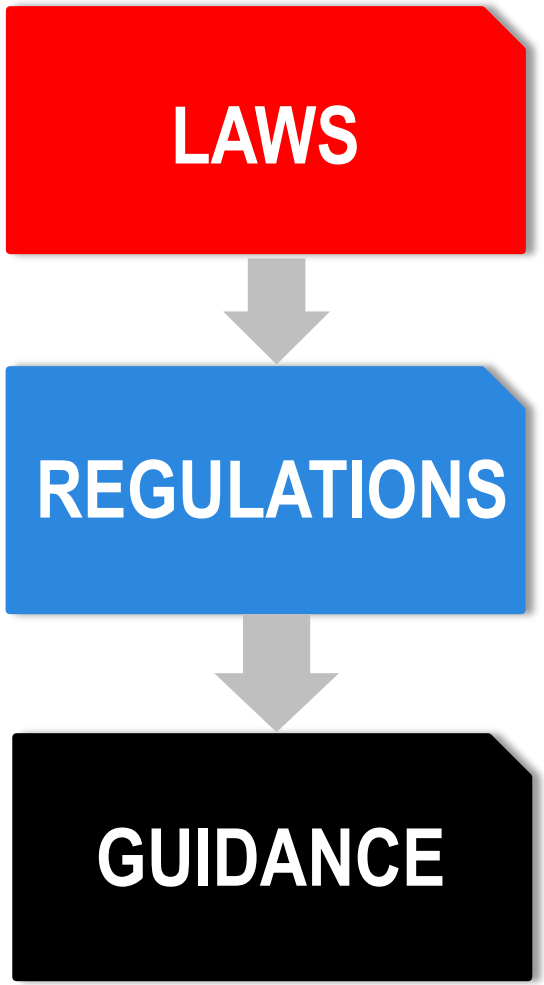

Atomic Energy Act of 1954
National Environmental Policy Act of 1969
Energy Reorganization Act of 1974

10 CFR Part 50
10 CFR Part 51
10 CFR Part 52
10 CFR Part 100

Policy Statements
Standard Review Plans
Regulatory Guides
Interim Staff Guidance

History of US NRC Regulatory Approach to Flooding

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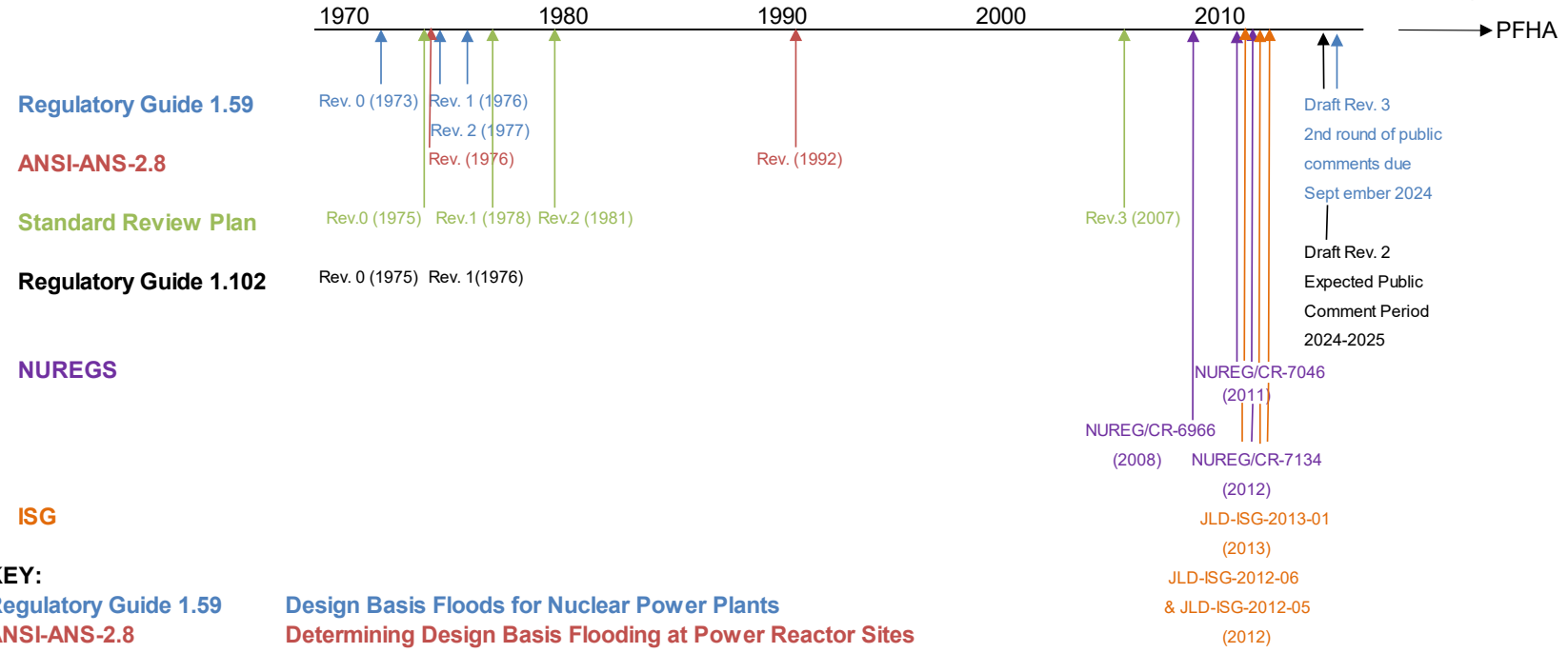

KEY:

Regulatory Guide 1.59	Design Basis Floods for Nuclear Power Plants
ANSI-ANS-2.8	Determining Design Basis Flooding at Power Reactor Sites
Standard Review Plan	Standard Review Plan
Regulatory Guide 1.102	Flood Protection for Nuclear Power Plants
NUREGS	
NUREG/CR-7046	Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America
NUREG/CR-6966	Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America
NUREG/CR-7134	the Estimation of Very-Low Probability Hurricane Storm surges for Design and Licensing of Nuclear Power Plants in Coastal Areas
Interim Staff Guidance (ISG)	
JLD-ISG-2013-01	Guidance for Assessment of Flooding Hazards Due to Dam Failure
JLD-ISG-2012-06	Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment
JLD-ISG-2012-05	Guidance for Performing the Integrated Assessment for External Flooding

Regulatory Approach … *continued*

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- General Design Criterion 2, Appendix A to 10 CFR Part 50

  "Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions "

- Local intense precipitation (LIP) not specifically addressed by GDC 2

- Consideration of LIP is addressed in SRP Chapter 2.4.2 ("Floods")

NRC Response to 2011 Fukushima Accident

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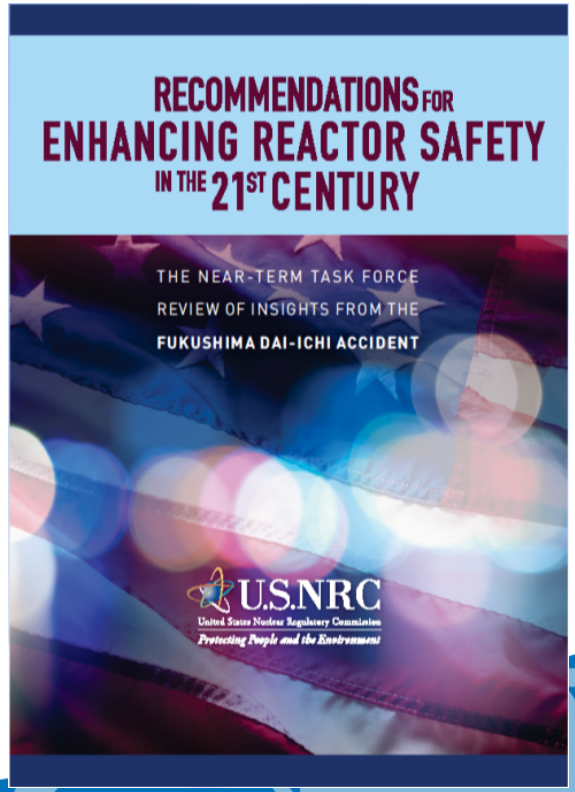
- Commission directed a methodical and systematic review of the safety of U.S. facilities in light of events in Japan
- Review includes:
  - Near-term review actions
  - Longer-term review actions
- Staff established a Near-Term Task Force (NTTF)
  - Issued report in July 2011



NRC Staff Response to 2011 NTTF Recommendations

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- NTTF recommended three actions
- NTTF Recommendation 2.1
  - "Order licensees to reevaluate the seismic and flooding hazards at their sites against current NRC requirements and guidance, and if necessary, update the design basis and SSCs important to safety to protect against the updated hazards."
- March 12, 2012, 10 CFR 50.54(f) information request letter
  - Reevaluate design bases for eight flood-causing mechanisms cited in NRC's standard review plan — the SRP (NUREG-0800)
  - Reevaluations were to rely on analytical approaches, methods, and data consistent with current engineering practice

NRC's Standard Review Plan (SRP)

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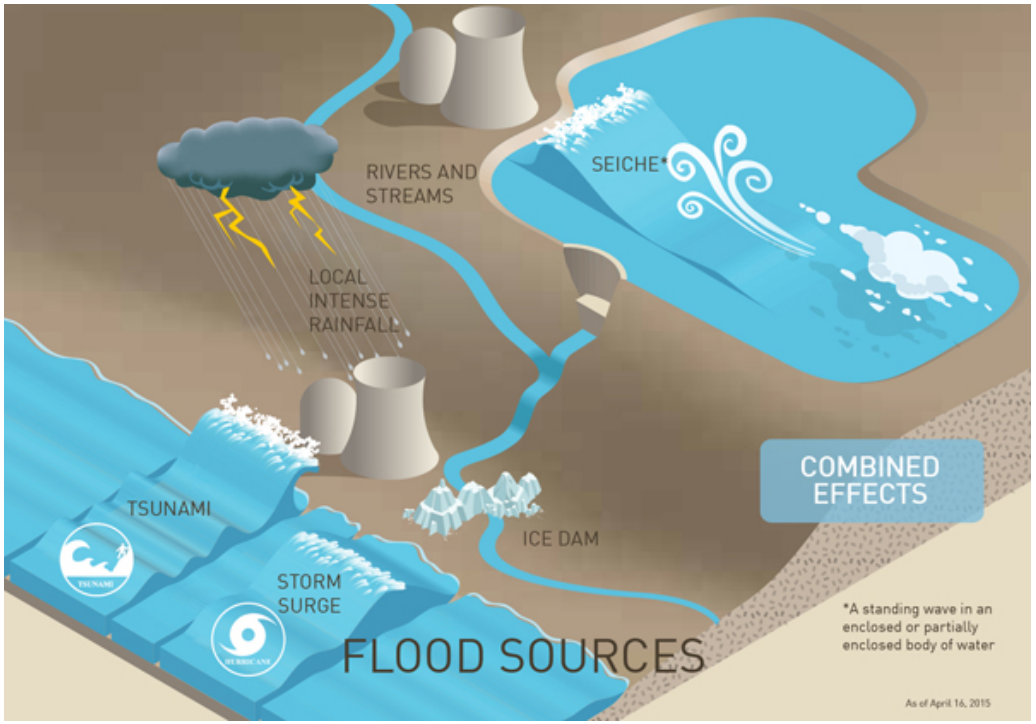

SRP Flood-Causing Mechanisms Evaluated in Connection with Staff's 2012 Information Request

- The SRP provides guidance to the NRC staff for reviewing applications to construct and operate power plants based on light-water reactor design
- LIP was one of eight SRP listed flood-causing mechanisms

2012 Flood Hazard Reevaluation Results: LIP

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- Pre-reevaluation status: 39 sites described a design basis elevation for LIP
  - LIP bounding at 16 (i.e., the CDB)
- 2012 flood hazard reevaluation results for LIP
  - Exceedances reported at 54 sites*
  - Consequential at 21 additional sites
  - Bounding flood-causing mechanism at 35 sites (i.e., the CDB)
  - No change in LIP design basis at 6 sites

** Exceedance totals includes both reevaluation results for those that did not have a previously-defined CDB as well as those sites for which a design basis flood elevation had been previously estimated*

FLOOD-CAUSING MECHANISM	PROJECT SITES WITH ESTIMATED EXCEEDANCES
Local Intense Precipitation	54
Streams/Rivers	25
Dam Failure	20
Storm Surge	19
Tsunami	3
Ice Jams	3
Seiche	1

Design Basis Flood Not a Static Concept

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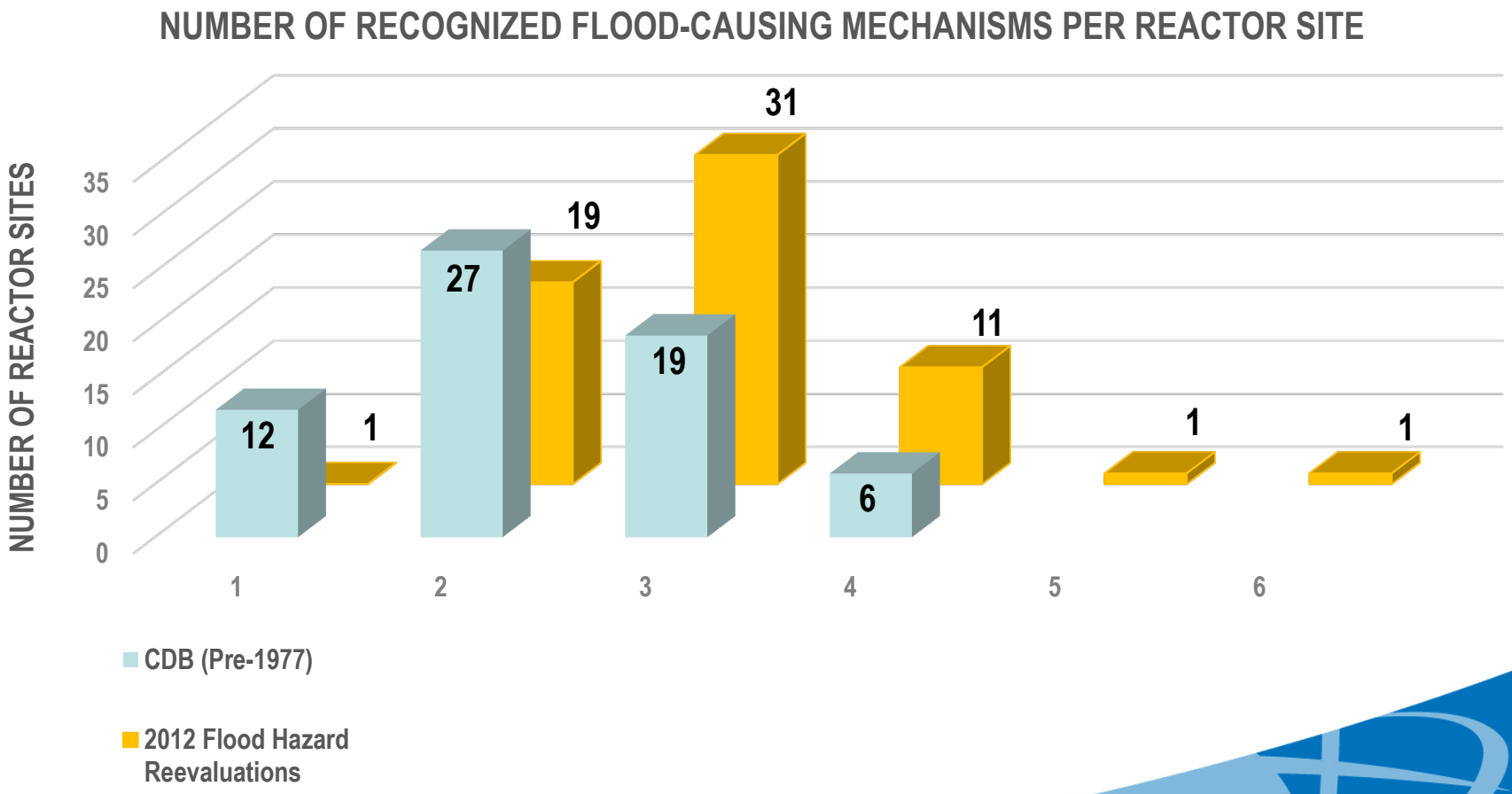

Design Basis Flood Not a Static Concept (cont.)

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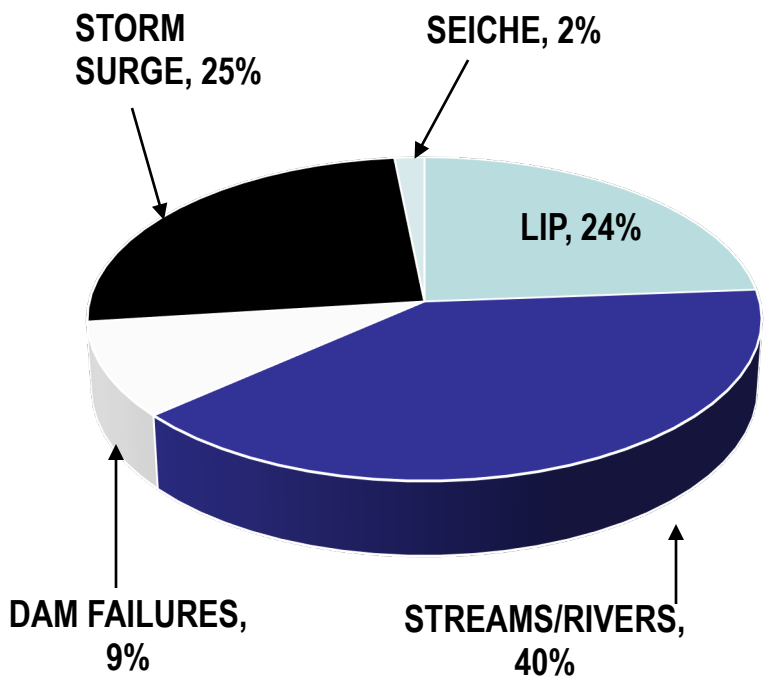
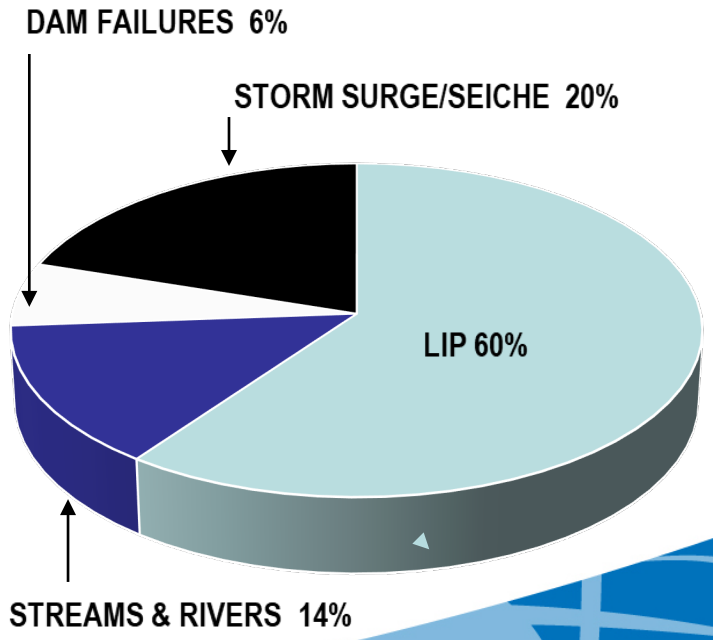
DESIGN BASES (PRE-FUKUSHIMA ASSESSMENT)



2012 FLOOD HAZARD REEVALUATION RESULTS



Distribution of flood-causing mechanisms defining licensing bases …

Specific history for domestic licensing of plants in the USA

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- Most power station were sited, designed, and constructed 1960s-1970s
- NRC's external flood guidance framework not implemented until post-licensing
  - Established mid-to-late 1970s
- Consensus practices adhered to in siting and design
  - *Handbook of Applied Hydrology* (Chow, 1964)
  - National Weather Service Hydrometeorological Reports

Likely Reasons for the Estimated LIP Exceedances

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- More comprehensive evaluation of LIP (at all 61 sites vs 39 initial licensing)
- Quantitative specification of a design basis event for LIP for the first time by staff (and adopted by licensees)
  - *Generally*, a LIP analysis has been identified as the Probable Maximum Precipitation (PMP) over a 1 square-mile area for a duration of 1-hour per applicable HMRs
  - Based on the recommendations found in NUREG/CR-7046*
- Introduction of high-speed digital computing capability in years following initial licensing complimented by ....
  - Digital topography
  - Computer software (e.g., FLO2d)

Likely Reasons for the Estimated LIP Exceedances

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- Conservative modeling decisions
  - Blocked roof scuppers
  - Clogged/unmaintained storm water management systems
  - Focused discharge points near door openings
- Unevaluated site-specific improvements to power station infrastructure
  - Local changes to site grades and ground covers
  - Introduction of vehicle barrier systems (bathtub effect)
- Reliance on a site-specific probable maximum precipitation estimate at only some project sites at initial licensing

Probable Maximum Precipitation (PMP) Definition

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- PMP definition... National Weather Service Hydrometeorological Report (HMR) 59 (1999)

  "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year."

- Definition makes PMP independent of the basin drainage properties
- Most HMRs date back to the 1960's
  - Most recent update was for California (*ca*. 1998)

National Weather Service Hydrometeorological Reports

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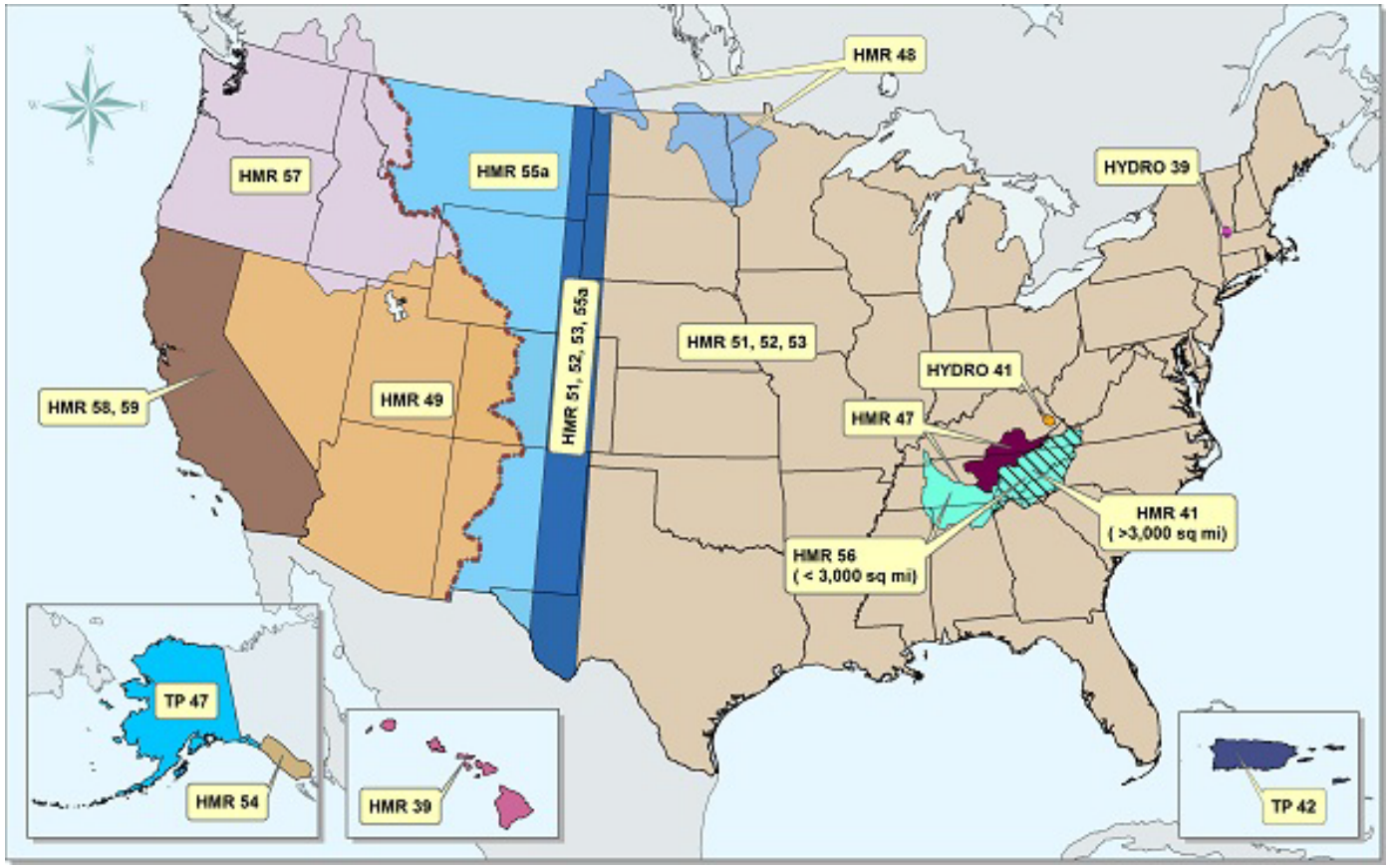

19 HMRS

1961-1999 vintage

https://www.weather.gov/owp/hdsc_pmp

Reliance on a Site-Specific (ssPMP) Estimate

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- About forty percent of the licensees relied on a ssPMP as an alternative to the HMRs
- Site-specific or watershed-specific PMP values were typically obtained from Applied Weather Associates (AWA)—a commercial entity
  - Staff conducted a technical audit of the AWA methodology to better understand the technical basis underlying the approach in 2015
  - Staff developed separate reports in 2021 summarizing lessons learned concerning the development and application of a ssPMP
    - NUREG/KM-0015, Considerations for Estimating Site-Specific Probable Maximum Precipitation at Nuclear Power Plants in the United States of America
    - NUREG/CR-7271, Application of Point Precipitation Frequency Estimates to Watersheds

NRC Audit* of AWA Methodology

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- Approach generally a logical extension of HMRs
- Further considerations ...
  - 1993 EPRI heuristic for storm representative dew point adjustment to harmonize historic storms with only 12-hour dew point data and more recent storms in a single database
  - Use of climatological averages for spatially interpolating 100-year dew point values rather than a more gauge-based approach

* NRC 2015, "Report for the Audit of Applied Weather Associates, LLC, Regarding Site Specific Probable Maximum Precipitation Development in Support of Near-Term Task Force Recommendation 2.1 Flood Hazard Reevaluations," May 19, 2015, ADAMS Accession No. ML15113A029

ssPMP Submissions and Results

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NRC Region 3 count = 13

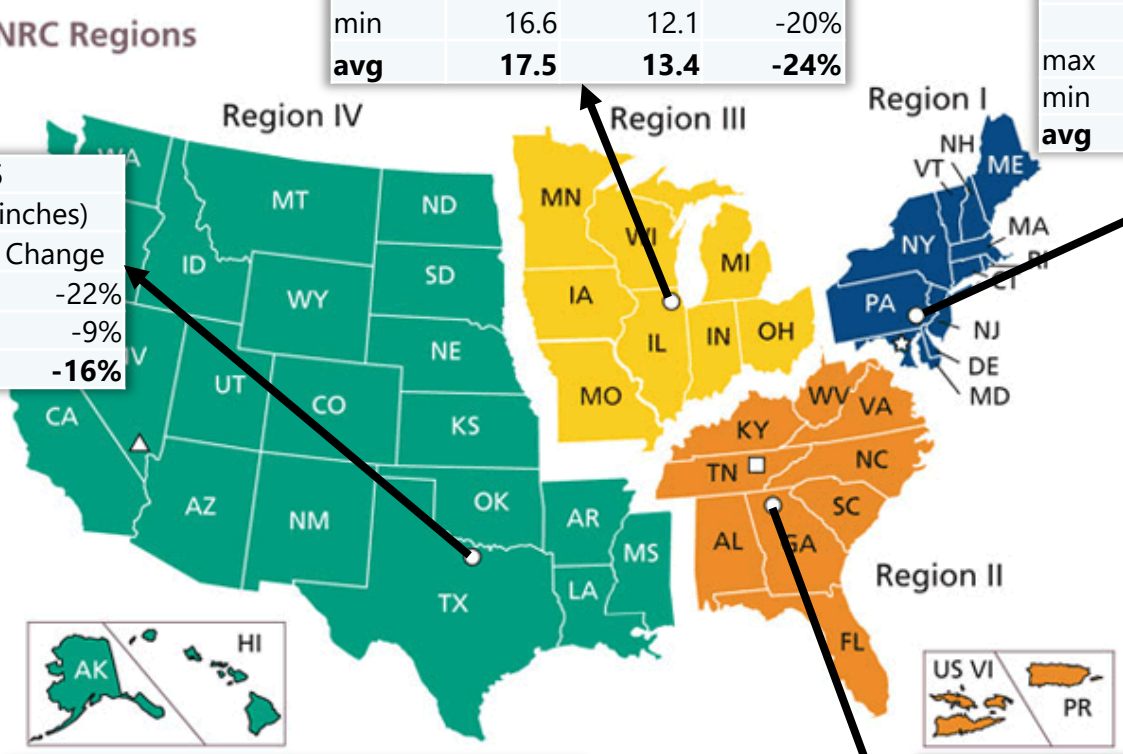
	1 hr- 1 sq. mi LIP (inches)		
	HMR	Site Spec	Change
max	18.2	14.1	-30%
min	16.6	12.1	-20%
avg	**17.5**	**13.4**	**-24%**

NRC Region 1 count = 5

	1 hr- 1 sq. mi LIP (inches)		
	HMR	Site Spec	Change
max	18.4	15.4	-46%
min	17.3	9.4	-13%
avg	**17.7**	**11.9**	**-33%**

NRC Region 4 count = 5

	1 hr- 1 sq. mi LIP (inches)		
	HMR	Site Spec	Change
max	19.4	16.3	-22%
min	5.5	4.5	-9%
avg	**12.7**	**10.7**	**-16%**



All Sites count = 26

	1 hr- 1 sq. mi LIP (inches)		
	HMR	Site Spec	Change
max	19.4	16.3	-46%
min	5.5	4.5	-9%
avg	**16.7**	**12.4**	**-25%**

NRC Region 2 count = 3

	1 hr- 1 sq. mi LIP (inches)		
	HMR	Site Spec	Change
max	19.1	12.4	-38%
min	18.4	11.8	-33%
avg	**18.7**	**12.0**	**-36%**

Perry Nuclear Power Station and LIP–Mini Case Study

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- Construction authorized 1974; Commissioned 1987
- Lake Erie waterfront
  - On a 50-ft bluff
  - Plant grade 620.5 ft
  - LIP managed by grading and a storm water management system (both surface and subsurface)
  - Stream-based floods managed by berm diversion feature constructed inland around powerblock footprint

Perry Nuclear Power Station and LIP *(continued)*

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- **LIP Evaluation Methodology (per Safety Analysis Report)**
  - Analysis methodology based on *Rational Method* (Q = CiA)
  - Powerplant footprint divided in subareas: ground surfaces, catchment basins, and roof structures
  - Runoff coefficients (C): 0.25 for the general site area; 0.90 for rooftops and pavement
  - Rainfall intensities (i): 4.1 to 9.1 in/hr based on surface type (HMR 33)
- **Licensing basis elevations (NGVD29) — *ca.* early 1970s**
  - LIP: 620.5 ft (1-hr/13.19" PMP event) ⟵
  - Streams and Rivers: 619.6—624.0 ft
  - Storm Surge/Seiche: 607.9 ft

Perry Nuclear Power Station and LIP *(continued)*

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- **2016: § 50.54(f) flood hazard reevaluation***
  - LIP analysis based on FLO2d® computer software
  - HMR 33/51-based: All-season PMP (1-hr/13.1" event)
  - Revised LIP estimate: 621.7 ft (**+1.2 ft**) at west side of powerblock
- **2017: Mitigating Strategies Assessment describing plans to manage exceedances***
- **2020: Focused Evaluation***
  - Alluded to development of an updated flood protection scheme
  - Reconstitute design basis for LIP- and stream-based flooding

**Performed by licensee*

Perry Nuclear Power Station and LIP *(continued)*

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- **2021: License Amendment Request (LAR) to address estimated exceedance***
  - Performed updated LIP analysis based on FLO-2d® computer code
    - 3-D flood routing model
    - Simulates street flow, flow obstruction, and storage loss in urban settings
  - LAR proposals
    - Introduce new permanent passive protection barriers
    - Incorporate temporary/removable barriers
- **2023: LAR approved**

**Performed by licensee*

Standard Review Plan Updates
Local Intense Precipitation

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- **Current edition of the SRP (NUREG-0800) does not include chapter dedicated exclusively to LIP**
  - Review provision generally addressed in context of SRP Section 2.4.2 ("Floods')
- **New separate section on LIP drafted and under internal review**
  - Reflect lessons-learned from 2012 § 50.54(f) reviews
- **Draft scope**
  - Focus on power station footprint and adjacent areas
  - Reflects computer-based analysis methods
  - Site-specific vs. HMRs-based PMP options

Regulatory Guide 1.59 *Design Basis Floods for Nuclear Power Plants*

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- **First issued in 1977**
  - Introduced new Appendix A on estimating seismically-induced (terrestrial) floods in streams
- **1976 Revision (R1)**
  - New Appendix B bearing on estimating a probable maximum flood in streams and rivers
  - New Appendix C containing simplified method for estimated solutions for storm surge along Atlantic and Gulf of Mexico coastlines
- **1977 Revision (R2)**
  - Revisions to Appendix A

Regulatory Guide 1.59 *(continued)*

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- **February 2022 revision (R3) issued as draft for public comment**
  - Improved correspondence with SRP Section 2.4 (“Hydrology’)
  - Updated guidance based on staff 2012 § 50.54(f) review experience
  - Acknowledges computer-based modeling methods
  - References NUREG/CR-7046*
  - New appendices dedicated to LIP, riverine floods, storm surge, seiche, tsunamis, and ice jams
  - Treatment of combined and associated effects discussed in separate appendices
  - Discussion of application of RG 1.59 to advanced and modular reactors (Appendix K)
- **Treatment of LIP in R3**
  - Focus on surface runoff
  - HMR-based: 1 hr/1 mi^2 PMP event

** Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America (February 2010)*

Regulatory Guide 1.59 *(continued)*

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- **Initial Public Comments on R3 received from ...**
  - ASME/ANS Joint Committee on Nuclear Risk Management
  - Kairos Power, LLC
  - DOE
  - NEI
- **Revised draft R3 and related dam failure guidance issued for public comment July 15, 2024**
  - Draft RG 1.59 R3 revised to reflect public comments from 2022
  - DG-1417, "Guidance for Assessment of Flooding Hazards due to Water Control Structure Failures and Incidents" is referenced in R3
- **Public meeting held on September 9, 2024, to discuss R3 and DG-1417**
- ***Regulatory Guide 1.102 ("Flood Protection at Nuclear Power Plants")*** *Update underway*

ADVANCE Act of 2024

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- **Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2024**
- **Key provisions ...**
  - Licensing nuclear facilities at brownfield sites
  - Strategies and guidance related to micro-reactors
  - Establish an expedited procedure for the review of qualifying combined license (COL) applications
- **Staff looking to expand use of risk insights in hydrology reviews to support future ADVANCE Act licensing actions**

Closing Thoughts

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- **Following additional reviews, staff concluded that each licensee demonstrated that effective flood protection exists for flood-causing mechanisms that were now estimated to exceed the licensing basis**
  - Includes the LIP flood-causing mechanism
- **Ongoing actions addressing Fukushima lessons-learned (near term)**
  - Draft revision of Regulatory Guide 1.59 (flood design bases) to include expanded discussion of LIP
  - Standard Review Plan maintenance and update to better reflect detailed safety reviews of LIP
- **Consider recommendations of National Academy of Sciences 2024 study on modernizing PMP estimates (long-term)**