Current Status on Information Notice regarding Dam Failure Rates used in NPP External Flooding Analysis

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Purpose of Information Notice (IN)

- Information Notice (IN) was intended to inform industry of a potentially non-conservative dam failure frequency used in external flooding analysis
- Non-conservative dam failure frequency estimate may result in underestimation of external flooding hazard risks
- Dam failure frequency values used in referenced documents, e.g., NSAC/60 are an order of magnitude lower than those found in literature and in APOB's internal analysis (ML100760108)

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Background

- Earlier version of IN was drafted through the NRR Generic Communications Branch but process was not completed during discussions with NRR/DPR/PGCB
- APOB staff discussed the past efforts and best path forward with PGCB PM, who provided these suggestions:
  - Re-write IN
  - Evaluate RES views for concurrence
  - Use less prescriptive language regarding failure rate

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Current Status

- Intended purpose of IN is still valid based on reevaluation of original analysis
- Issuance of IN will improve technical consistency on external events hazard analyses across other NRC Offices, e.g., NRO & RES
- Effort on IN draft supports parallel efforts: (i) Generic Issue submittal from NRR/DE and NRR/DRA to RES/DRA, (ii) RTE tasks on external event initiators

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Current Status (continued)

- Based on feedback from PGCB and RES, APOB staff initiated these actions:
  - Developed new draft of IN
  - Provided the new draft of IN to APOB subject matter experts for review and comment
  - Obtained verbal concurrence on new IN draft from RES/DRA subject matter expert on dams

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Main Message of Current Draft

- Alert addressees of potentially non-conservative dam failure frequency estimate due to:
  - Approach used in NSAC/60
  - Site-specific characteristics
  - Data issues (i.e., sparseness and quality)
- Draft only indicates that dam failure frequency values significantly lower than 1E-4/year are not supported by literature or NRC's internal assessments when based on historical data

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Path Forward

- Work with PGCB for concurrence and issuance
- Follow up with Generic Flood Risk Analysis efforts

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BACKUP SLIDES

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High Level Issues

Screening Criteria

↓

Flood Routing/Impact to the Site

↓

Mitigation Strategy

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Issues to Address (1)

- Parsing of failures in PMP/Seismic/Other
- Screening PMP as in NSAC/60
- Parsing of "Other" failure via engineering assumptions
- Widening of dam population when no failures are listed for a specific category (embankment vs. rockfill only)
- Defining a period range of 1940 – Present for a dam built in 1972

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Issues to Address (2)

- Assumption of the functional form in NSAC/60 for dam failure rates (no aging)?
- Screening of aging failures AND assumption of the functional form in NSAC/60
- Assumption of failure rate in a particular year for a certain dam (regardless of its age) = failure rate of new dam built in that same year.
- Use of NSAC/60 values for dam failures at other sites

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Path Forward

- Indicate non-conservatism in NSAC/60
  - Incorrect reference in NUREG/CR-5042
- No NRC position on actual value
  - Refer to expert literature
- Indicate alternatives (?)
- Indicate implications/need for awareness
- Additional analysis to be performed (?)

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Path Forward on Information Notice

- Applicability to 10 CFR Part 52, 72
- Official Use Only designation
- Concurrence with other offices
- Follow up with Generic Flooding Effort

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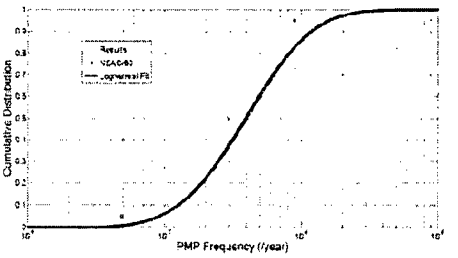
Comparison of Results (PMP)



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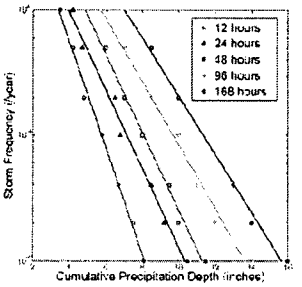
PMP Data in NSAC60

$c_f = a \exp(b\, h/\tau^n)$

i.e., f(*a*,*b*,*n*)

where, h = depth
c_f = frequency



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Dam Frequency Analysis in NSAC60

- Assumed Functional Form

  $L(t) = a\, t^{-b}$ i.e., f(*a*,*b*)
  where t = dam-years

- Large Earth, Earth-Rockfill, Rockfill (> 45 ft)
- Failure Modes (1) Piping (except conduit and spillway)
  (2) Seepage
  (3) Embankment slides
  (4) Structural failure foundation/abutment
- US catastrophic failures only (age > 5 years)
- (1900 – 1981), (1940 – 1981), (1960 – 1981)
  – set by construction year (dam-years)

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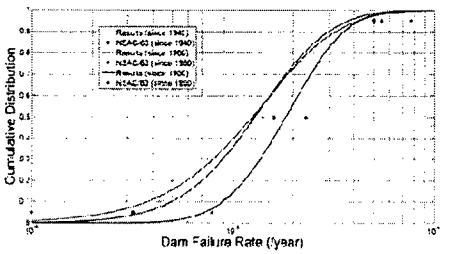
Comparison of Results (Dams)



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Specific Issues (1)

- Methodology
  – Bayesian updating
  – Functional form of Dam Failure Rate
- Assumptions
  – Parsing Failure Rates (PMP(I), Seismic, Others)
  – Parsing of Other Failures (Piping, Seepage, ...)
  – Screening by Construction Period
  – Early Failures Cut-off
- Accuracy of the Analysis
  – in 1981
  – as of today

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Specific Issues (2)

- Applicability to Other Sites
- NUREG/CR-5042

"Realistic calculations of the dam failure probability of a specific dam as a function of extreme conditions are difficult to find in the literature; bounding calculations are more common, and would be fully acceptable if based on defensibly conservative models and data. Some bounding calculations provide values of F_F that are quoted as being in the range of 10^{-6}/year or even smaller, especially for modern well-engineered dams [Ref. 5.7 Oconee PRA, 1984]. On the other hand, some dam failures could easily be in the range of about $F_F = 10^{-3}$/year, since the mean value of the data base for F_F for all dams is in the range between 10^{-4}/year and 10^{-5}/year (according to a survey published in the Oconee PRA [Ref. 5.7, Oconee PRA,1984])."

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NSAC/60 Input Data (1900 – 1981)

Failures = 5 (4 Earthfill, 1 Mixed)

$$\frac{\text{ROCKFILL + EARTHFILL + MIXED}}{\text{ROCKFILL + EARTHFILL + MIXED}}$$

Dam-Years ≈ 100,000 (1981)

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NSAC/60 Input Data (1940 – 1981)

Failures = 2 (1 Earthfill, 1 Mixed)

$$\frac{\text{ROCKFILL + EARTHFILL + MIXED}}{\text{ROCKFILL + EARTHFILL + MIXED}}$$

Dam-Years ≈ 70,000 (1981)

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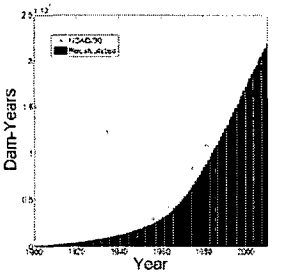
Dam-Years (1900 – 2010)



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Comparison using NSAC/60 Screening

- Screened out per NSAC/60
  - Failure Modes (no PMP, Seismic, Piping via conduit)
  - Dam Height and Type
  - Construction Year
  - Age (> 5 years)
  - End year (1981 & 2010)
- Sources
  - NRR/DRA Generic Rockfill Dam Failure Rate
    - National Performance of Dams Program (NPDP)
    - Other Sources
  - NSAC/60
  - Journal Paper "Critical appraisal of piping phenomena in earth dams" (2007)

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Failures (1900 – 1981)

	Dam Name	Built	Failed	Height	Type	Failure Description
	Pinkston, MO	?	1978	70	Earth (assumed)	Piping static liquefaction
4	Lambert, TN	?	1963	54	Earth	Piping-small leak increased leading to breach
	Pleasant Valley, UT	?	1928	63	Mixed	Piping through foundation and up an observation pipe, failure occurred within 24 h of first notice
	Scofield, UT	?	1928	78, 99	Earth	Piping through settlement cracks near abutment
	Dresser No. 4 Dam, MO	?	1975	105	Mixed (REEROT)	Piping
2	Kem Brothers Reservoir	?	1949	54	Mixed (REER)	Failure due to excessive settlement of fill
	Baldwin Hills, CA	1951	1963	180	Earth	Piping into foundation from fault movement
	Lake Toxaway, NC	1902	1916	62	Earth	Piping into rock fissures
5	Goodrich	1900	1956	56	Earth	Limited piping due to seepage caused a void and abnormal weight of ice or ice pressure over void caused failure
	Sinker Creek	1910	1943	92	Earth	Failed completely after many years of saturation of downstream slope + leakage through upper portion of dam
	Walter Bouldin	1967	1975	170	Mixed (ERPG)	The dam may have failed due to piping in the downstream shell

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Failures (1940 – 1981)

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2	Kern Brothers Reservoir	?	1949	54	Mixed (REER)	Failure due to excessive settlement of fill
	Baldwin Hills, CA	1951	1963	160	Earth	Piping into foundation from fault movement
2	Walter Bouldin	1967	1975	170	Mixed (ERPG)	The dam may have failed due to piping in the downstream shell

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Failures (1900 – 2010)

	Dam Name	Built	Failed	Height	Type	Failure Description
	Big Bay Lake, MS	?	2004	57	Earth	Piping through French drains (failed within 24 h of observed seepage)
	Quail Creek, UT	?	1988	209	Earth	Piping through settlement cracks
	Cedar Lake, OK	?	1986	45	Earth	Piping in abutment, fissures in foundation
7	Pinkston, MO	?	1978	70	Earth (assumed)	Piping static liquefaction
	Lambert, TN	?	1963	54	Earth	Piping-small leak increased leading to breach
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	Taum Sauk, MO	1963	2005	184	Rock	Overpumping
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