

**Mitman, Jeffrey**

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**From:** Philip, Jacob *1 RES*  
**Sent:** Tuesday, November 16, 2010 3:38 PM  
**To:** Ferrante, Fernando  
**Subject:** RE: Draft IN on Dam Failure Rates  
**Attachments:** image001.jpg

Hi Fernando,

The draft looks good...I was away from the office Nov 6 thru 15 and hence the tardy response!

Regards....Jake

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**From:** Ferrante, Fernando *NRK*  
**Sent:** Tuesday, November 09, 2010 3:25 PM  
**To:** Philip, Jacob  
**Cc:** Wong, See-Meng  
**Subject:** RE: Draft IN on Dam Failure Rates

Jake,

As we discussed back in September, the draft Information Notice on dam failure rates that you had looked at will finally be part of a discussion with the Front Office here in NRR/DRA next week, and it will most likely follow the internal NRR process for issuance.

I altered a few words based on our phone conversation where you indicated there were no other comments and that the content appeared acceptable based on your review. For your convenience, the paragraph altered is shown below, where the modifications were to address (i) what type of dam failure historically represents the majority of events observed and (ii) what type of piping failure mechanisms were excluded in the NSAC/60 analysis. Attached is the final draft IN (no other changes aside from the ones highlighted below).

If you could be so kind to re-confirm via e-mail the acceptability of this draft, I would greatly appreciate it.

Thank you very much,  
Fernando Ferrante, Ph.D.  
Office of Nuclear Reactor Regulation (NRR)  
Division of Risk Assessment (DRA)  
PRA Operational Support Branch (APOB)  
Mail Stop: 0-10C15  
Phone: 301-415-8385  
Fax: 301-415-3577

## DISCUSSION

While revisiting this estimate, the NRC staff recently noted that many assumptions in the dam failure rate estimation approach used in NSAC/60 are strongly dependent upon the completeness and accuracy of the dam data used and the criteria for including or excluding certain failure events and operational years deemed to be applicable to characteristics specific to the dam considered in NSAC/60 (i.e., type, height, construction year, and years of operation). In particular, the failure frequency derived in NSAC/60 was considered to be representative of failure modes resulting from causes other than hydrologic (e.g., severe precipitation), and seismic events. In effect, this choice of exclusions eliminates the majority of failure modes that has been historically observed for dams (e.g., overtopping). Additionally, the phenomena associated with non-hydrologic, non-seismic (e.g., internal erosion/degradation) events was further screened for other failure modes not deemed applicable based on design considerations also specific to the Jocassee dam (i.e., piping through a conduit passing through the dam, and structural failures of the spillway during flood discharge).

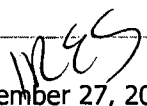
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**From:** Ferrante, Fernando  
**Sent:** Monday, September 27, 2010 2:44 PM  
**To:** Philip, Jacob  
**Subject:** RE: Draft IN on Dam Failure Rates

No problem, Jake. I appreciate your help with this.

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**From:** Philip, Jacob   
**Sent:** Monday, September 27, 2010 2:40 PM  
**To:** Ferrante, Fernando  
**Subject:** RE: Draft IN on Dam Failure Rates

Fernando,

Thanks for your note... I will get back to you on this in a day or two... sorry for not replying earlier, but I was tied up as an acting Branch chief for a week or so in addition to my normal work load.... Jake

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**From:** Ferrante, Fernando  
**Sent:** Monday, September 27, 2010 1:55 PM  
**To:** Philip, Jacob  
**Subject:** RE: Draft IN on Dam Failure Rates

Jake,

I'm about to brief my Division's Front Office in the next week or so. I was wondering if you had a chance to look at the IN and the supporting material, and if there are any comments. Specifically, your overall assessment on any potential concurrence issues with RES. If you could let me know, I would greatly appreciate it.

Thanks,  
Fernando

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**From:** Ferrante, Fernando  
**Sent:** Friday, September 10, 2010 4:20 PM  
**To:** Philip, Jacob  
**Subject:** Draft IN on Dam Failure Rates

Jake,

As we discussed, I am progressing on the IN write-up and have a draft that will be shown to our front office within the next few weeks.

I am sharing it with you as a heads-up (FYI only at this stage). When the internal NRR/DRA discussions are completed, there will be a final draft and probably a more formal submittal for review to RES and NRO. If there are any questions or comments at this stage, please let me know.

Thank you,

Fernando Ferrante, Ph.D.  
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Division of Risk Assessment (DRA)  
Operational Support and Maintenance Branch (APOB)  
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UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
OFFICE OF NUCLEAR REACTOR REGULATION  
WASHINGTON, DC 20555-0001

NRC INFORMATION NOTICE 2010-xx:     APPLICABILITY OF HISTORICAL DAM FAILURE  
FREQUENCY ESTIMATES IN PROBABILISTIC  
RISK ASSESSMENTS

**ADDRESSEES**

All holders of an operating license or construction permit for a nuclear power reactor issued under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of or applicants for an early site permit, standard design certification, standard design approval, manufacturing license, or combined license issued under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

**PURPOSE**

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees of a potentially non-conservative dam failure frequency estimate used in external flooding analysis that originated in reference documents published in the 1980s and was adopted by some licensees in their probabilistic risk assessment (PRA).

Using a non-conservative dam failure frequency may result in underestimating the risks to the plant associated with external flooding or loss of heat sink from the failure of upstream and/or downstream dams or levees. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to correct any error resulting from the use of these reference documents. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

**DESCRIPTION OF CIRCUMSTANCES**

The NRC staff recently reviewed the use of dam failure frequency estimates previously published in documents related to PRA for US nuclear power plants. Analysis performed in a PRA study (NSAC, 1984) by the Nuclear Safety Analysis Center (NSAC) of the Electric Power Institute (EPRI) and participating utilities has been used by licensees performing external flooding analyses to evaluate vulnerabilities due to potential dam failure events. A subsequent report published by the US NRC on external event contributors to overall risk for the U.S. nuclear power plants, titled "NUREG/CR-5042, Evaluation of External Hazards to Nuclear Power Plants in the United States" also refers to the NSAC/60 study on the subject of dam failure frequency estimates (USNRC, 1987).

Published in 1984, NSAC/60 provided an estimate for a dam failure frequency as part of the external flooding screening analysis. The framework used in NSAC/60 to develop this estimate was the compilation of historical dam failure events and operational years deemed applicable to specific dam characteristics considered in the study (a large, modern embankment dam).

Assumptions were made to screen out the applicable failure events which parsed the information available when the study was published by (i) dam composition, (ii) construction completion date, and (iii) failure modes. A mathematical equation modeling a decrease in generic dam failure rates with an increase in operational dam-years was assumed to reflect improvements to methods of design and construction. A Bayesian analysis using historical dam failures was then performed to estimate the annual failure frequency at the time the analysis was performed (1981) and associated uncertainty range for dams built within different time periods: 1900 – 1981, 1940 – 1981, and 1960 – 1981. The median annual failure frequencies in NSAC/60 are in the range between  $1.0 \times 10^{-5}$ /year and  $2.5 \times 10^{-5}$ /year.

This study recognized the challenge in collecting sufficient historical information based on the scarcity of the data applicable to the specific dam characteristics considered, as well as the complexity of the actual phenomena controlling dam failures and its potential impacts to a nuclear power plant site. Subsequently, NUREG/CR-5042 reported bounding calculations with results of " $10^{-6}$ /year or even smaller" for modern well-engineered dams and a range of values between " $10^{-4}$ /year and  $10^{-5}$ /year," referring to NSAC/60 in both cases (USNRC, 1987).

## **BACKGROUND**

### Related NRC Communications

- U.S. Nuclear Regulatory Commission, "Evaluation of External Hazards to Nuclear Power Plants in the United States," NUREG/CR-5042, Lawrence Livermore National Laboratory, December 1987, ADAMS Accession No. ML062260222.

### Related External Databases

- Stanford University, Department of Civil and Environmental Engineering, National Performance of Dams Program (<http://npdp.stanford.edu/index.html>).
- US Army Corps of Engineers, National Inventory of Dams (<http://nid.usace.army.mil>)

### Related non-NRC Communications

- Nuclear Safety Analysis Center/Electric Power Research Institute, "NSAC-60 Oconee PRA: A Probabilistic Risk Assessment of Oconee Unit 3," Palo Alto, CA, 1984.
- Baecher, G. B., M. E. Paté, and R. De Neufville (1980), "Risk of Dam Failure in Benefit-Cost Analysis," *Water Resource Research*, 16(3), 449–456.

- Martz, H.F., and M.C. Bryson (1982), "Predicting Low-Probability/High-Consequence Events," Proceedings of the Workshop on Low-Probability/High-Consequence Risk Analysis, June 15-17, 1982, Arlington, Virginia.
- ICOLD (1995), "Dam Failures Statistical Analysis," Bulletin 99, International Commission on Large Dams.
- Foster M, Fell R, Spannagle M (2000a), "The statistics of embankment dam failures and accidents," *Canadian Geotechnical Journal*, 37, 1000-1024.
- Foster M, Fell R, Spannagle M (2000b) "A method for assessing the relative likelihood of failure of embankment dams by piping," *Canadian Geotechnical Journal*, 37, 1025-1061.
- Donnelly, R. (2004), "Issues in Dam Safety," ACRES International Innovations Autumn Edition
- U.S. Bureau of Reclamation, "A Framework for Characterizing Extreme Floods for Dam Safety Risk Assessment," U.S. Department of the Interior, Technical Service Center, Denver, CO, 1999.
- U.S. Bureau of Reclamation, "Dam Safety Risk Analysis Methodology," Version 3.3.1, U.S. Department of the Interior, Technical Service Center, Denver, CO, 2003.
- U.S. Bureau of Reclamation, "Dam Safety Risk Analysis Best Practices Training Manual," Version 2.0, U.S. Department of the Interior, Technical Service Center, Denver, CO, 2010.

## DISCUSSION

While revisiting this estimate, the NRC staff recently noted that many assumptions in the dam failure rate estimation approach used in NSAC/60 are strongly dependent upon the completeness and accuracy of the dam data used and the criteria for including or excluding certain failure events and operational years deemed to be applicable to characteristics specific to the dam considered in NSAC/60 (i.e., type, height, construction year, and years of operation). In particular, the failure frequency derived in NSAC/60 was considered to be representative of failure modes resulting from causes other than hydrologic (e.g., severe precipitation), and seismic events. In effect, this choice of exclusions eliminates the majority of failure modes that has been historically observed for dams (e.g., overtopping). Additionally, the phenomena associated with non-hydrologic, non-seismic (e.g., internal erosion/degradation) events was further screened for other failures modes not deemed applicable based on design considerations also specific to the dam considered in the study (i.e., piping through a conduit passing through the dam, and structural failures of the spillway during flood discharge).

To assess the impact of these screening assumptions, the NRC staff reviewed currently available US databases for both historical dam failure events (primarily, the National Performance of Dams Program by Stanford University) and the existing population of US dams

(the National Inventory of Dams maintained by the US Army Corps of Engineers) that provide more complete and accurate information than available when NSAC/60 was prepared. While valuable historical information is contained in both databases, the NRC staff also observed an inherent challenge regarding the incompleteness of failure event accounts (e.g., construction year of failed dam, and failure mode), sparse data and inconsistencies on definitions used on both failed and operating dams (e.g., dam types).

In addition, the NRC staff also performed analyses of the ranges of generic failure frequency estimates that can be derived from these databases, as well as a literature review on previously published dam failure rates. The literature review included published analyses mostly based on historical evidence for the US and the international population of dams: Baecher *et al* (1980); Martz and Bryson (1982); ICOLD (1995); Foster *et al* (2000a); Foster *et al* (2000b); Donnelly (2004); and USBR (2010). From both efforts, the information gathered provides significant evidence that generic dam failure frequencies considerably lower than  $10^{-4}$ /year may not be justifiable based on historical dam performance information. Additionally, as stated in NUREG/CR-5042, dam failure rates above this value are also possible and, therefore, a technical justification would have to be provided in support of any specific estimate used. This is due to the variability on site-specific characteristics (i.e., hydrologic, geologic, and operational) and the potential contributions of site-specific failure modes not covered by databases, such as the potential activation of failure modes in dams which have never been filled beyond a certain operational reservoir level (e.g., first-fill scenarios). This is compounded by the data analysis challenges discussed above. In reaching this conclusion, the NRC staff also considered available information on current state-of-art methodologies in risk assessment of dams published by multiple sources, including federal agencies such as the US Department of Interior's Bureau of Reclamation (e.g., USBR, 1999; USBR, 2003).

In conclusion, the generic failure frequency estimate used in NSAC/60 combined generic information with site-specific screening criteria that produced median values an order of magnitude lower than published literature and NRC staff's assessments support. Consideration of data sources currently available also indicates that (i) such significantly lower values may not be justified by historical data alone, and (ii) applicability of the NSAC/60 estimate to other dams with different characteristics may be inappropriate. Reasons for these conclusions include the fact that generic failure frequency values may not account for site-specific features and can be highly dependent on completeness and applicability of available information to site-specific dams; which may counteract conservative assumptions in the use of data.

These considerations recognize that data available in these databases is useful in deriving bounding values and approximate generic dam failure rate estimates, but that the justification for its use in obtaining significantly lower values than the established averages may not be conservative and therefore inappropriate for screening purposes.

## CONTACT

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below.

XXXXXXXXXXXX, Director  
Division of Policy and Rulemaking  
Office of Nuclear Reactor Regulation

Technical Contacts: Fernando Ferrante, NRR/DRA  
301-415-8385  
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Jeffrey Mitman, NRR/DRA  
301-415-2843  
E-mail: [jtm1@nrc.gov](mailto:jtm1@nrc.gov)

Note: NRC generic communications may be found on the NRC public Web site, <http://www.nrc.gov>, under Electronic Reading Room/Document Collections.



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This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below.

XXXXXXXXXXXX, Director  
Division of Policy and Rulemaking  
Office of Nuclear Reactor Regulation

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Note: NRC generic communications may be found on the NRC public Web site, <http://www.nrc.gov>, under Electronic Reading Room/Document Collections.

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