

Hydrologic Hazard Analysis

Best Practices in Dam and Levee Safety Risk Analysis Part B - 1

Hazards and Loading

DLS-104, Module B-1



U.S. ARMY



**US Army Corps
of Engineers®**

Dam and Levee Safety Program

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LAKE ZUMBRO DAM, MN (SOURCE: USACE)

Why Flood Hazards are Important

Annualized Failure Probability

$$f = P_l * P_{r|l}$$

Risk: Annualized Life Loss

$$Risk = P_l * P_{r|l} * C$$

P_l = Probability of Load – ***Hydrologic Hazard Curve***

$P_{r|l}$ = Probability of Adverse Response Given Load

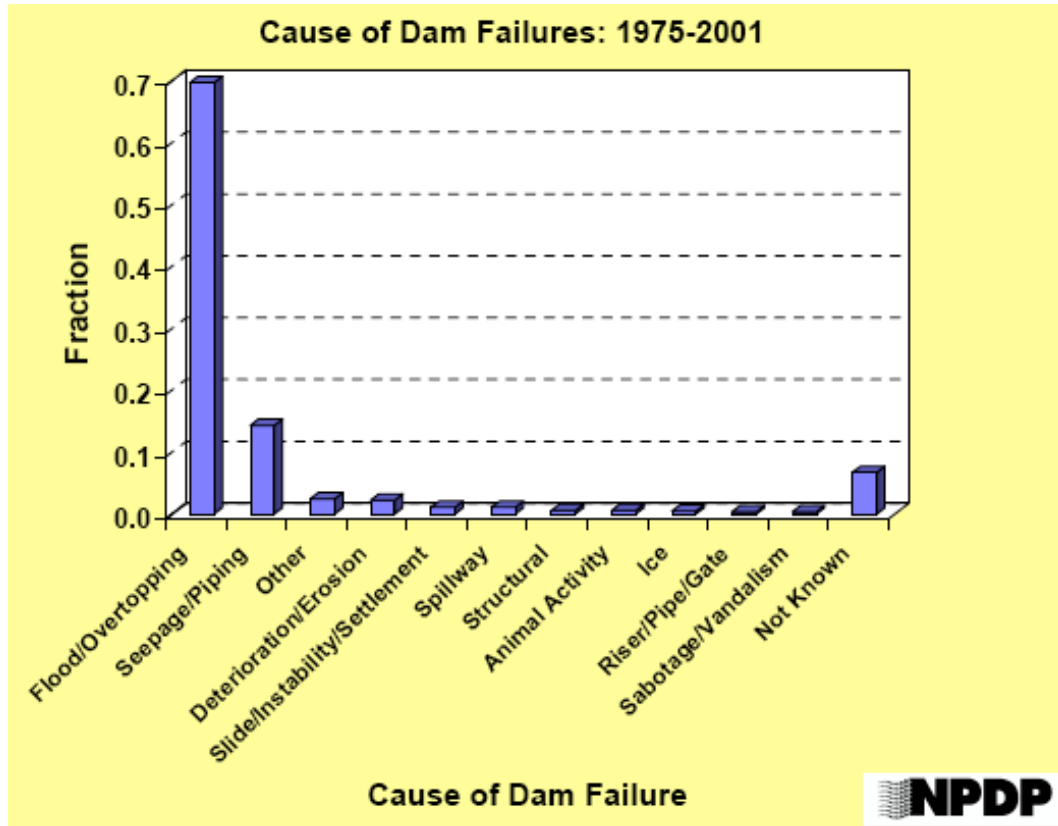
C = Consequences (or Loss of Life, N)

Why Flood Hazards are Important

Potential Failure Modes impacted by Flood Loading

- **Almost all of them**
 - No water = No failure mode
- **Overtopping of dams and levees**
 - Erosion of downstream toe, foundation, or dam crest
- **High reservoir levels or river stages**
 - Internal erosion, instability, and many others
- **Spillway and stilling basin**
 - Erosion, cavitation, wall overtopping
- **Misoperation or malfunction**
 - Gate electrical/mechanical, pump stations, closures

Why Flood Hazards are Important



Overtopping Dam Failure

| | Year | Fatalities |
|-------------------|------|------------|
| South Fork, PA | 1889 | 2,209 |
| Walnut Grove, AZ | 1890 | 100 |
| Buffalo Creek, WV | 1905 | 125 |
| Swift Dam, MT | 1964 | 19 |
| Canyon Lake, SD | 1972 | 237 |
| Laurel Run, PA | 1977 | 40 |
| Kelly Barnes, GA | 1977 | 39 |
| Rainbow Lake, MI | 1986 | 3 |
| Callaway, TX | 2002 | 2 |
| Ka Loko, HI | 2006 | 7 |
| Delhi Dam, IA | 2010 | 0 |

Why Flood Hazards are Important

Refer to case histories for more details and more examples.



Oroville Dam Spillway Flows,
Oroville, CA Feb 2017



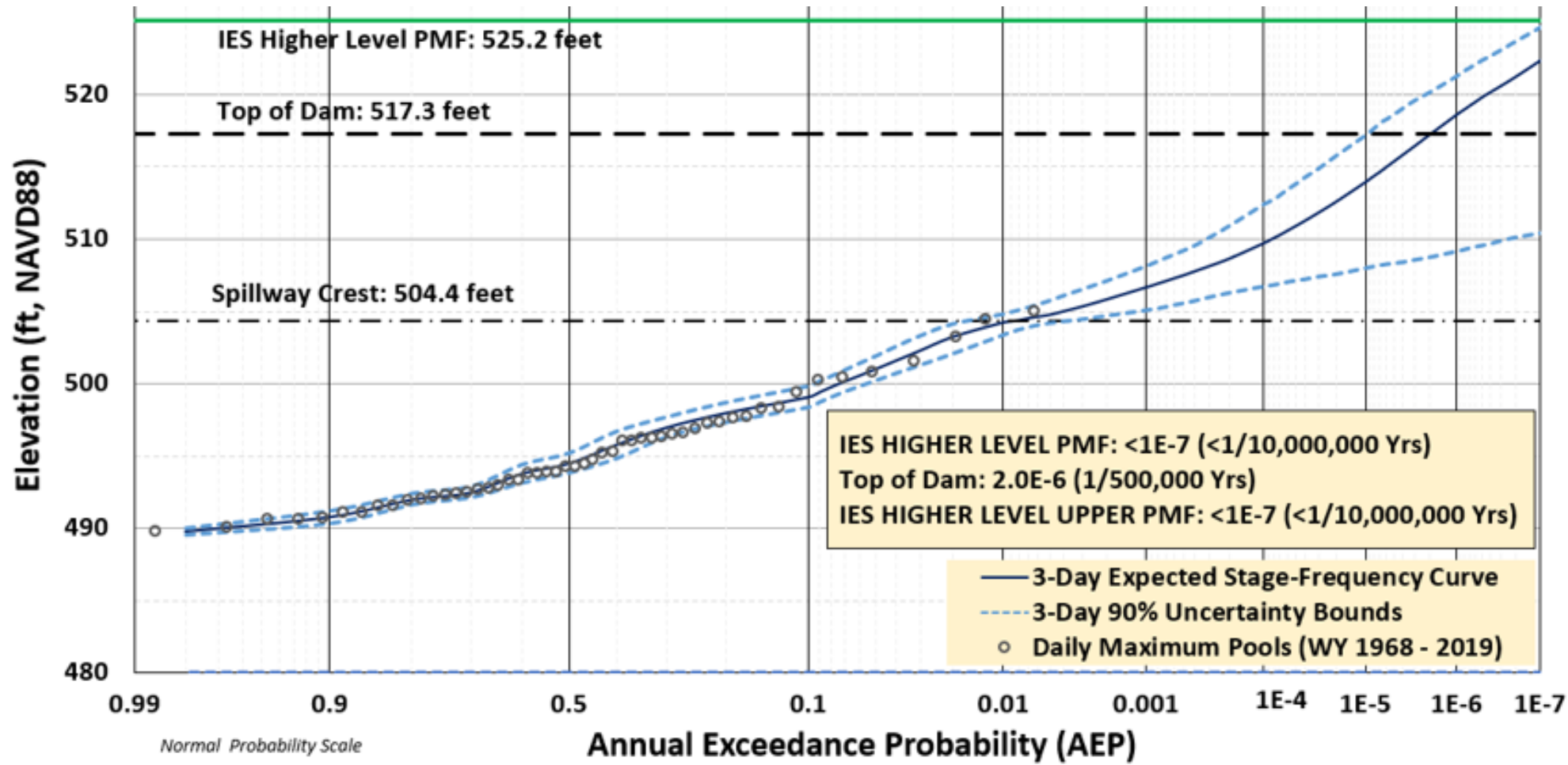
Floodway Operation
Mississippi River
May 2011



Delhi Dam Overtopping
Iowa
July 2010

What is a Hydrologic Hazard Curve?

What is a Hydrologic Hazard Curve?

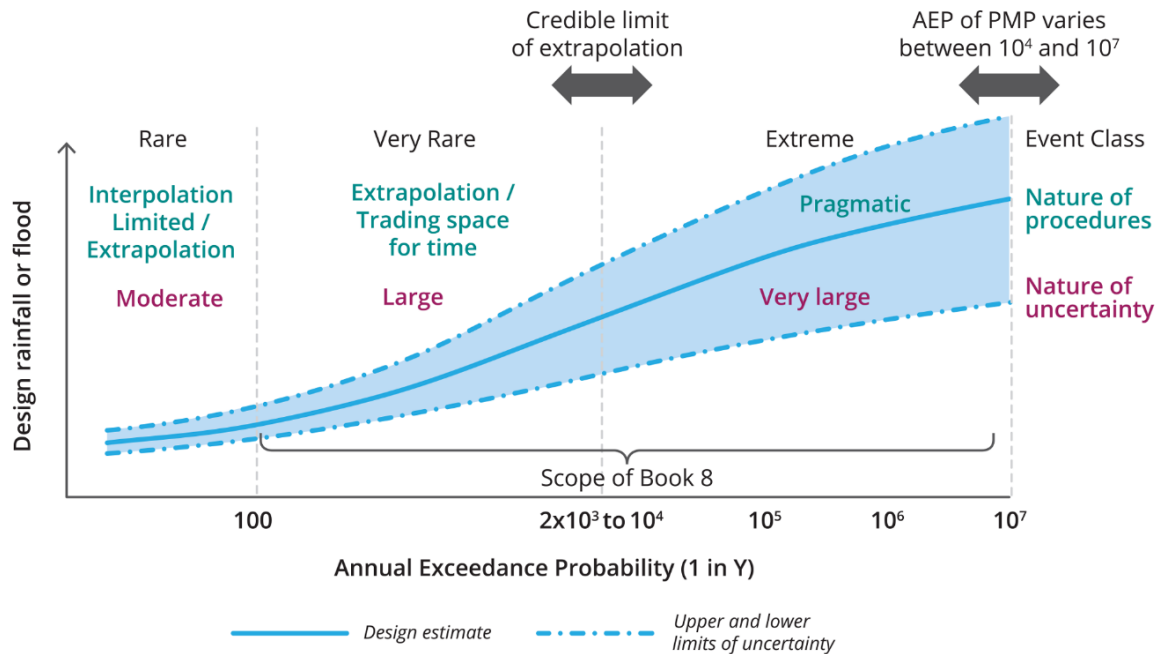


- Annual probability that stage will be exceeded ($>$)
- Risk estimates need the full range of values, with uncertainty
- Range that drives risk will depend on PFMs and consequences

Expertise



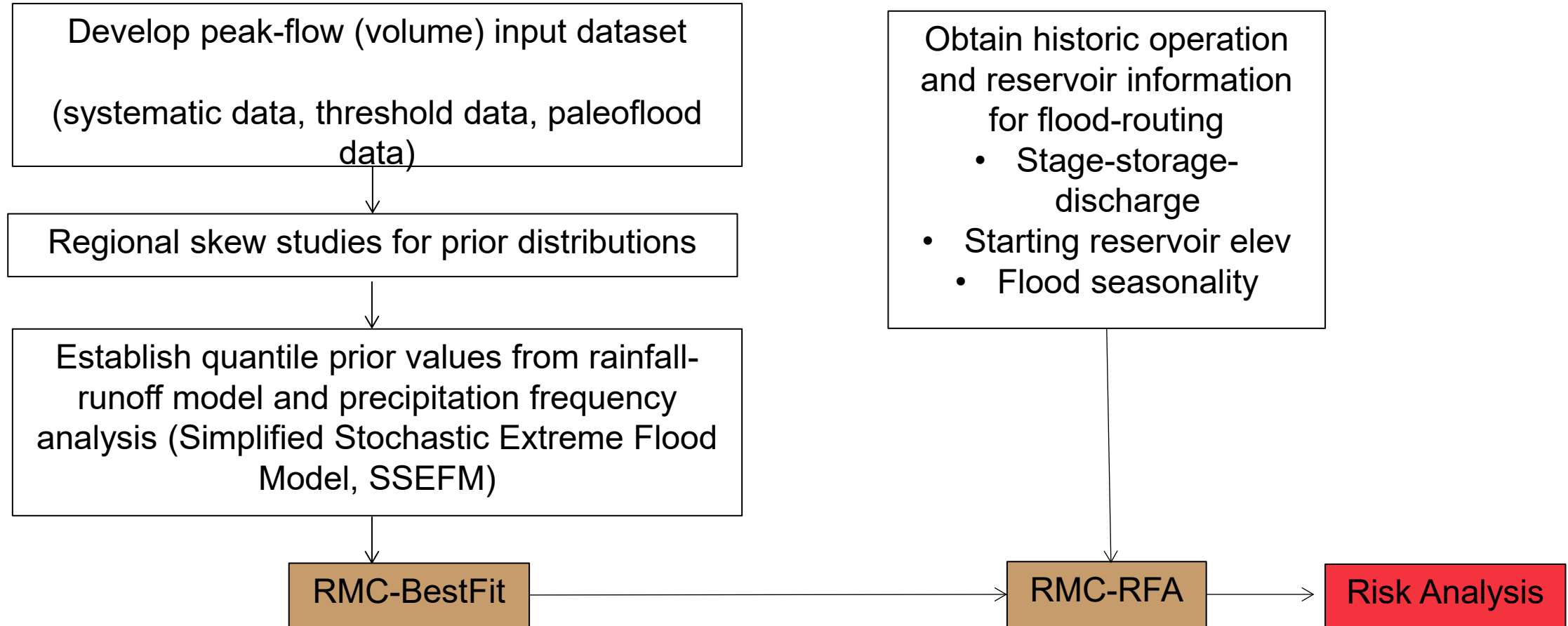
Credible Extrapolation



| Type of data used for flood frequency analysis | Range of credible extrapolation for Annual Exceedance Probability | |
|--|---|--------------|
| | Typical | Optimal |
| At-site streamflow data | 1 in 100 | 1 in 200 |
| Regional streamflow data | 1 in 500 | 1 in 1,000 |
| At-site streamflow and at-site paleoflood data | 1 in 4,000 | 1 in 10,000 |
| Regional precipitation data | 1 in 2,000 | 1 in 10,000 |
| Regional streamflow and regional paleoflood data | 1 in 15,000 | 1 in 40,000 |
| Combinations of regional data sets and extrapolation | 1 in 40,000 | 1 in 100,000 |

- USBR - USU (1999), Swain et al. (2006) USBR Hydrologic Hazard Estimating Procedures
- Also in: Australian Rainfall & Runoff (2019) Book 8 Estimation of Very Rare to Extreme Floods by Nathan and Weinmann

Hydrologic Hazard Methods, Data, and Extrapolations



? Questions