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Managing Water in the West

Dam Safety Program

Managing Risk to Support the Core Mission

U.S. Department of the Interior
Bureau of Reclamation

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Manager, Flood Hydrology and Consequences Group

Reclamation manages 476 dams and dikes in the Western 17 United States
(2011 Annual Report)

370 are High or Significant Hazard
106 are Low Hazard

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Teton Dam Failure – 6/5/1976

11 killed, ½ billion dollars property damage

- Prompted new federal legislation on dam safety
- Reclamation's dam safety program established soon after

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Reclamation Safety of Dams Act

(1978, Amended 1984, 2000, 2002, 2004)

" In order to preserve the structural safety of Bureau of Reclamation dams and related facilities, the Secretary of the Interior is authorized to perform such modifications as he determines to be reasonably required. "

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The Act:

- Authorizes modification of Reclamation dams “the cause of which results from new **hydrologic** or **seismic** data or **changes in the state of the art** criteria…deemed necessary for safety purposes”

- Does **not** address conditions “resulting from age and normal deterioration or from nonperformance of reasonable maintenance”

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Dam Safety Related Legislation

- Federal Guidelines for Dam Safety - 1979
- National Dam Inspection Act (1972)

  (COE)
- National Dam Safety Program Act (2002)

  (FEMA)
- Dam Safety and Security Act (2002)

  (FEMA)

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Interim

Dam Safety Public Protection Guidelines

A Risk Framework to Support Dam Safety Decision-Making

U.S. Department of the Interior
Bureau of Reclamation
Dam Safety Office
Denver, Colorado

August 2011

Benefits of Risk Based Decisions

- Complies with Federal Guidelines for Dam Safety
- More comprehensive and consistent evaluations - less subjectivity
- Better focus on process of data collection
- Improved consistency in decisions
- Better focus in recommendations
- Better definition of objectives in scoping out work products
- Resource prioritization
- Project Justification

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Why Risk Based Decisions?

- Risk estimates focused on identified failure modes are easier to understand for decision makers, management, our customers and the public.
- Uncertainties are identified
- Risk is a convincing tool to explain why the dam safety program takes actions and how funds are being expended.
- Given the limited resources (ie money) risk is now the primary justification for prioritizing and pursuing work activities.

What is Risk?

Dam Safety Program

Annualized failure probability

- AFP= P (load) x P (response to the load)

Annualized loss of life

- Risk = P (load) x P (response) x LOL

Security Program

- Risk is a function of economic consequences as well

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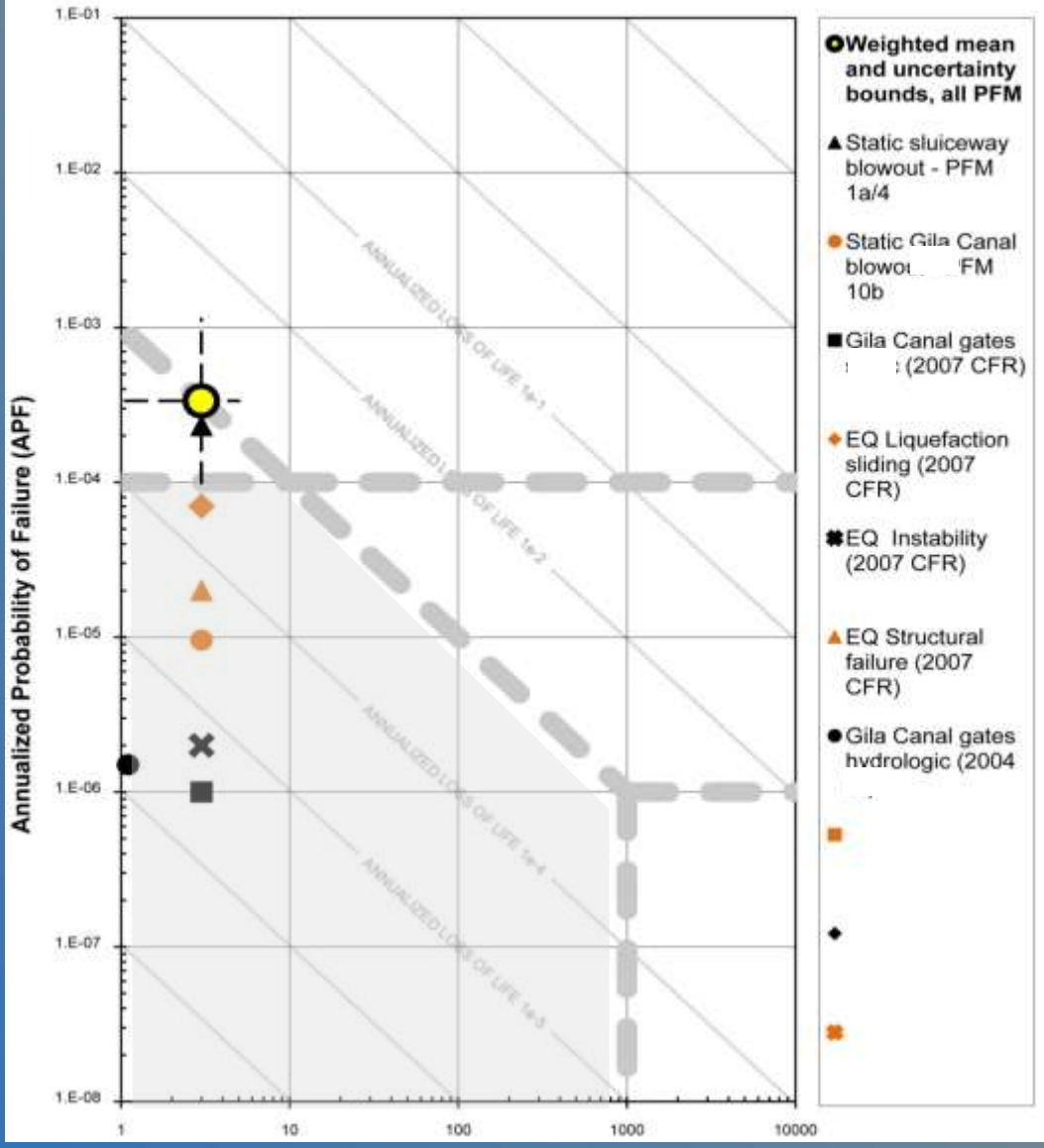
Dam

Notes:



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Computing Risk

Risk Analysis

The procedure to identify and quantify risk by establishing potential failure modes, providing numerical estimates of the likelihood of an event in a specified time period, and estimating the magnitude of the consequences.

Risk Assessment

The use of risk estimation (analysis) in decision-making

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Risk Analysis Process

- Determine Failure Modes
- Estimate probability of events
- Estimate probability of failure
- Construct event tree
- Discuss nodes
- List what's known/unknown
- Estimate probability
- Examine conclusions

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Determine Failure Modes

- Static loads
  - Seepage/piping, slope stability, foundation stability, operational problems
- Floods
  - Overtopping, spillway failure, increased chance of static failure
- Seismic
  - Foundation liquefaction, deformation, cracking, increased chance of static failure

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SPILLWAY CHUTE OR STILLING BASIN FAILURE MODE

El Guapo 12/1999

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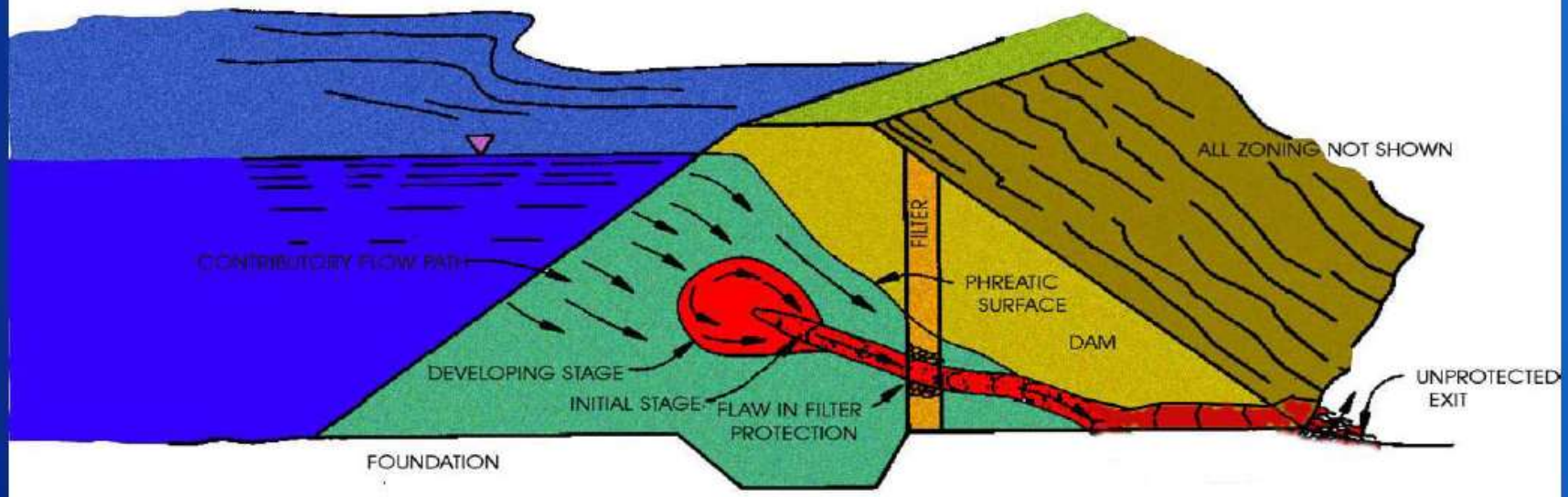
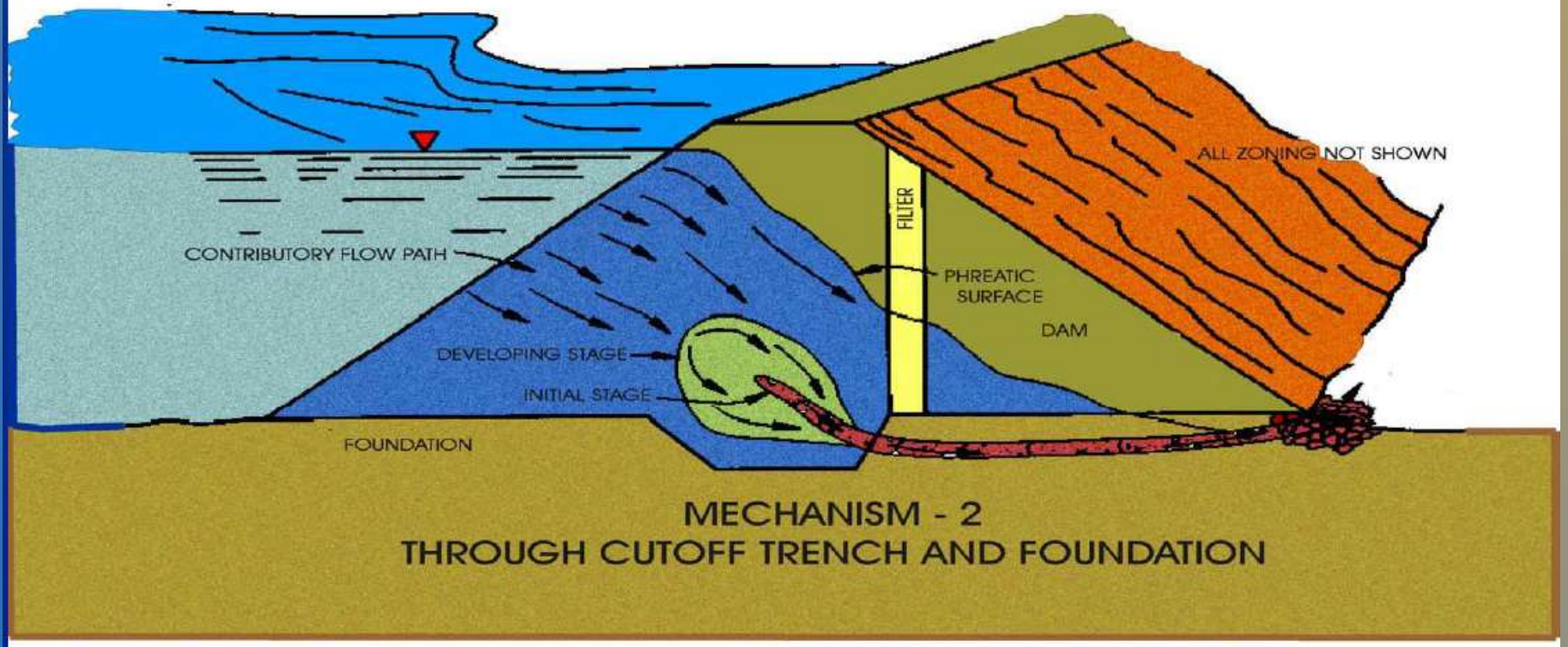
HIGH RESERVOIR LEVEL FAILURE MODE

Piping through Embankment



MECHANISM - 1
THROUGH EMBANKMENT

Internal Erosion from Embankment into Foundation



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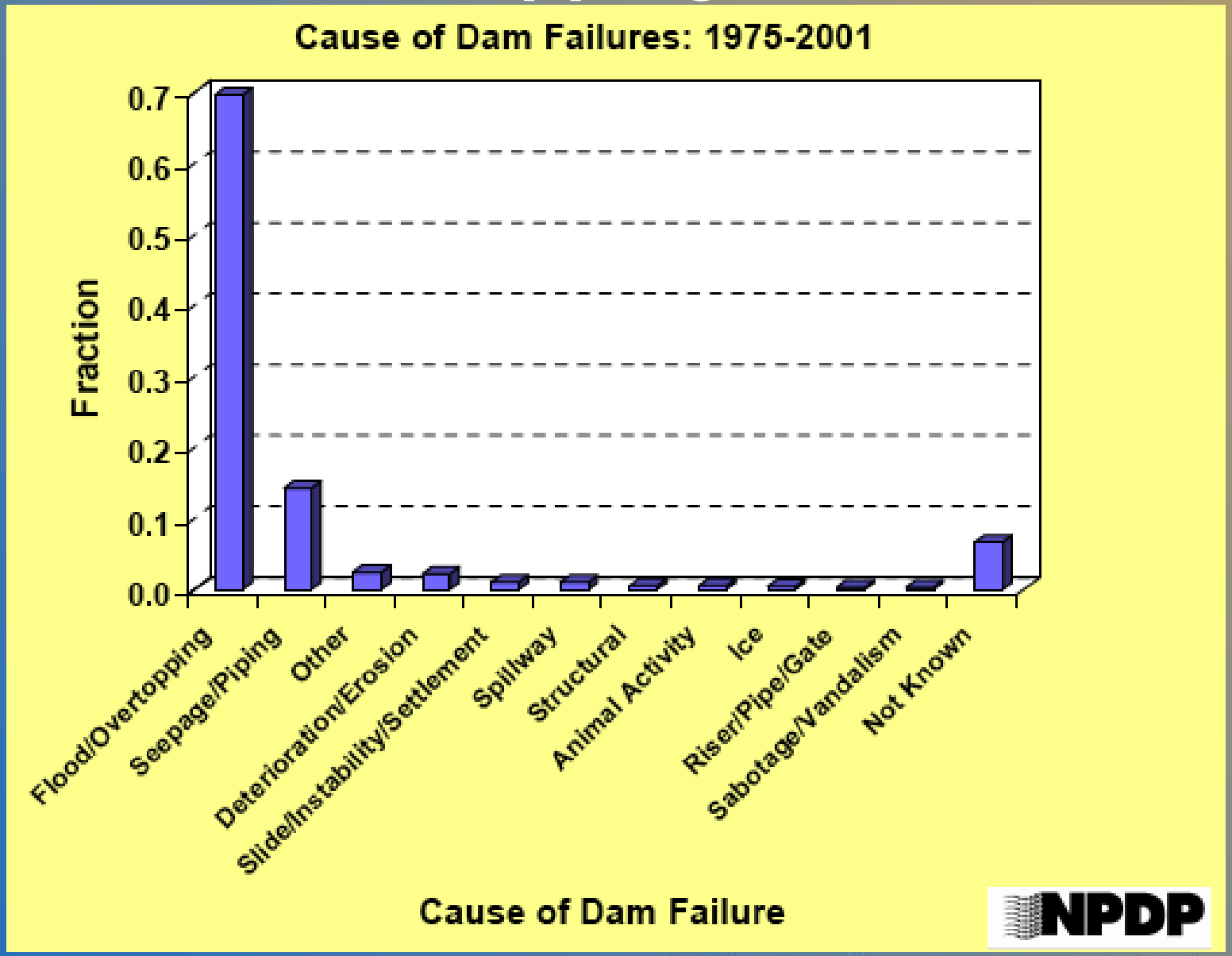
Flood Overtopping Dam Failures



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Gibson Dam, MT June 1964

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Gibson Dam, MT

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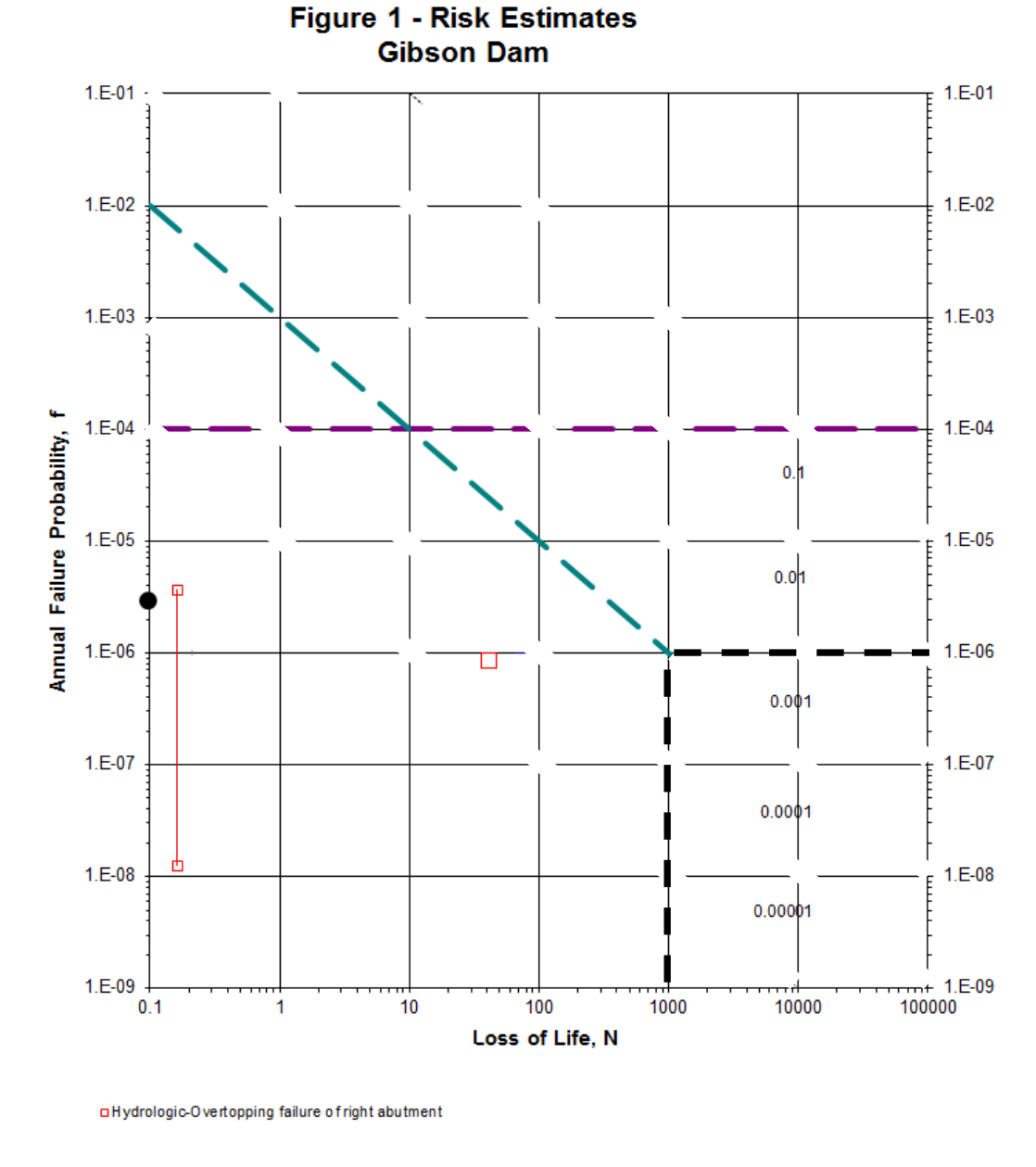

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Risk Analysis Process

- Determine Failure Modes (overtopping)
- Estimate probability of event

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Hydrologic Hazard Summary

- Reclamation utilizes a suite of methods for estimating hydrologic hazard curves for dam safety
- Combining streamflow, paleoflood and rainfall data allows more confidence in extrapolated flood frequency curves
- The procedure relies on extracting information from existing studies and available data

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Estimate Load Probabilities

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U.S. Department of the Interior
Bureau of Reclamation

June 2004

Hydrologic Hazard Data

Some key sources and types

- Extreme Storm Rainfall
  - point gages – NCDC
  - Depth-Area Duration storm catalog from USACE, Reclamation, NWS (HMRs)
- Extreme Flood Data
  - USGS stream gages: peaks, hydrographs
  - Historical information
  - Paleoflood data

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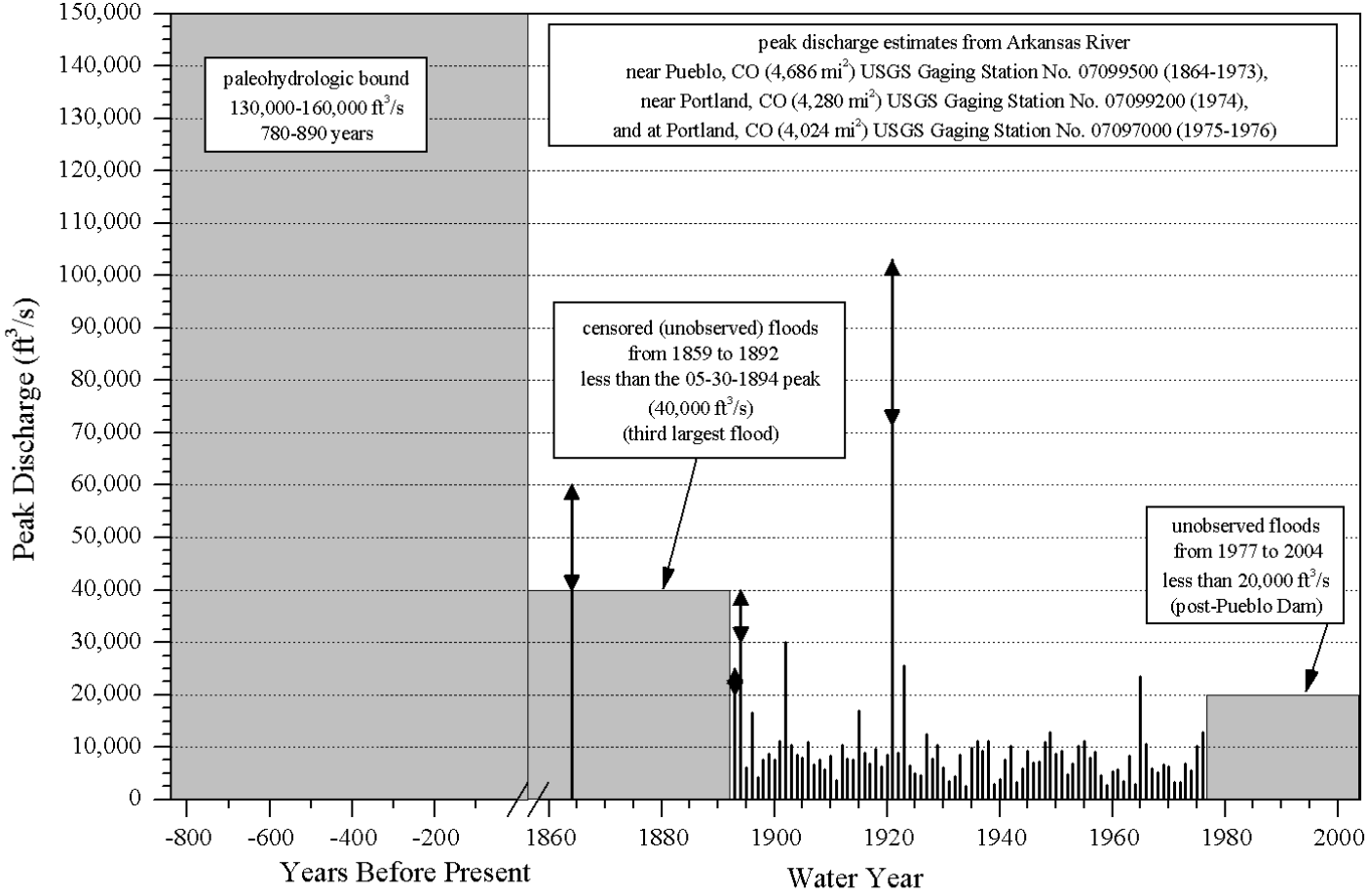
Pueblo, CO Peak Flow Time Series



Hydrologic Hazard Data

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 (1999)

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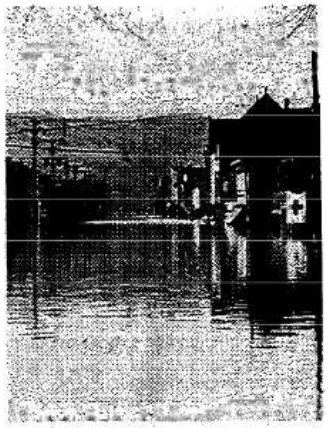

Guidelines For Determining

Flood Flow Frequency

Bulletin # 17B
of the
Hydrology Subcommittee

Revised September 1981
Editorial Corrections March 1982

INTERAGENCY ADVISORY COMMITTEE
ON WATER DATA

U.S. Department of the Interior
Geological Survey
Office of Water Data Coordination
Reston, Virginia 22092

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Hydrologic Hazard Curves: Extreme Flood Probability Estimation Methods

- Flood Frequency Analysis with Historical/Paleoflood Data
- Hydrograph Scaling and Volumes
- GRADEX Method
- Australian Rainfall-Runoff Method
- Stochastic Event-Based Precipitation Runoff Modeling (SEFM)
- Stochastic Rainfall-Runoff Modeling with TREX

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Final Hydrologic Hazard Curve

- The amount of effort expended on analyzing a hydrologic hazard is dependent on the nature of the problem and potential cost of the solution
- When multiple methods are used, best estimate is based on sound physical and scientific reasoning for weighting or combining results
- Initial characterization is usually replaced by more detailed studies
- Reclamation uses the PMF as the upper limit of flood potential at a site for storm durations defined by the PMP

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Risk Analysis Process

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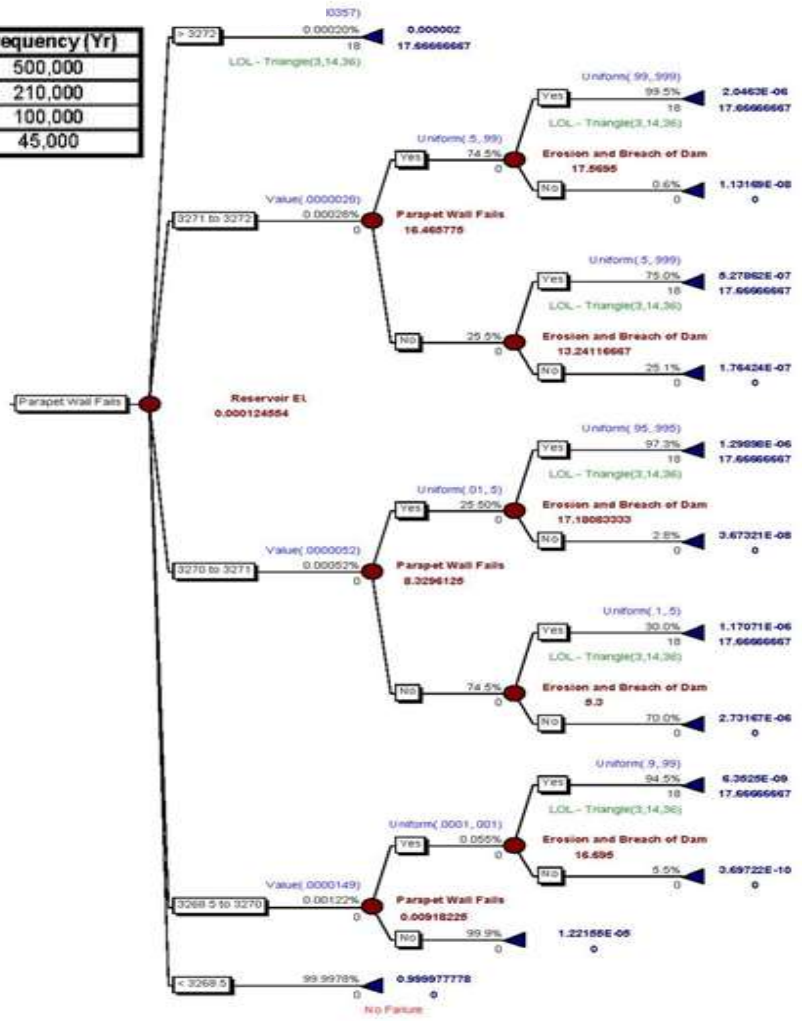
Estimate Response Probabilities

- Usually the most difficult part of the process
- Made by those most familiar with the behavior of the dam
- Break down the overall dam responses into smaller steps that are easier to understand and estimate
- “Toolboxes” have been and continue to be developed

Hydrologic Overtopping

Reservoir El.	Frequency (Yr)
3272	500,000
3271	210,000
3270	100,000
3268.5	45,000



Annualized Probability of Failure	Annualized Loss of Life
2.00E-06	3.53E-05
2.05E-06	3.62E-05
5.28E-07	9.33E-06
1.30E-06	2.29E-05
1.17E-06	2.07E-05
6.35E-09	1.12E-07
7.05E-06	1.25E-04

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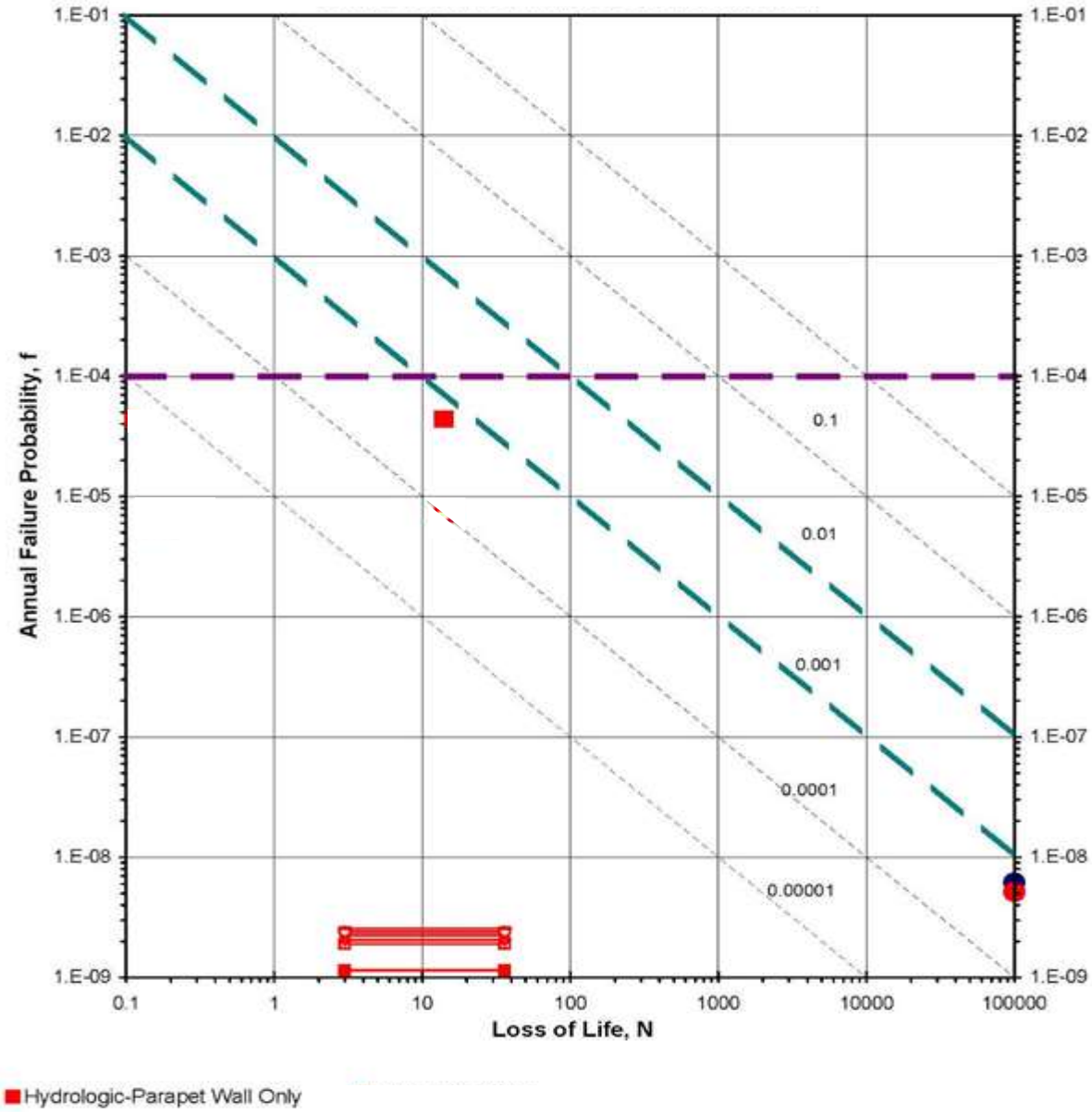

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DSAT

- The Dam Safety Advisory Team (DSAT) reviews ALL Dam Safety Recommendations that result from Risk Analyses

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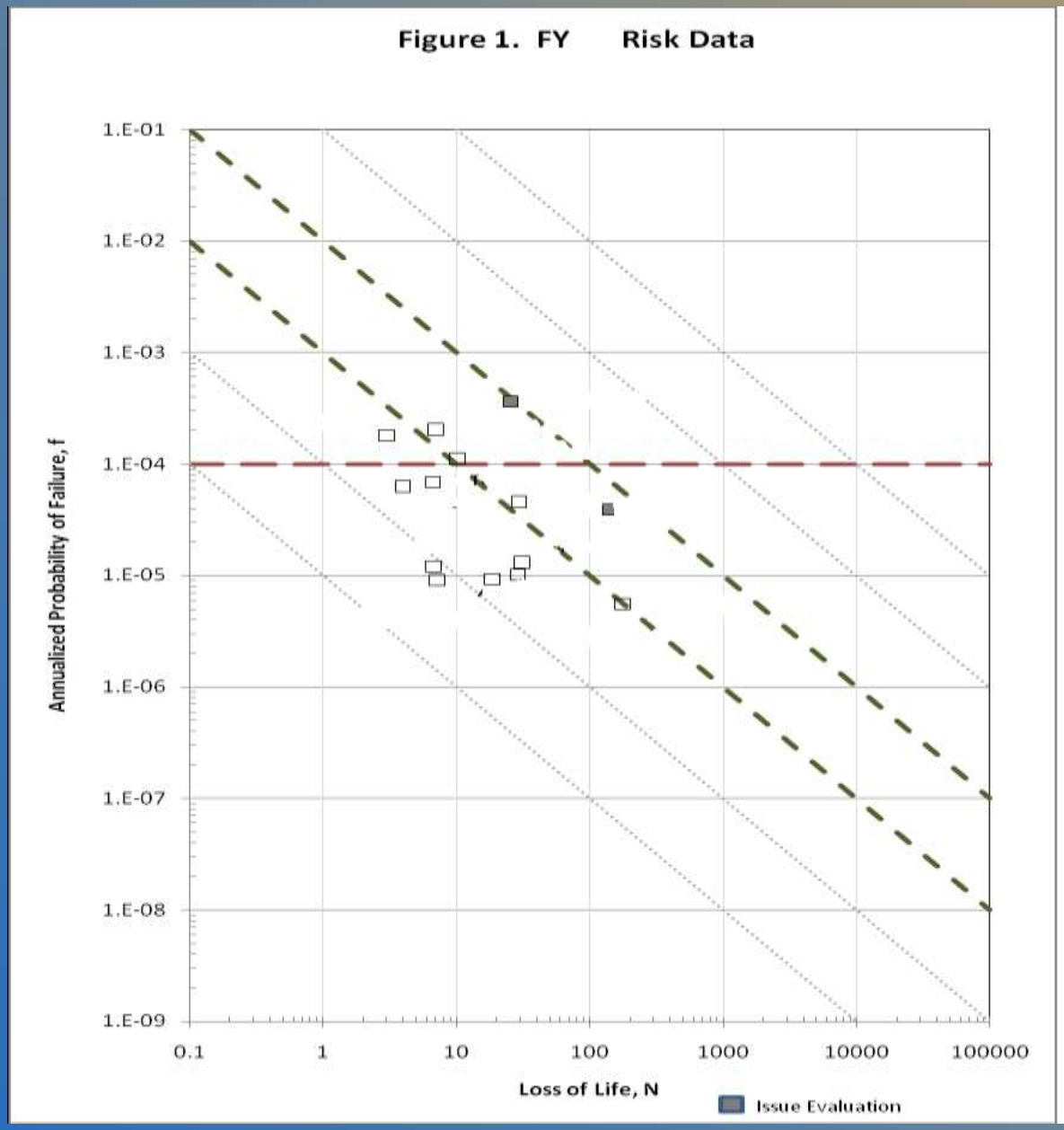

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Decision Making

- Public Safety is Reclamation's primary concern, however there are other major factors that weigh in on final decisions
- Overall Technical Case
- Legal
- Political
  - Operational
  - Public Involvement
- Environmental
- International
- Decisions made by group of decision makers

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Questions?

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Federal Guidelines for Dam Safety - 1979

"The purpose of the Guidelines is to enhance national dam safety by promoting consistent, comprehensive practices"

Federal Guidelines address all aspects of a dam safety program:

- Dam site investigations
- Design
- Construction
- Operation and maintenance
- Dam Inspections
- Emergency preparedness

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