

Introduction to RMC-RFA Methodology

DLS-114, Module 2.1



**US Army Corps
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March 2026 / Version 1

FORT GIBSON DAM, OK (SOURCE: HDR)

Learning Objectives

- Discuss the basic framework of a stochastic simulation
- Describe two kinds of uncertainty
- Review Monte Carlo methodology
- Define RMC-RFA simulation framework



Gavin's Point Dam, SD

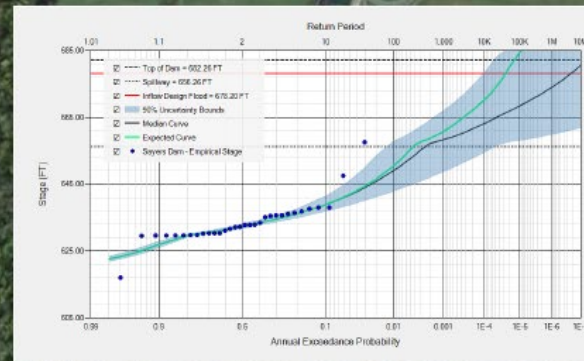
Guidance Document for RMC-RFA

RMC-TR-2018-03

Hydrologic Hazard Methodology for Semi-Quantitative Risk Assessments

RMC-TR-2018-03

An Inflow Volume-Based Approach to Estimating Stage-Frequency for Dams



US Army Corps
of Engineers
Institute for Water Resources
Risk Management Center



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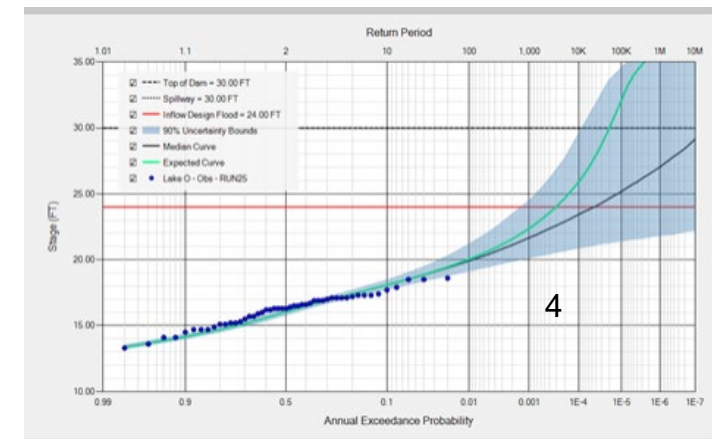
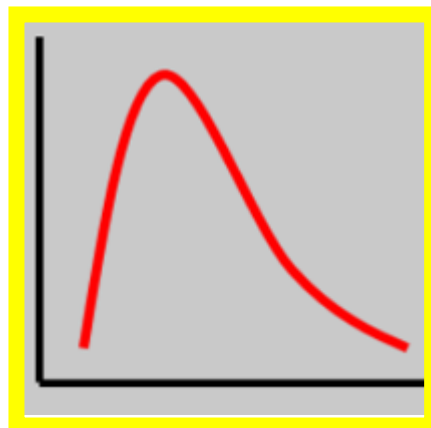
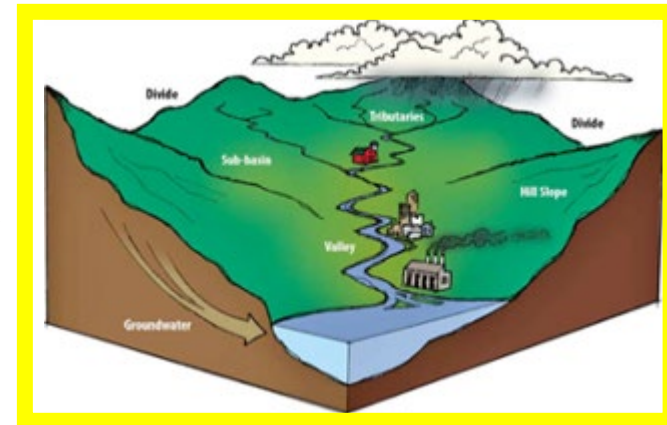
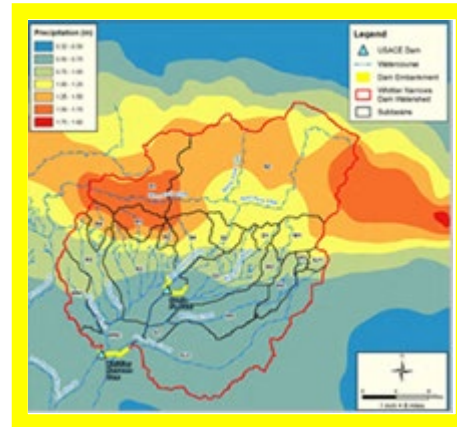
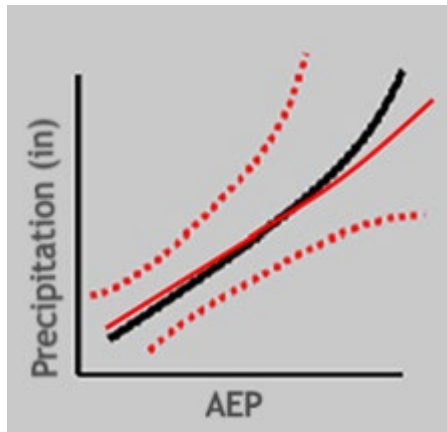
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<https://www.rmc.usace.army.mil/>

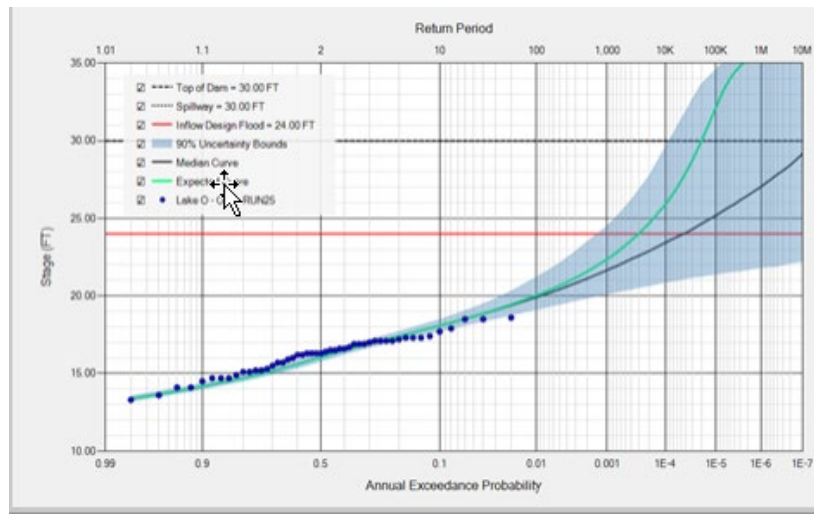
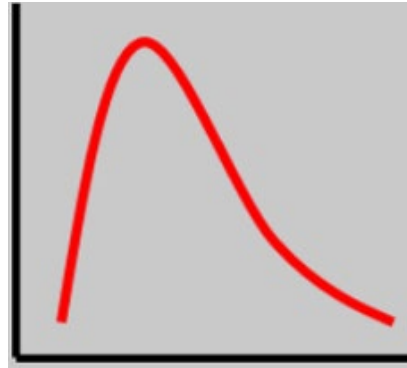
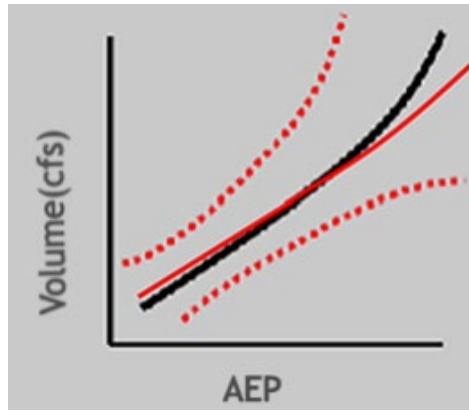
Basic Framework: Two Options – Stochastic Simulation

Method 1: Precipitation-based approach



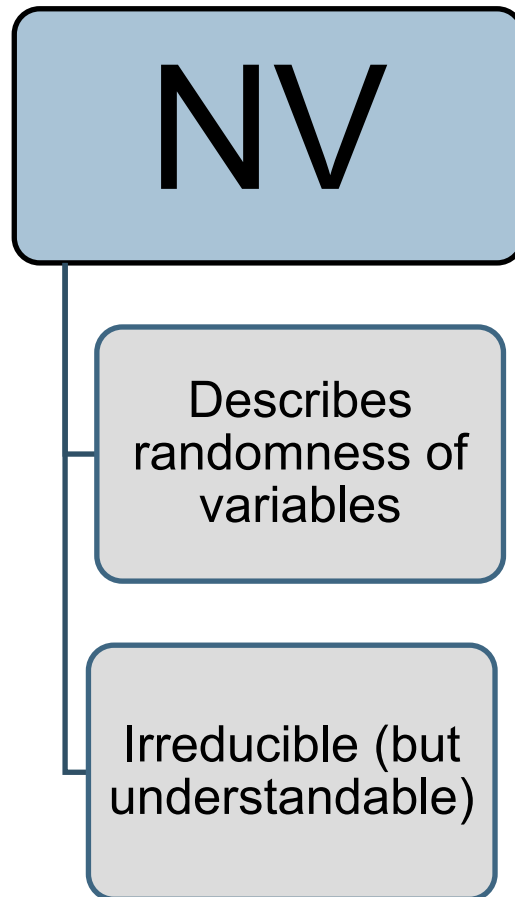
Basic Framework: Two Options – Stochastic Simulation

Method 2: Inflow volume-based approach

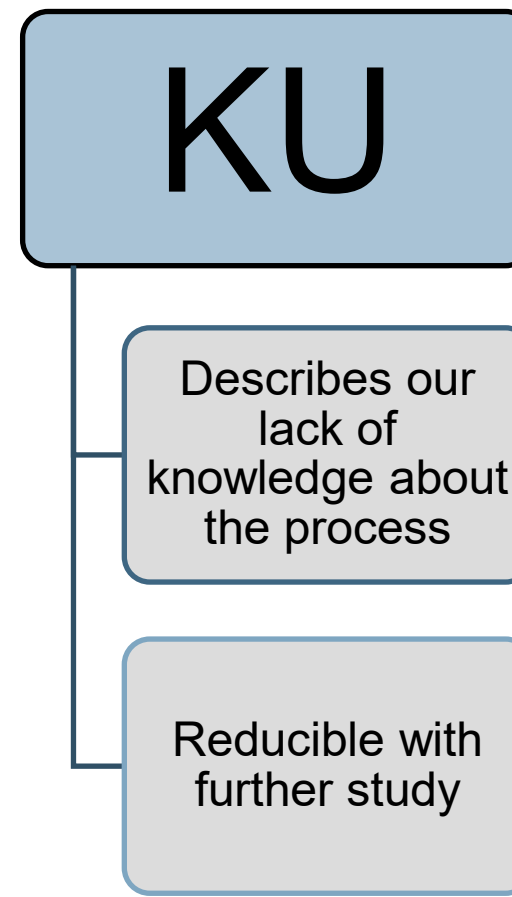


Two Kinds of Uncertainty

1. Natural variability (aleatory)

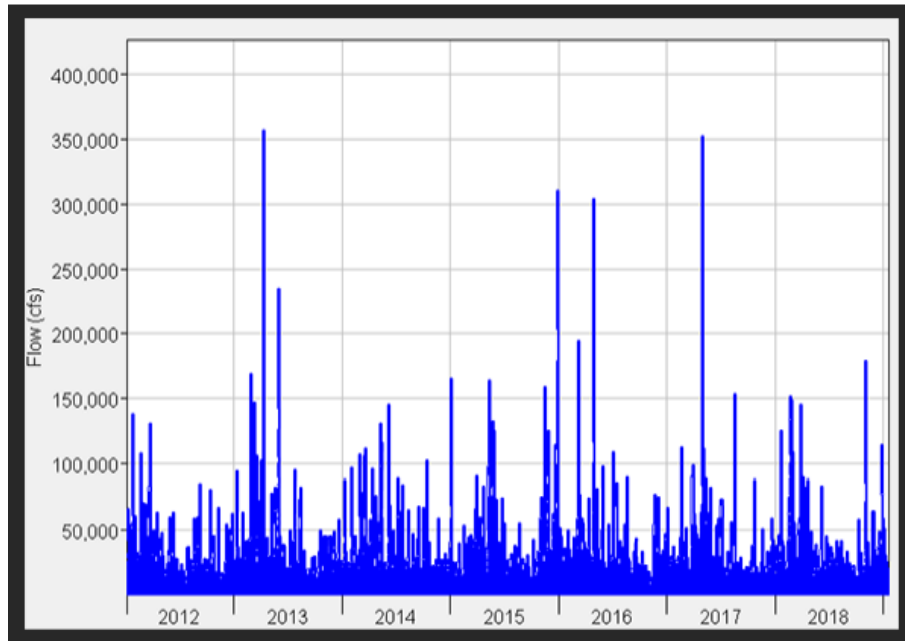


2. Knowledge uncertainty (epistemic)

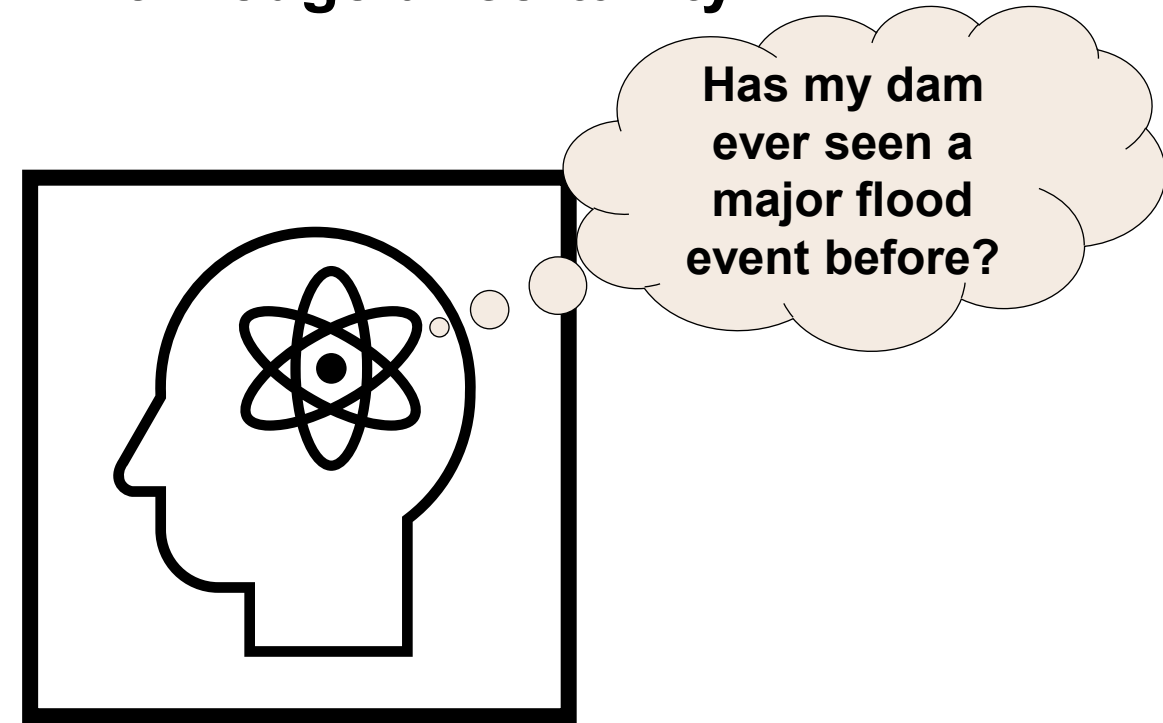


Natural Variability versus Knowledge Uncertainty (1 of 2)

1. Natural variability

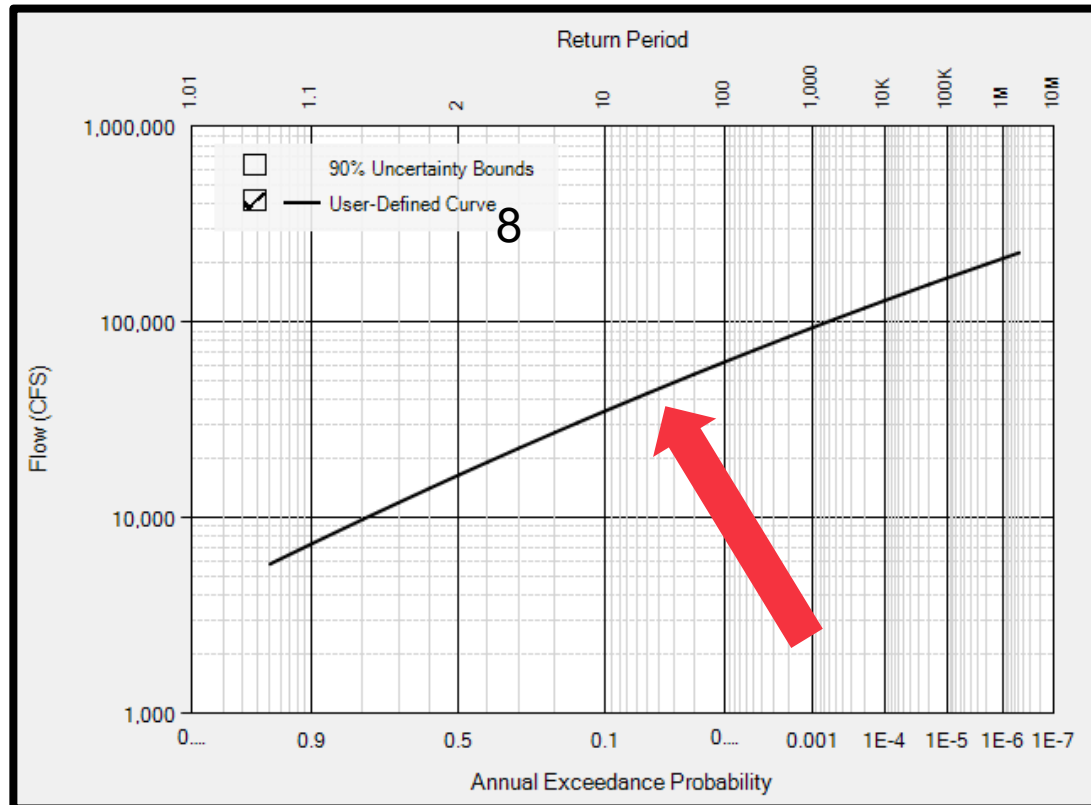


2. Knowledge uncertainty

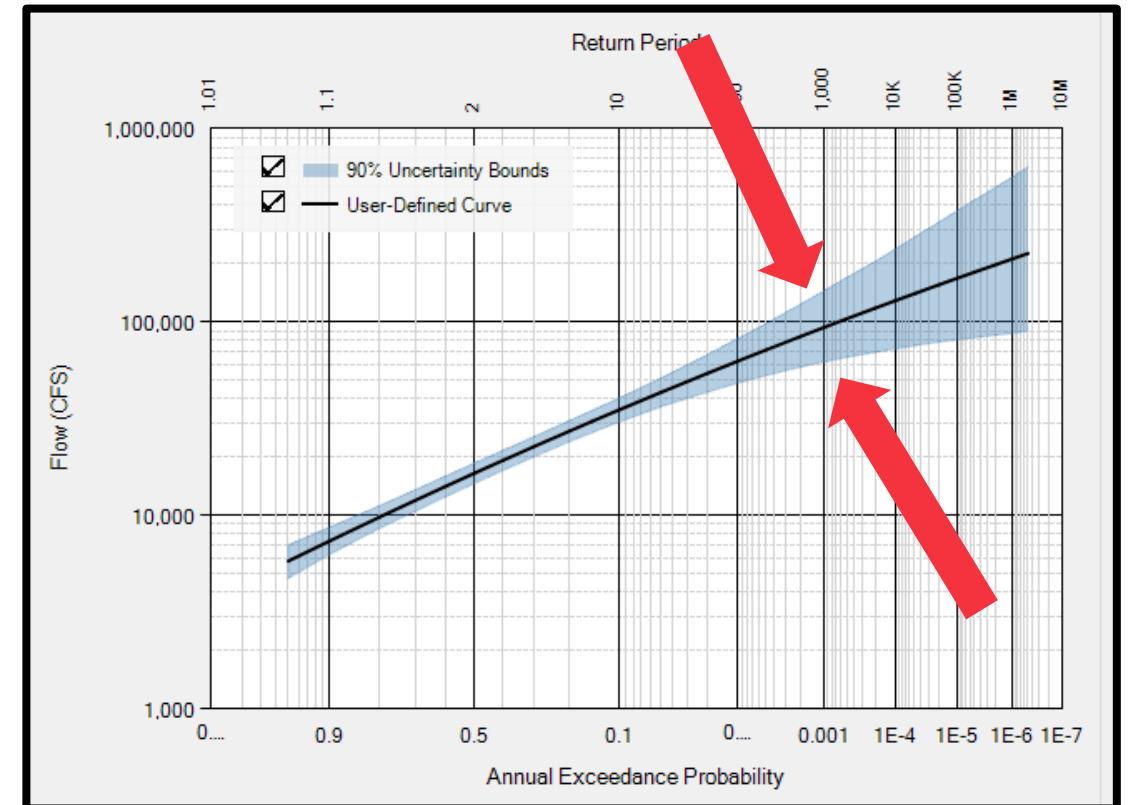


Natural Variability versus Knowledge Uncertainty (2 of 2)

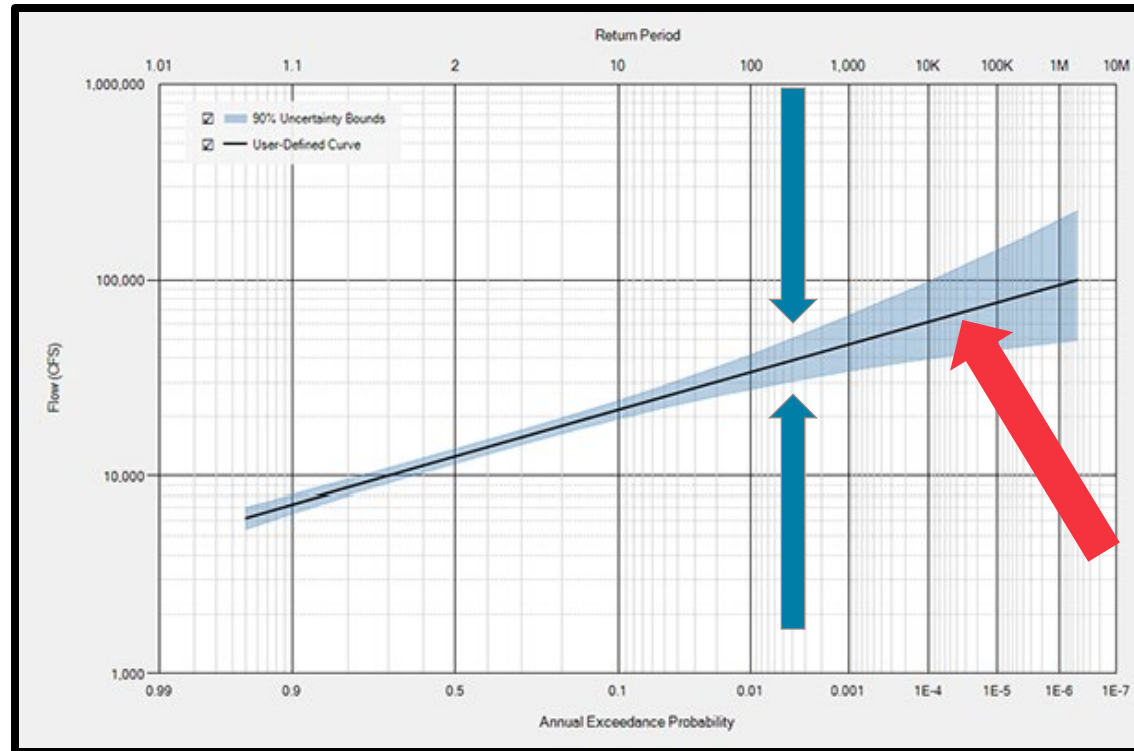
The user defined volume-frequency curve in RFA describes the **natural variability** in inflow volumes



The confidence interval or uncertainty bounds describe the **knowledge uncertainty** in a frequency curve

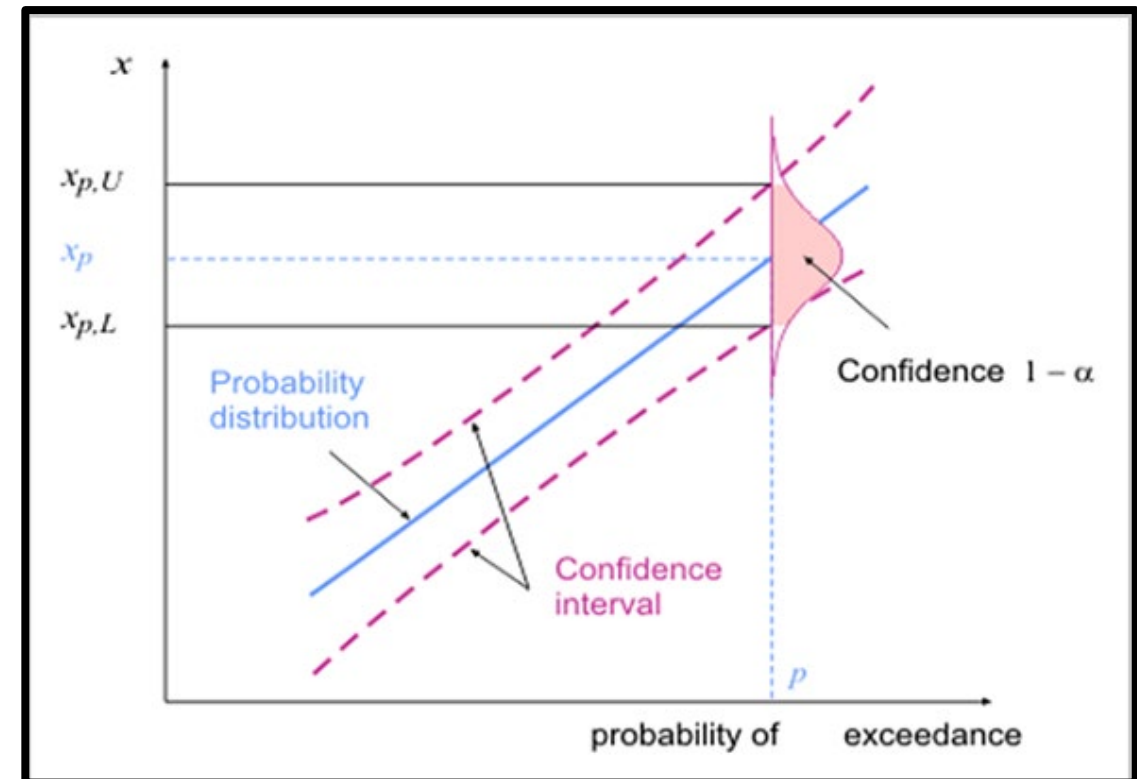


How Uncertainty is Represented



However, there is a 90% chance the population (or parent distribution) could reside anywhere within these shaded bounds, and a 10% chance the parent distribution could be outside of these bounds

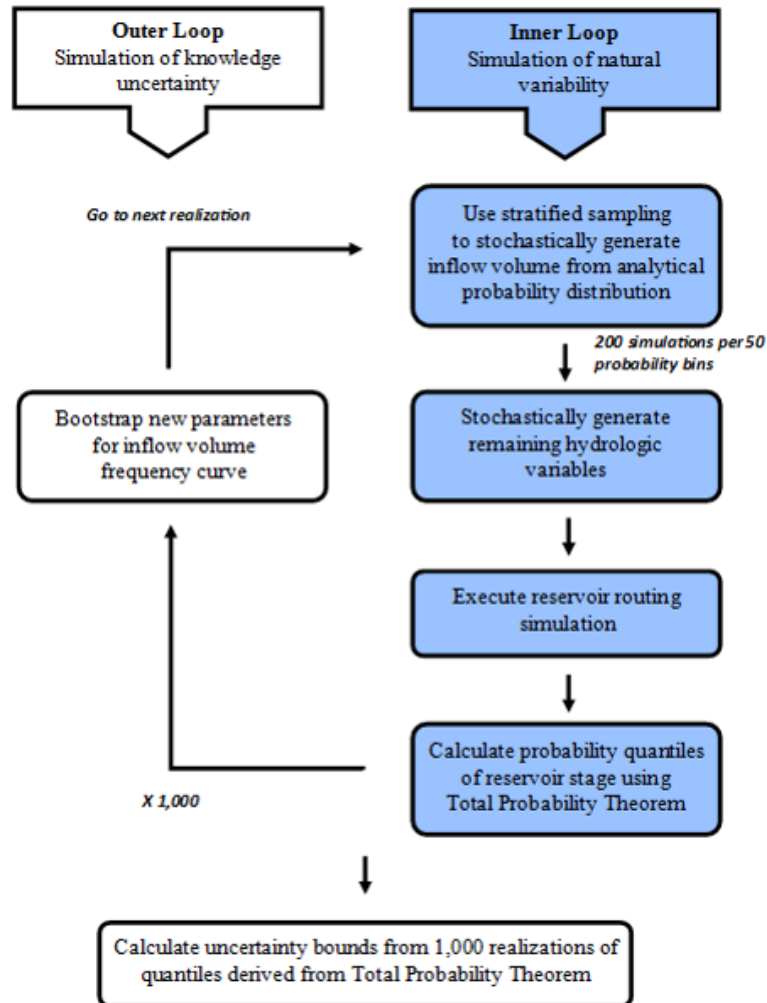
In statistical terms, the black curve is the likely distribution to represent the population of inflow volumes



Monte Carlo Calculations



Overview of RMC-RFA Simulation Framework



Two-looped, nested Monte Carlo methodology:

Outer Loop:

Knowledge uncertainty

- Inflow volume

Inner Loop:

Natural variability

- Seasonality
- Antecedent reservoir stage
- Inflow volume
- Inflow hydrograph shape

Outer Loop: Knowledge Uncertainty (1 of 4)

Bootstrapping:

Taking (n) samples from a distribution

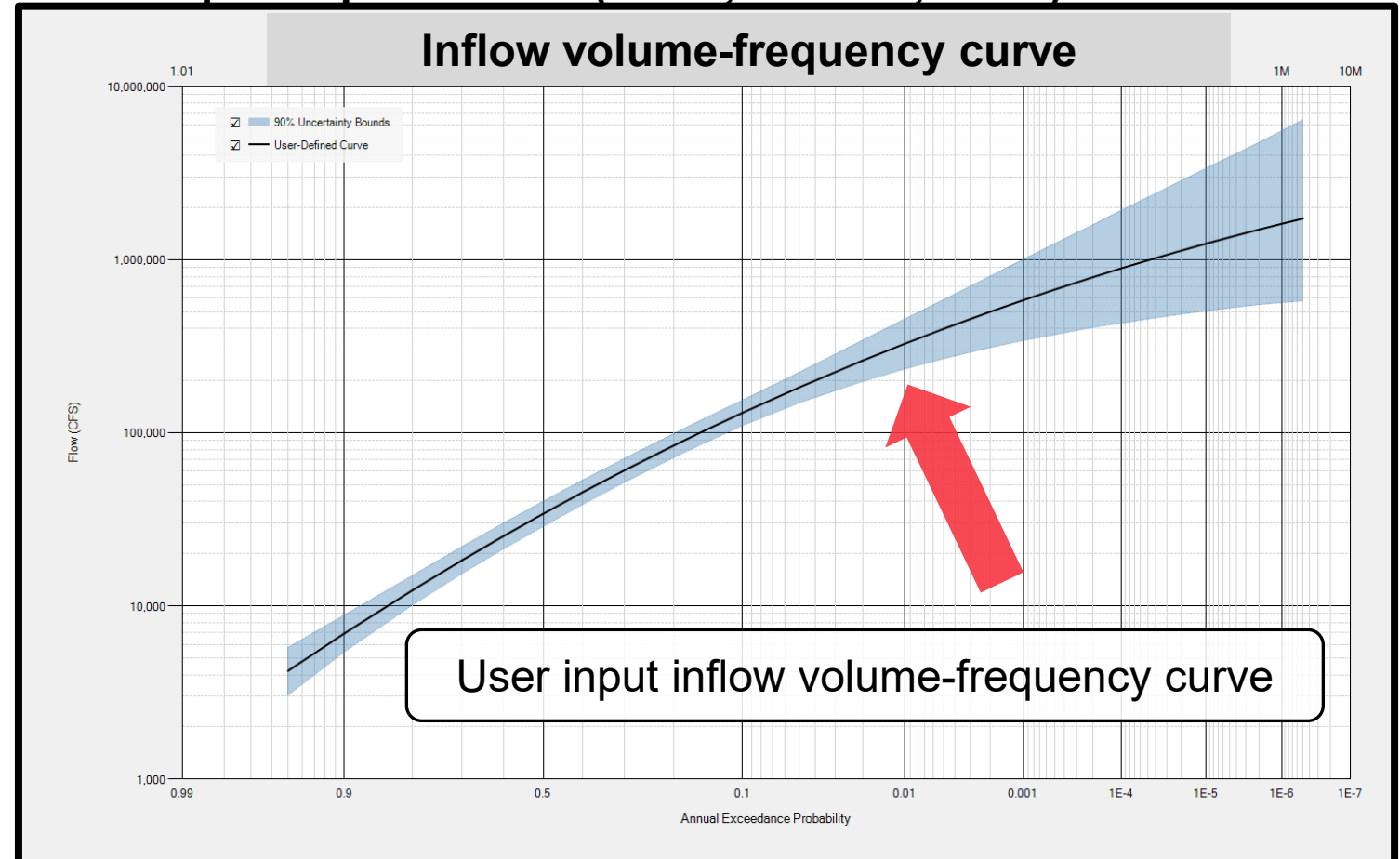
Bootstrapping creates

NEW inflow frequency curve

Bootstrap sample size (n) = Same as effective record length (**ERL**)

For each realization:

Bootstrap new parameters (mean, std. dev, skew)



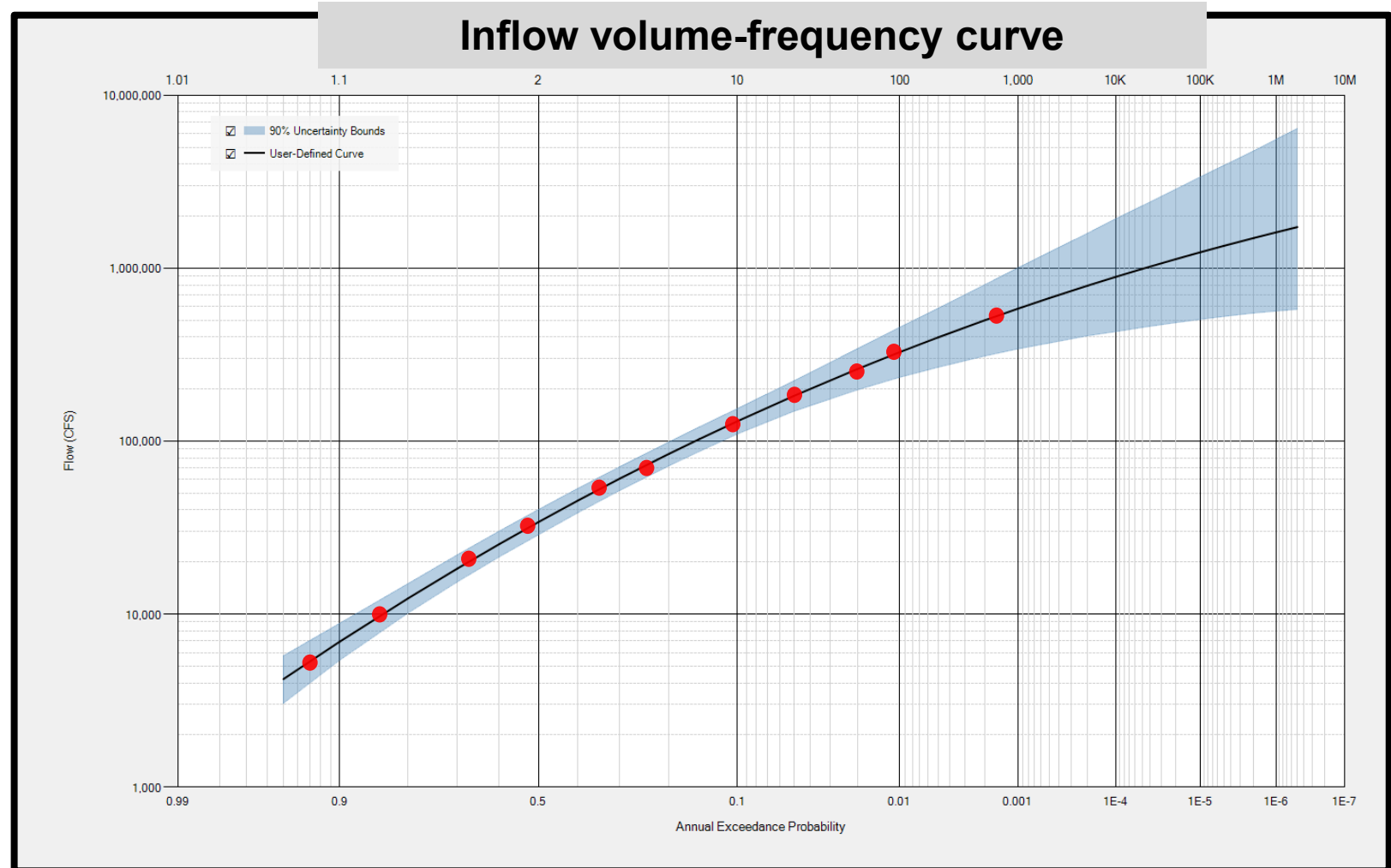
Outer Loop: Knowledge Uncertainty (2 of 4)

Bootstrap sample size (n)
= Same as effective
record length (ERL)

NEW mean

NEW standard deviation

NEW skew



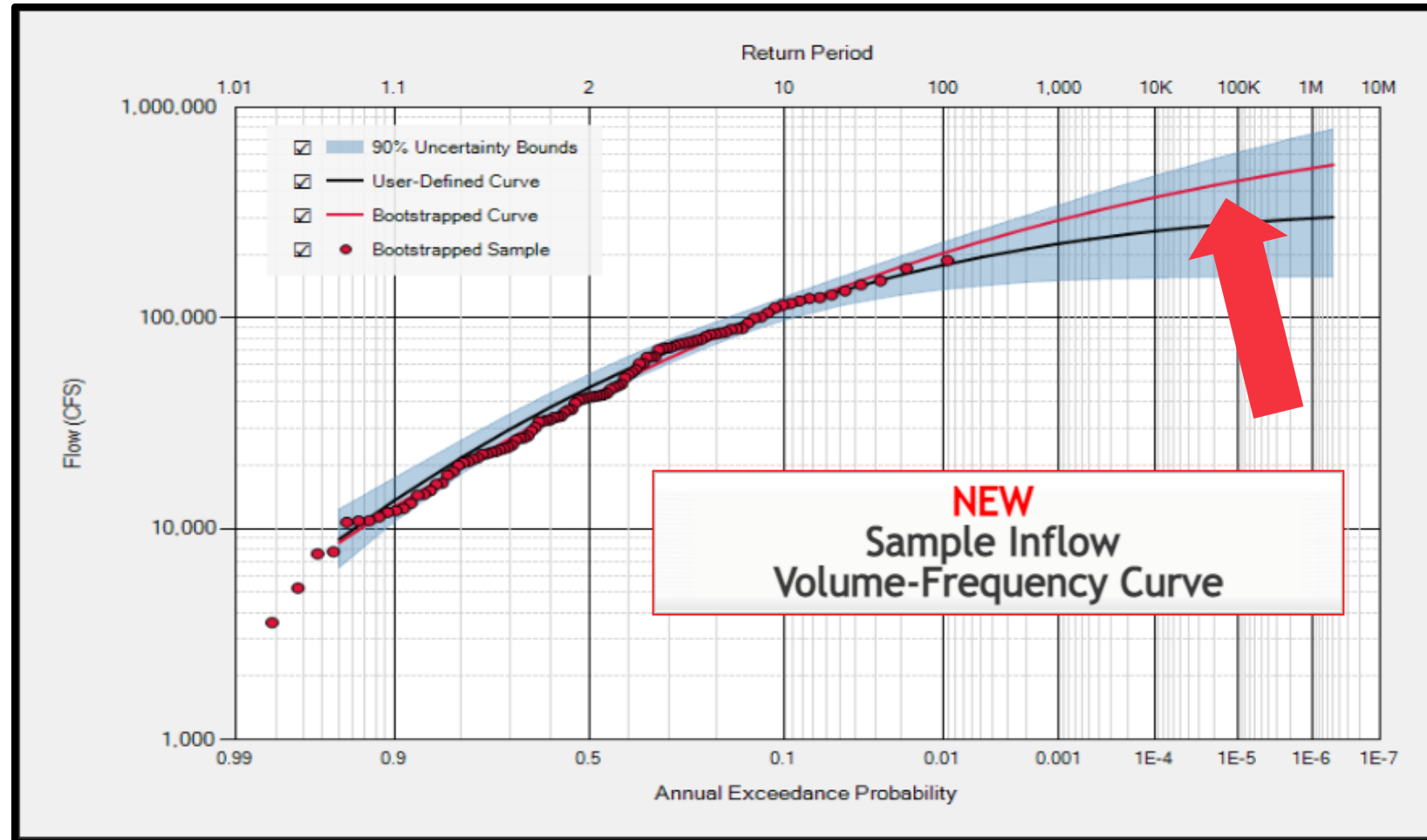
Outer Loop: Knowledge Uncertainty (3 of 4)

Bootstrap sample size (n)
= Same as effective
record length (**ERL**)

NEW mean

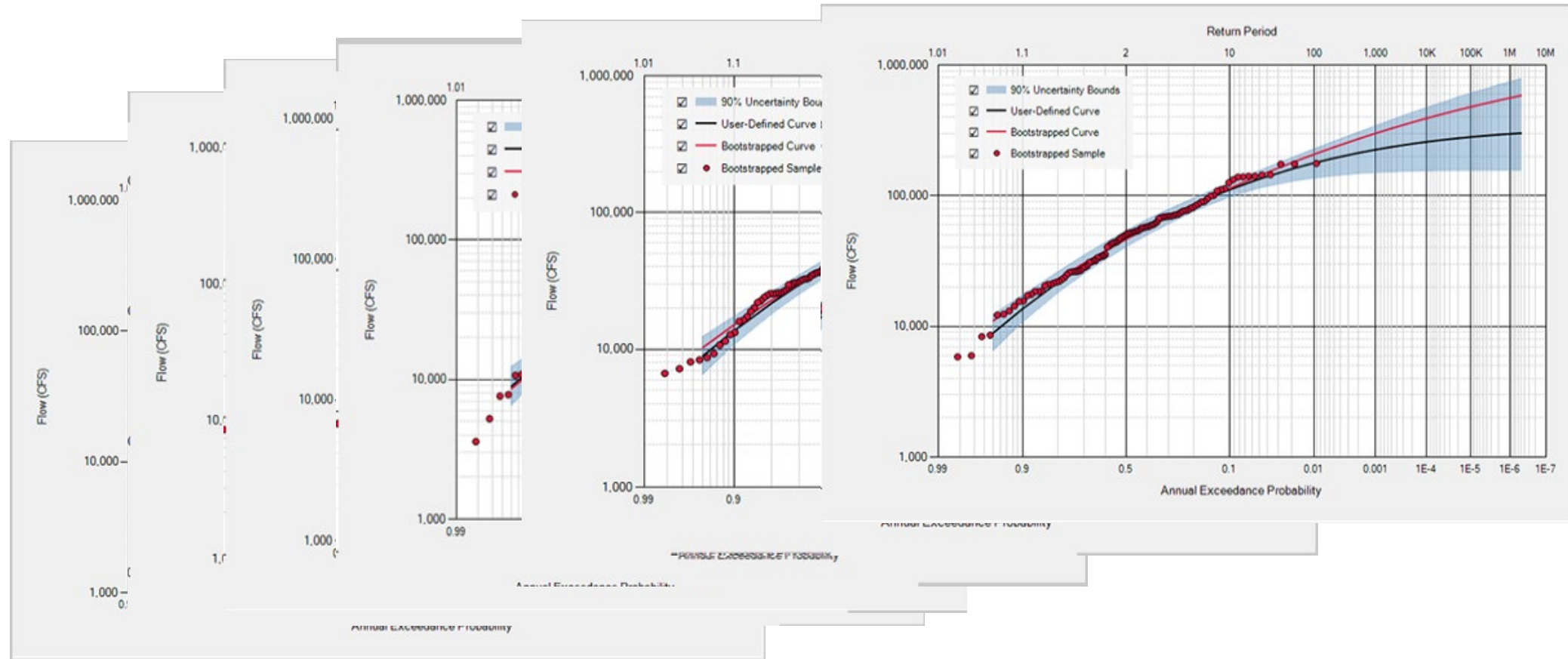
NEW standard deviation

NEW skew



Outer Loop: Knowledge Uncertainty (4 of 4)

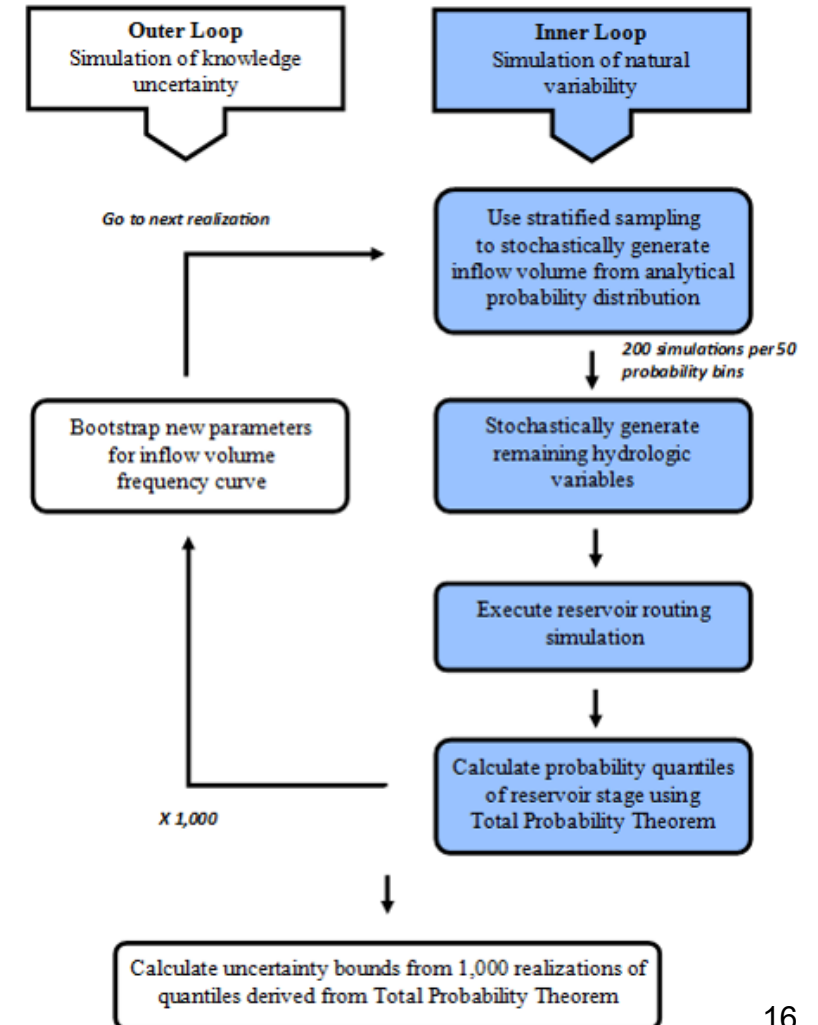
1 realization = 1 new (red) volume-frequency curve



Inner Loop: Natural Variability (1 of 2)

Each inner loop realization has 4 steps:

- Step 1: Sample **10,000** inflows
- Step 2: Randomly sample other variables
 - **Starting month**
 - **Starting reservoir stage**
 - **Inflow hydrograph shape**
- Step 3: **Scale the inflow hydrograph** and simulate reservoir routing to compute **peak stages**
- Step 4: Calculate the **probability** of stages



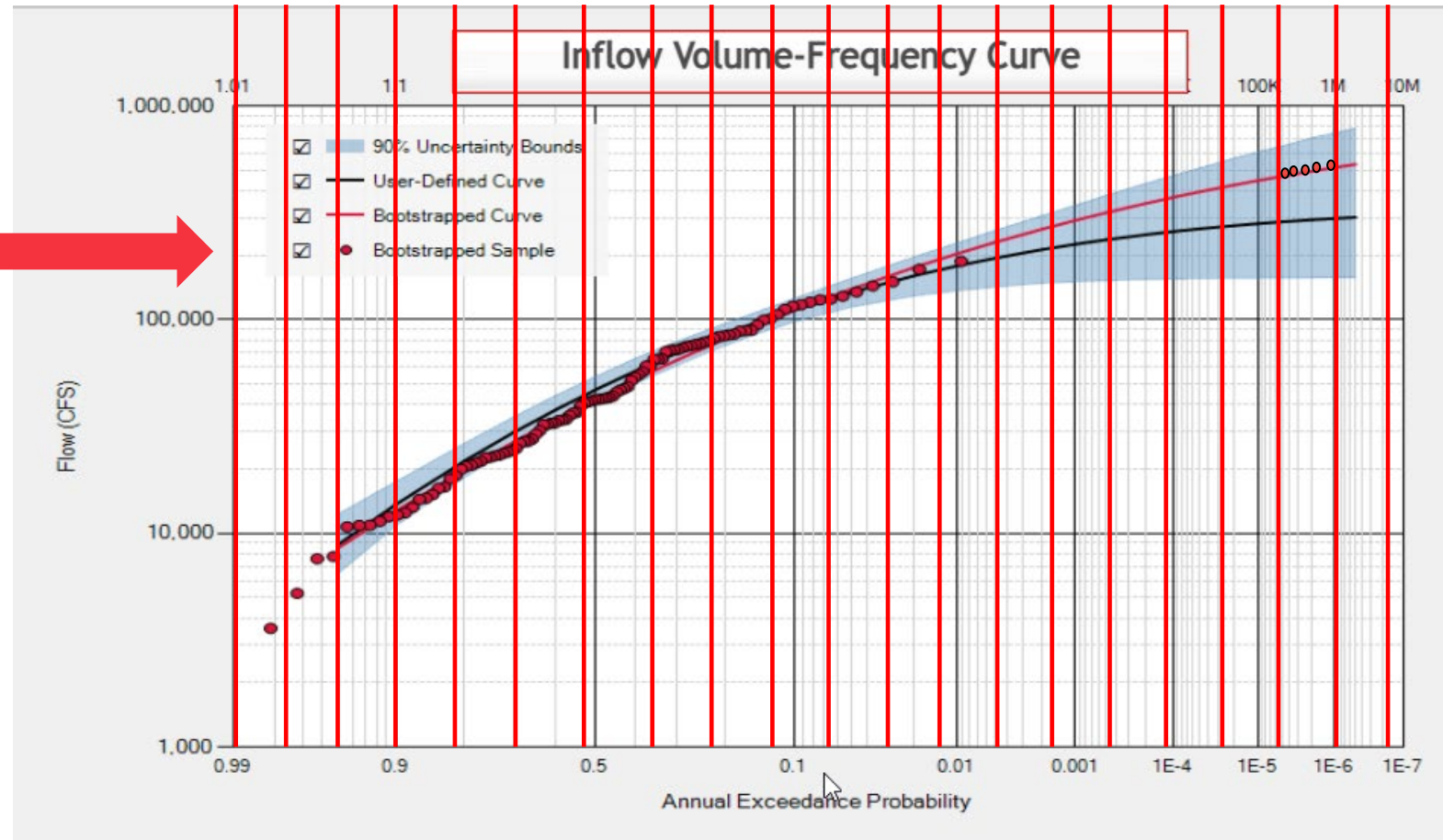
Inner Loop: Natural Variability (2 of 2)

50 evenly
spaced bins

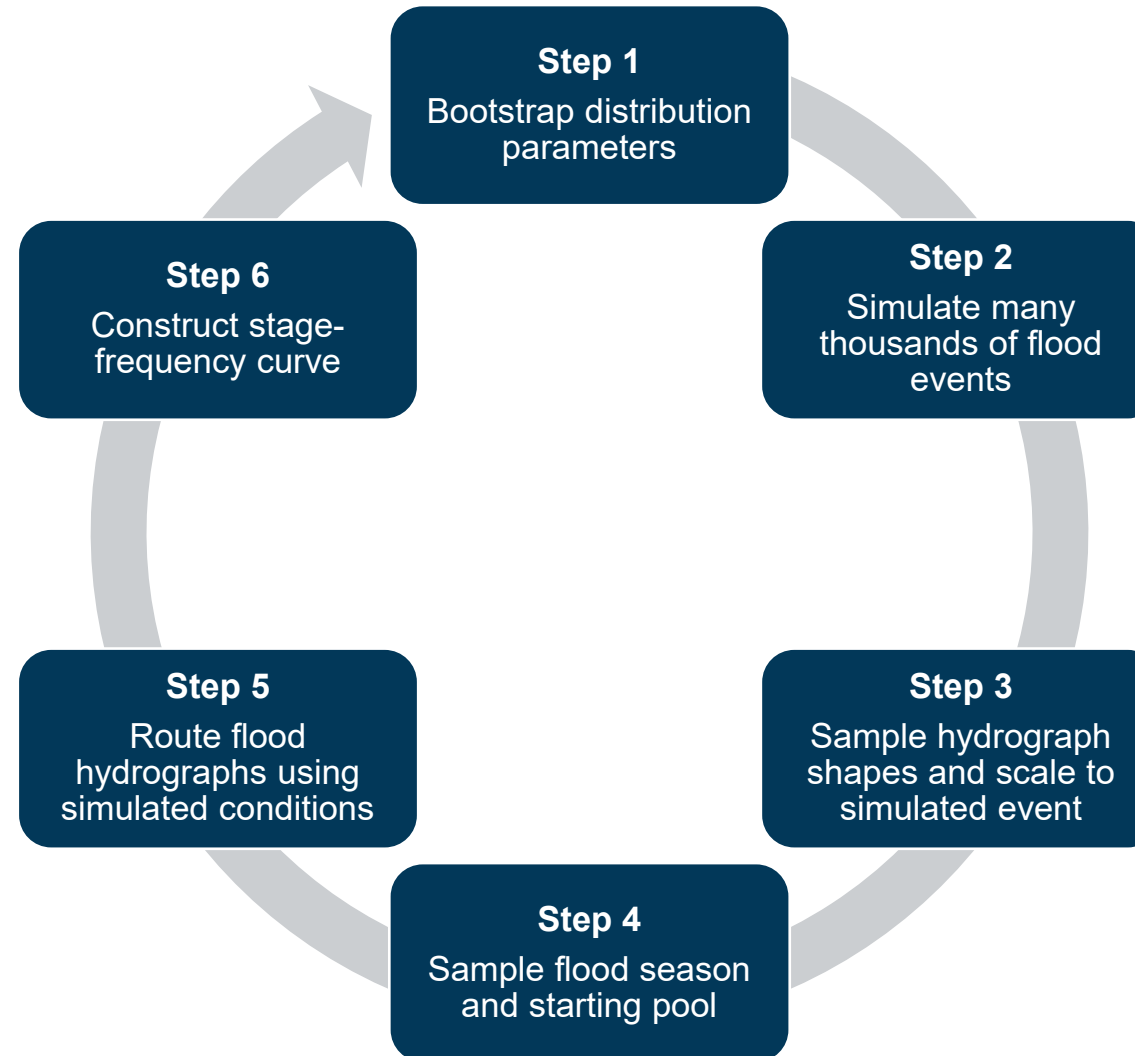
200 inflows
from each bin

Each of the 10,000
inflow volumes
used for a
**reservoir routing
simulation**

Importance and stratified sampling approach



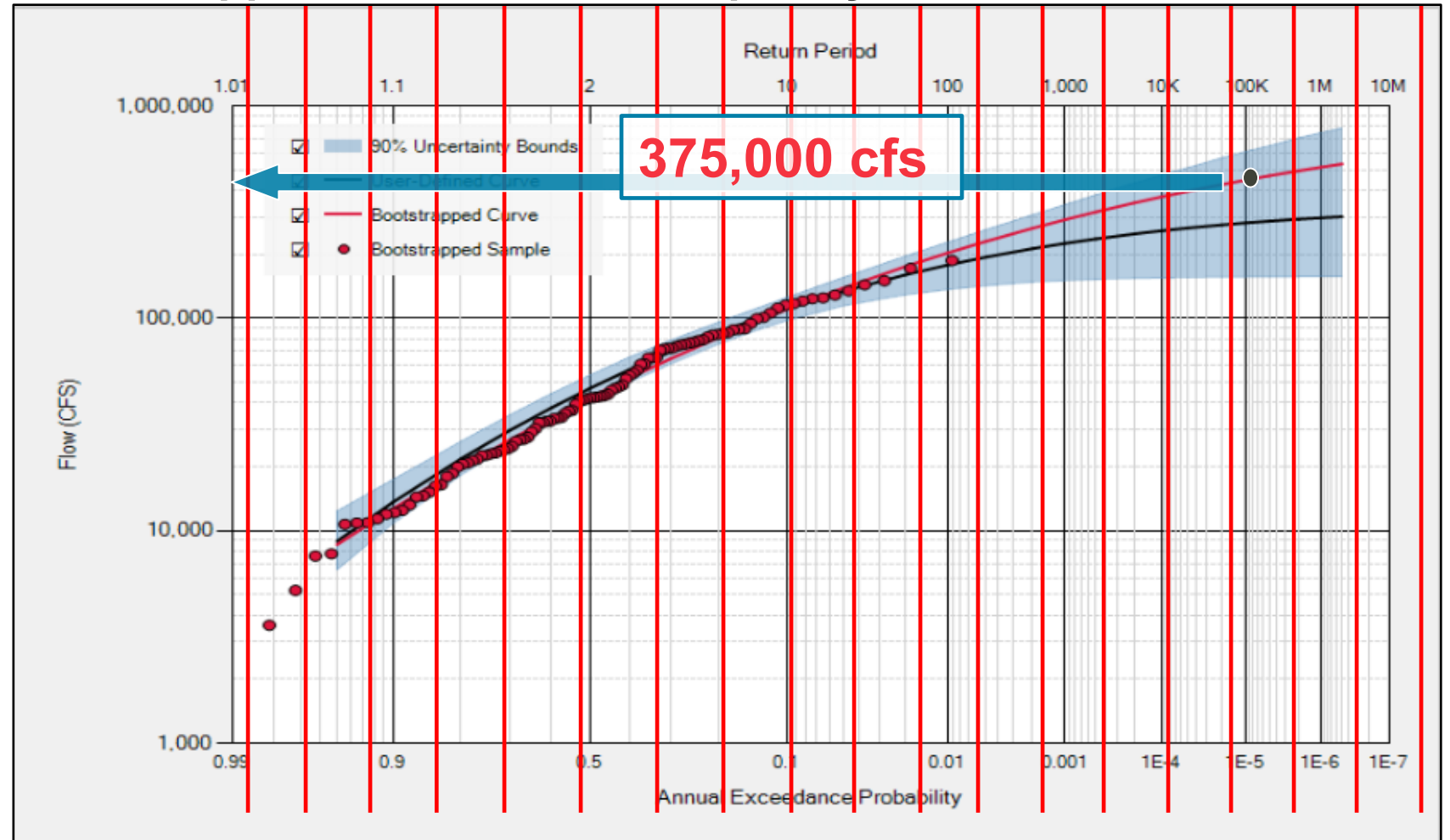
RMC-RFA Simulation: Basic Procedure



RMC-RFA Simulation: Example (1 of 9)

Monte Carlo
sampling of:
Inflow volume
375,000 cfs

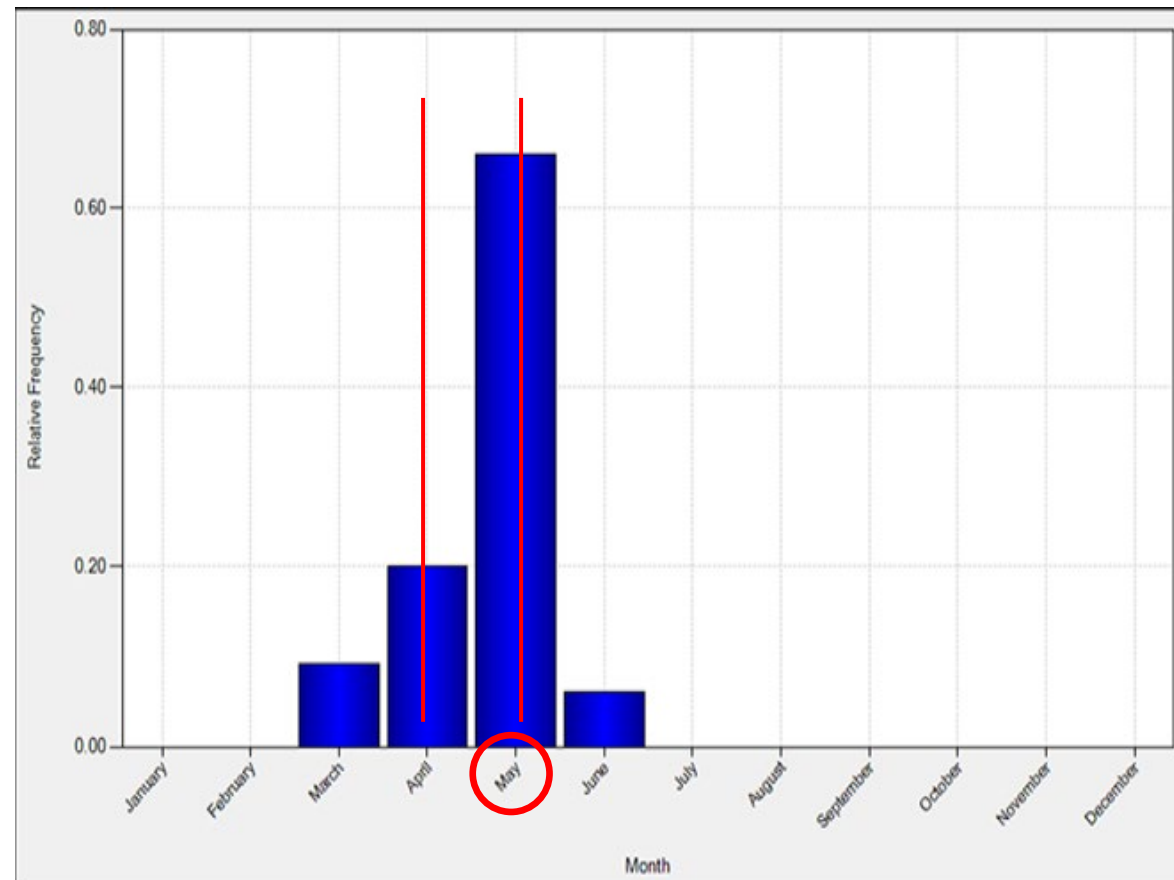
Bootstrapped inflow volume-frequency curve



RMC-RFA Simulation: Example (2 of 9)

Monte Carlo
sampling of:
Inflow volume
375,000 cfs
Starting month
May

Starting months developed from flood
seasonality analysis of inflow dataset



RMC-RFA Simulation: Example (3 of 9)

Monte Carlo
sampling of:

Inflow volume

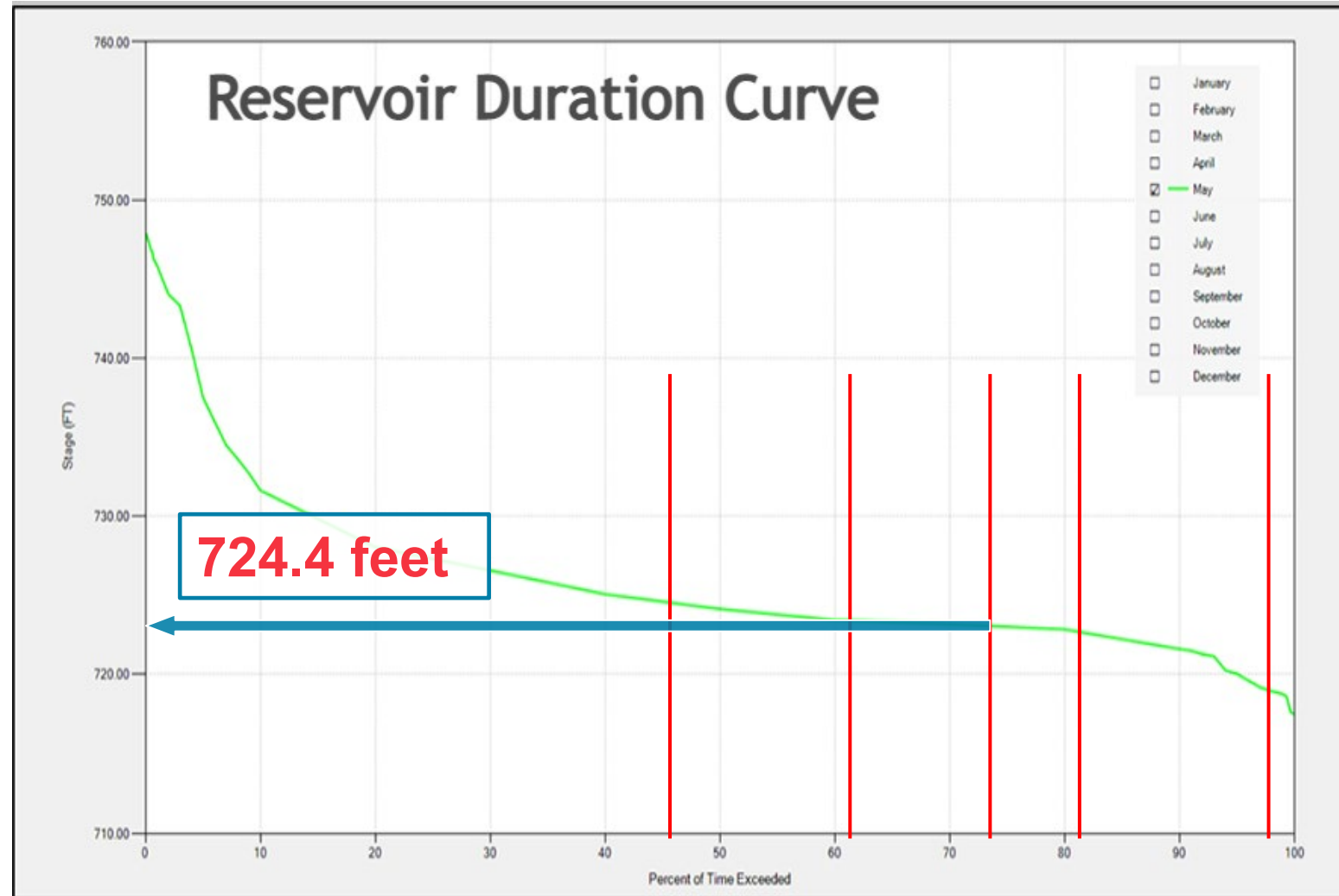
375,000 cfs

Starting month

May

Starting reservoir elevation

724.4 ft



RMC-RFA Simulation: Example (4 of 9)

Monte Carlo
sampling of:

Inflow volume

375,000 cfs

Starting month

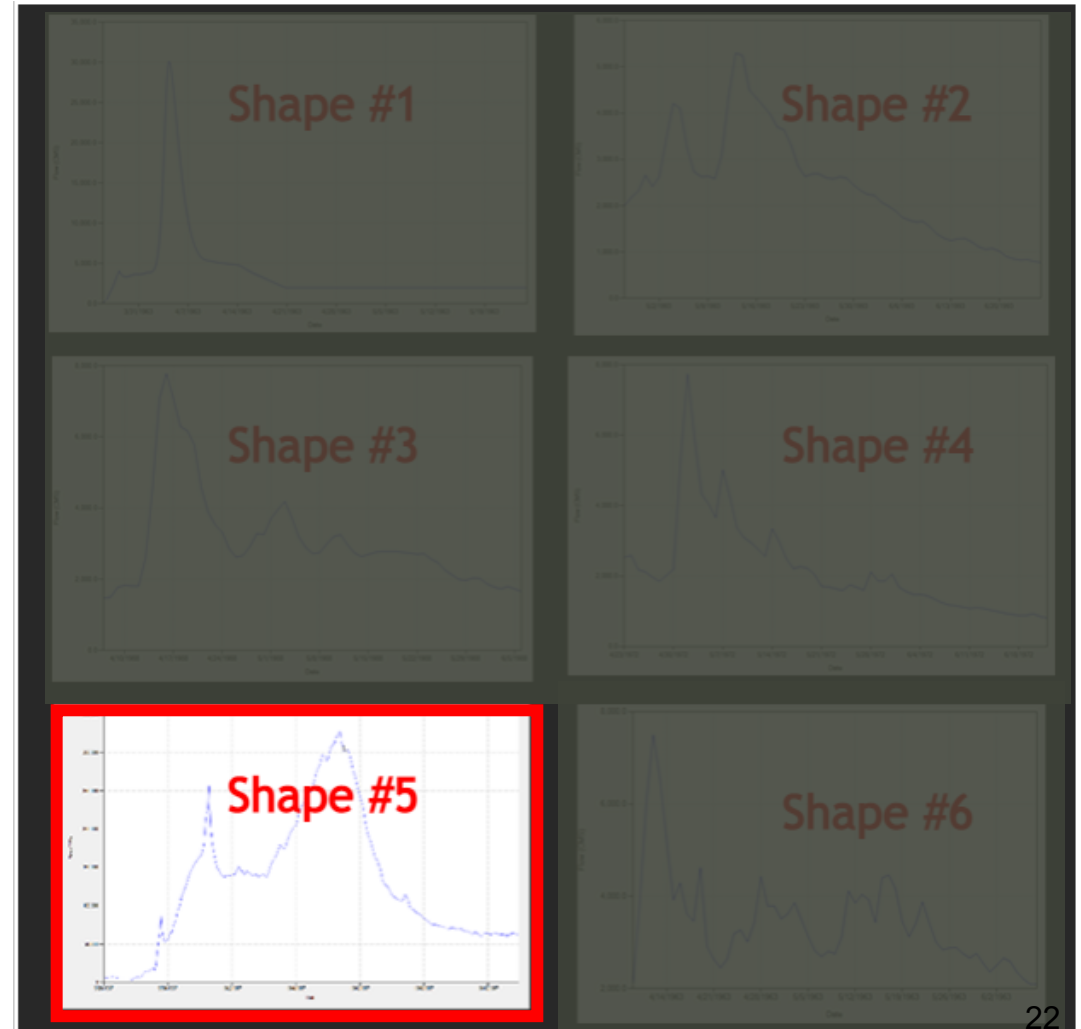
May

Starting reservoir elevation

724.4 ft

Inflow hydrograph shape

Shape # 5



RMC-RFA Simulation: Example (5 of 9)

Monte Carlo
sampling of:

Inflow volume

375,000 cfs

Starting month

May

Starting reservoir elevation

724.4 ft

Inflow hydrograph shape

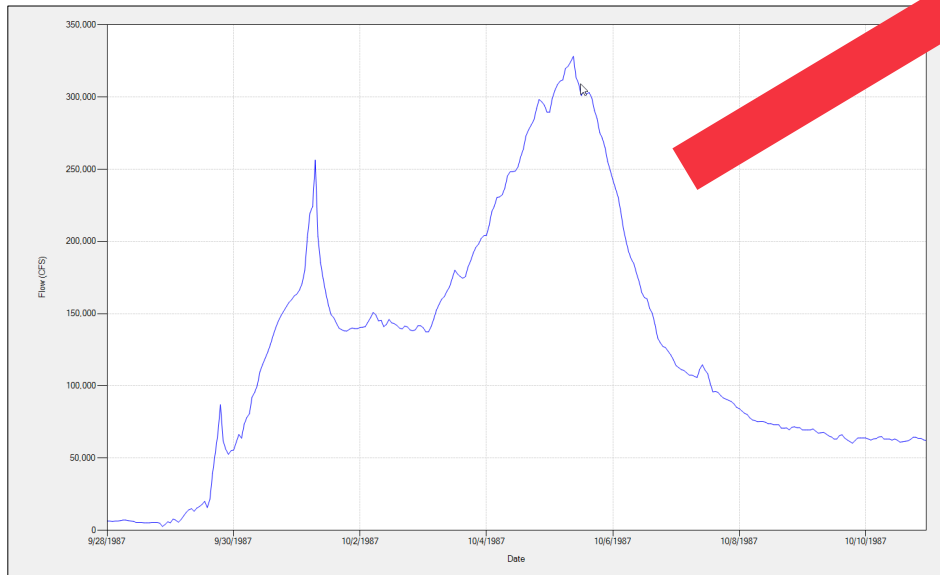
Shape # 5



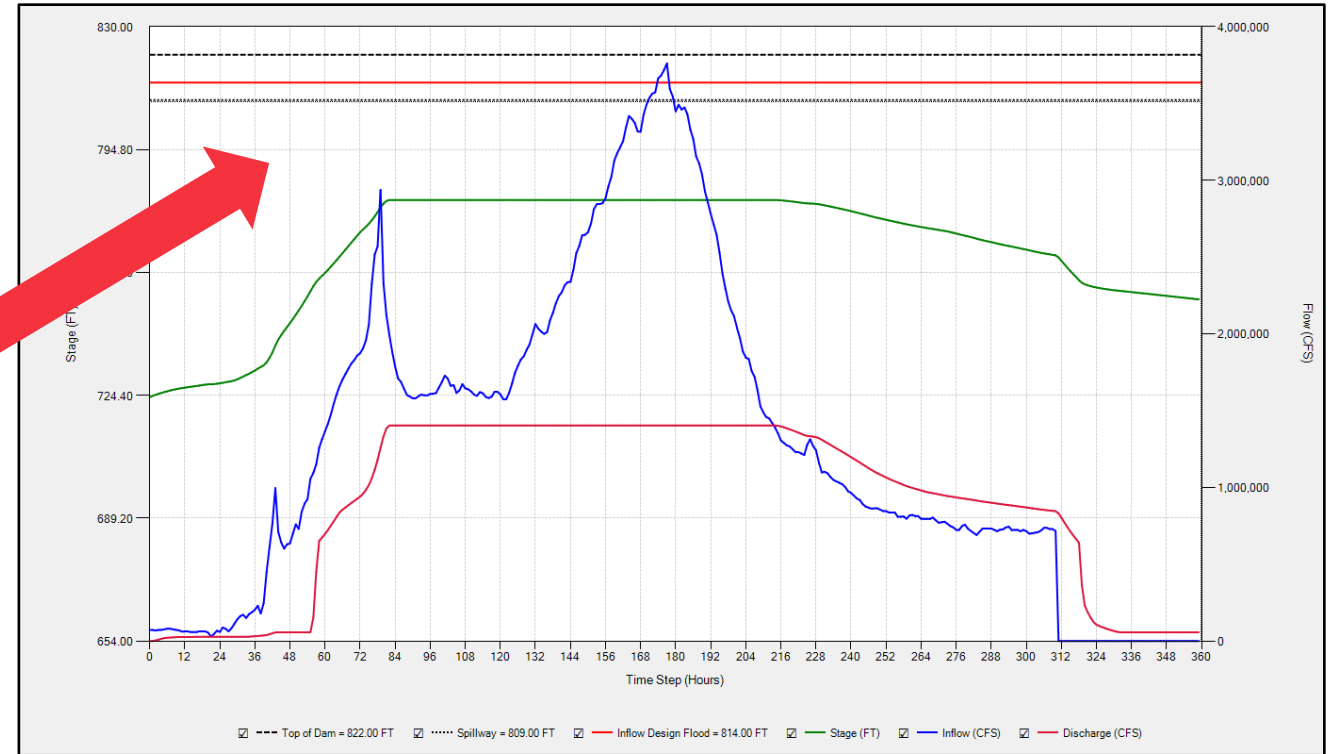
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RMC-RFA Simulation: Example (6 of 9)

User-input hydrograph shape

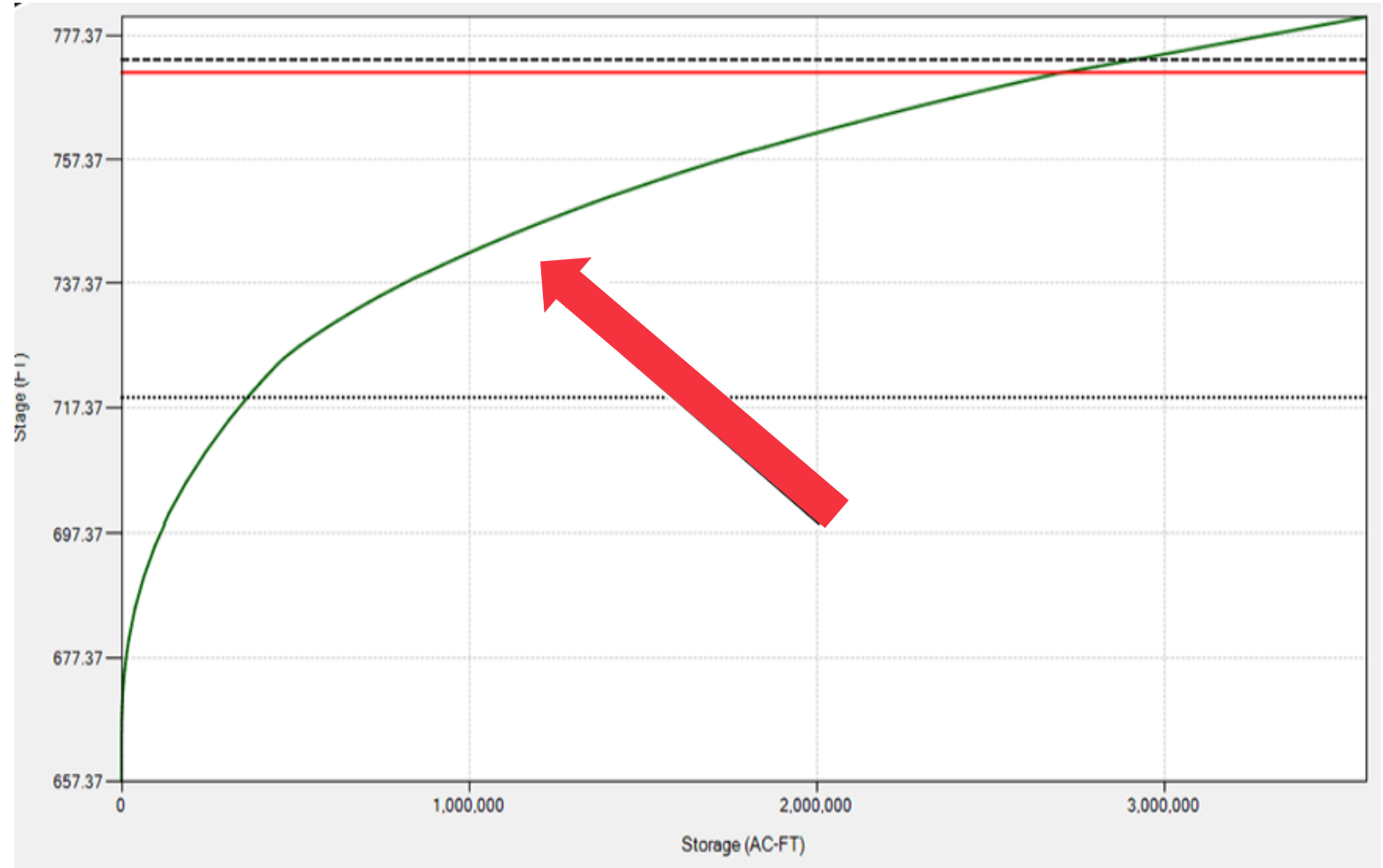


Scaled hydrograph shape



RMC-RFA Simulation: Example (7 of 9)

Reservoir Data			
Stage-Storage-Discharge Function		Reservoir Features	
Ordinate	Stage (FT)	Storage (AC-FT)	Discharge (CFS)
1	657.37	0	0
2	659.37	1	0
3	660.37	4	0
4	661.37	11	0
5	662.37	24	0
6	663.37	55	0
7	664.37	119	0
8	665.37	244	0
9	666.37	448	0
10	667.37	766	0
11	668.37	1,204	0
12	669.37	1,767	0
13	670.37	2,492	0
14	671.37	3,413	0
15	672.37	4,535	0
16	673.37	5,875	0
17	674.37	7,447	0
18	675.37	9,243	0
19	676.37	11,255	0
20	677.37	13,462	0
21	678.37	15,864	0
22	679.37	18,450	0
23	680.37	21,232	0
24	685.37	39,064	0
25	690.37	64,114	0



RMC-RFA Simulation: Example (8 of 9)

Monte Carlo
sampling of:

Inflow volume

375,000 cfs

Starting month

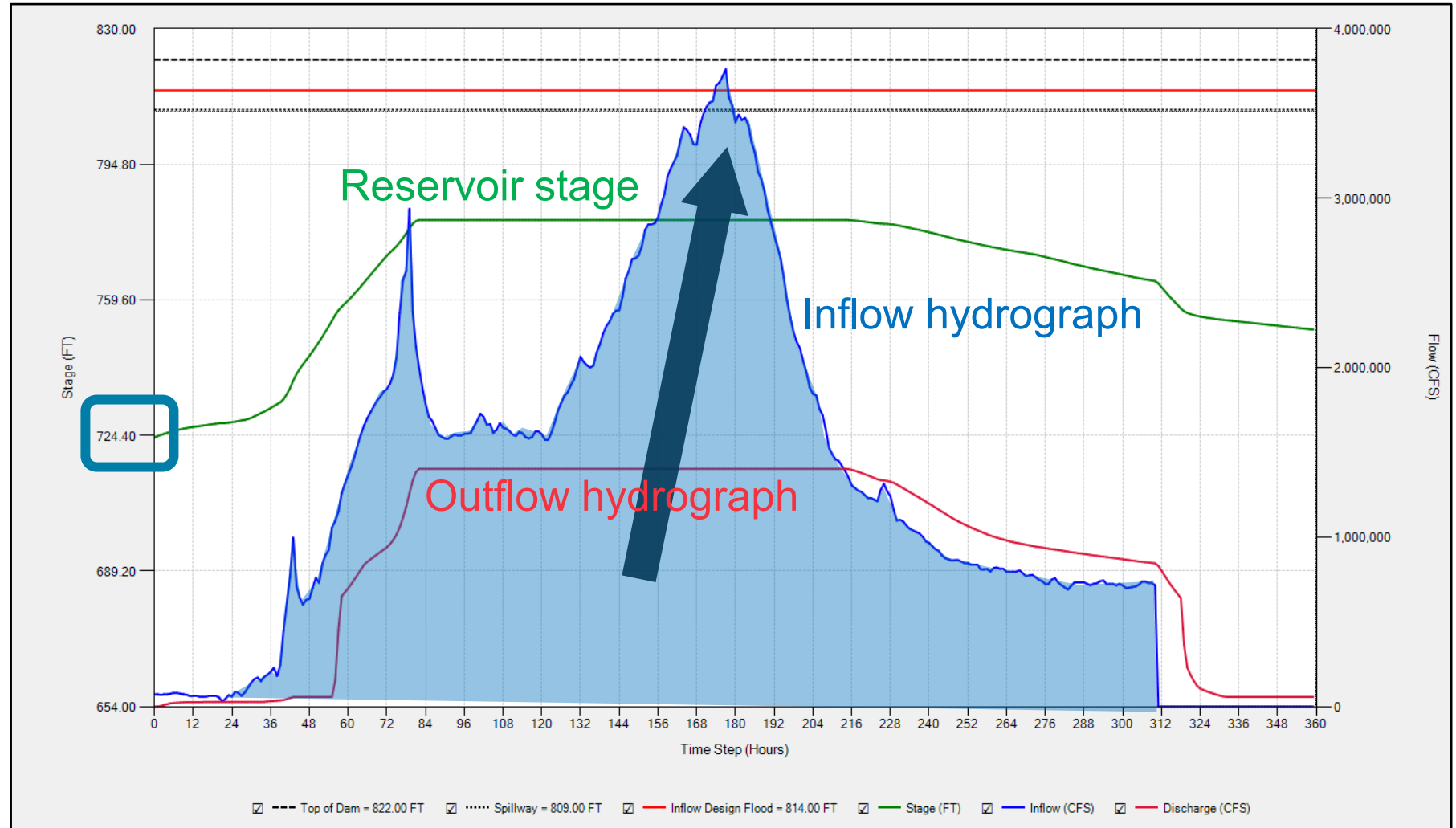
May

Starting reservoir
elevation

724.4 ft

Inflow hydrograph

Shape # 5



RMC-RFA Simulation: Example (9 of 9)

Monte Carlo
sampling of:

Inflow volume

375,000 cfs

Starting month

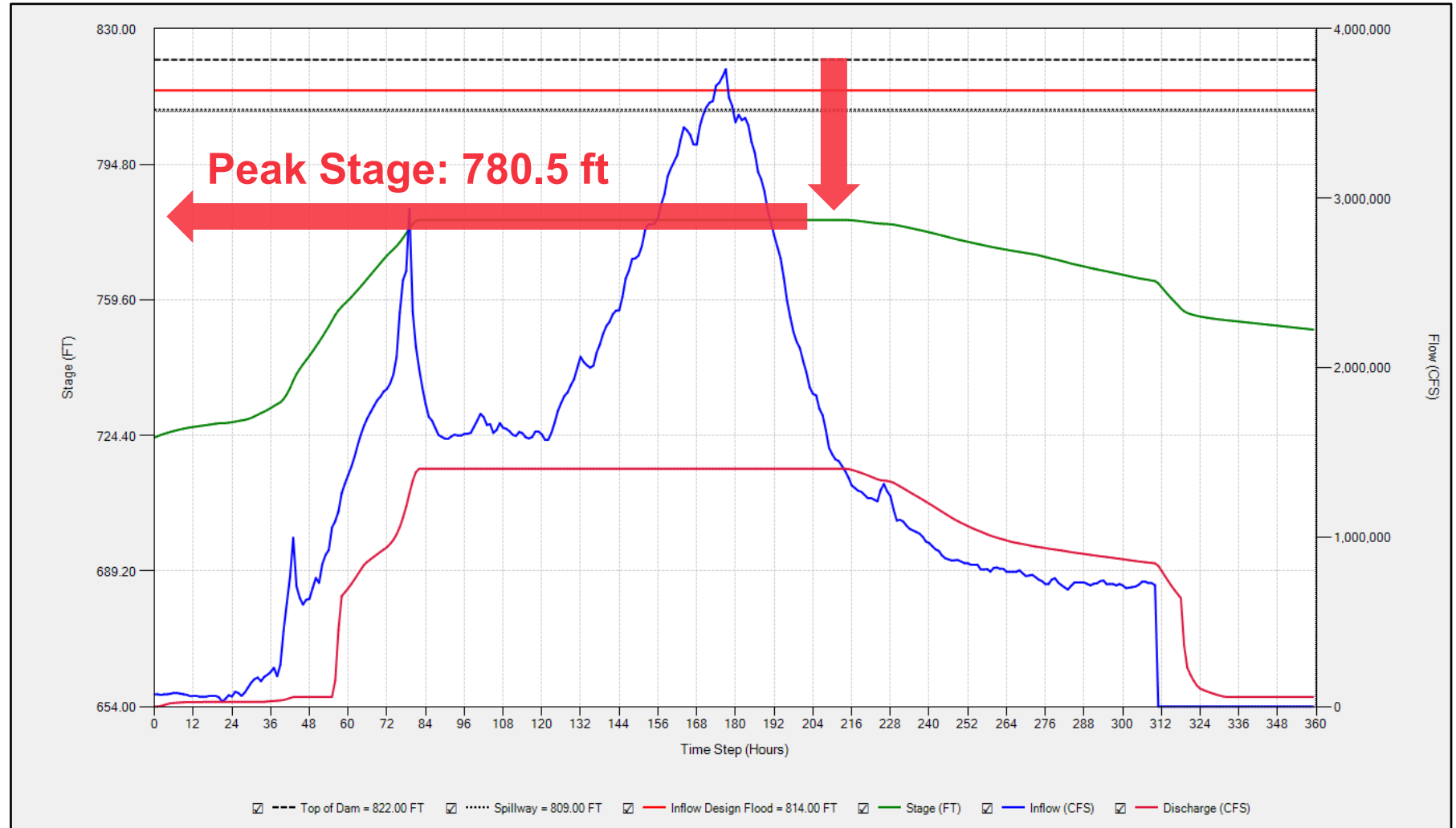
May

Starting reservoir
elevation

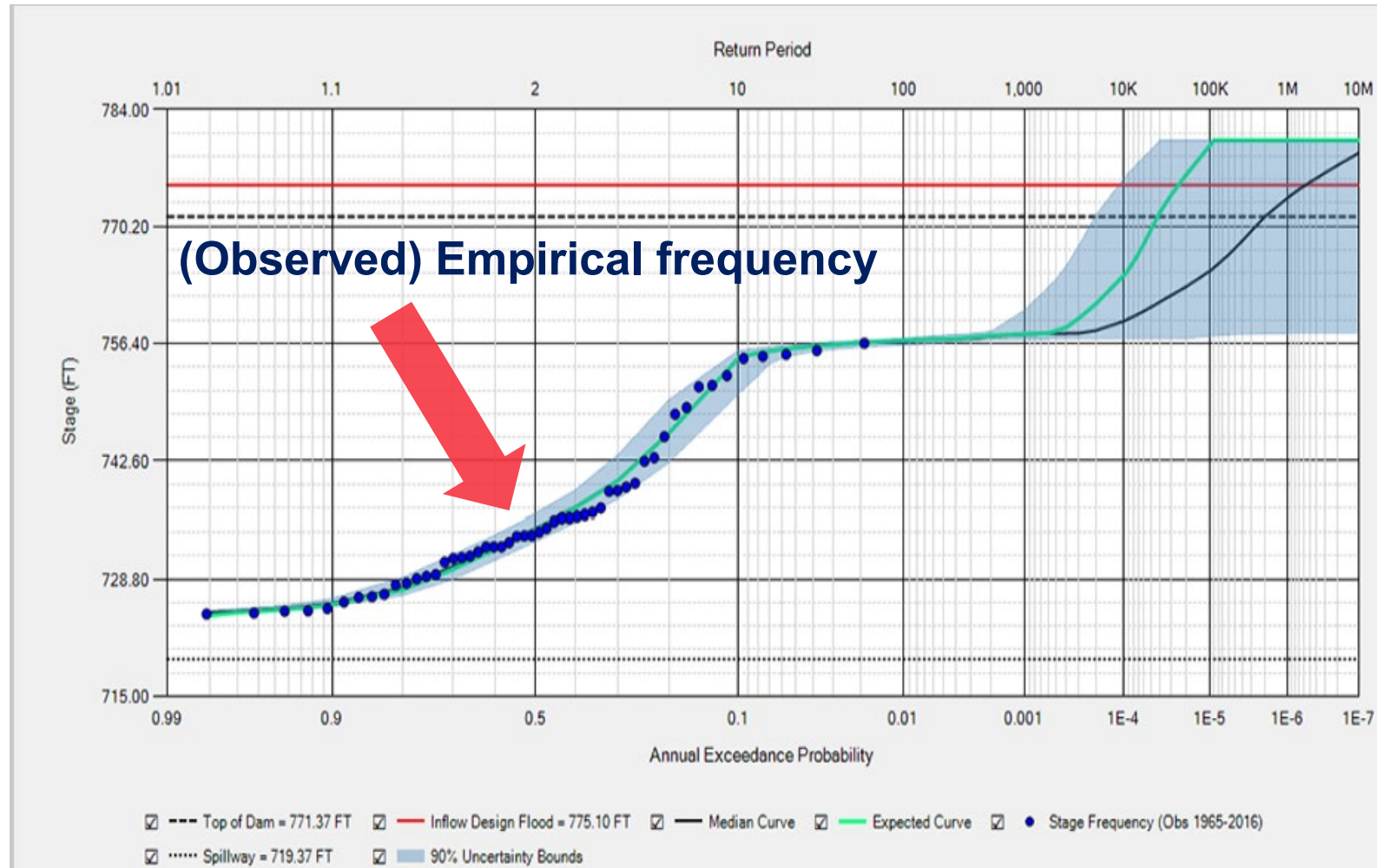
724.4 ft

Inflow hydrograph

Shape # 5



Combining Empirical & Stochastic Frequency



? Questions

