Reliability of reservoir firm yield determined from the historical drought of record

WSSS Seminar

October 15, 2004

USGS
science for a changing world

Outline

I. Introduction and goals

II. Approach

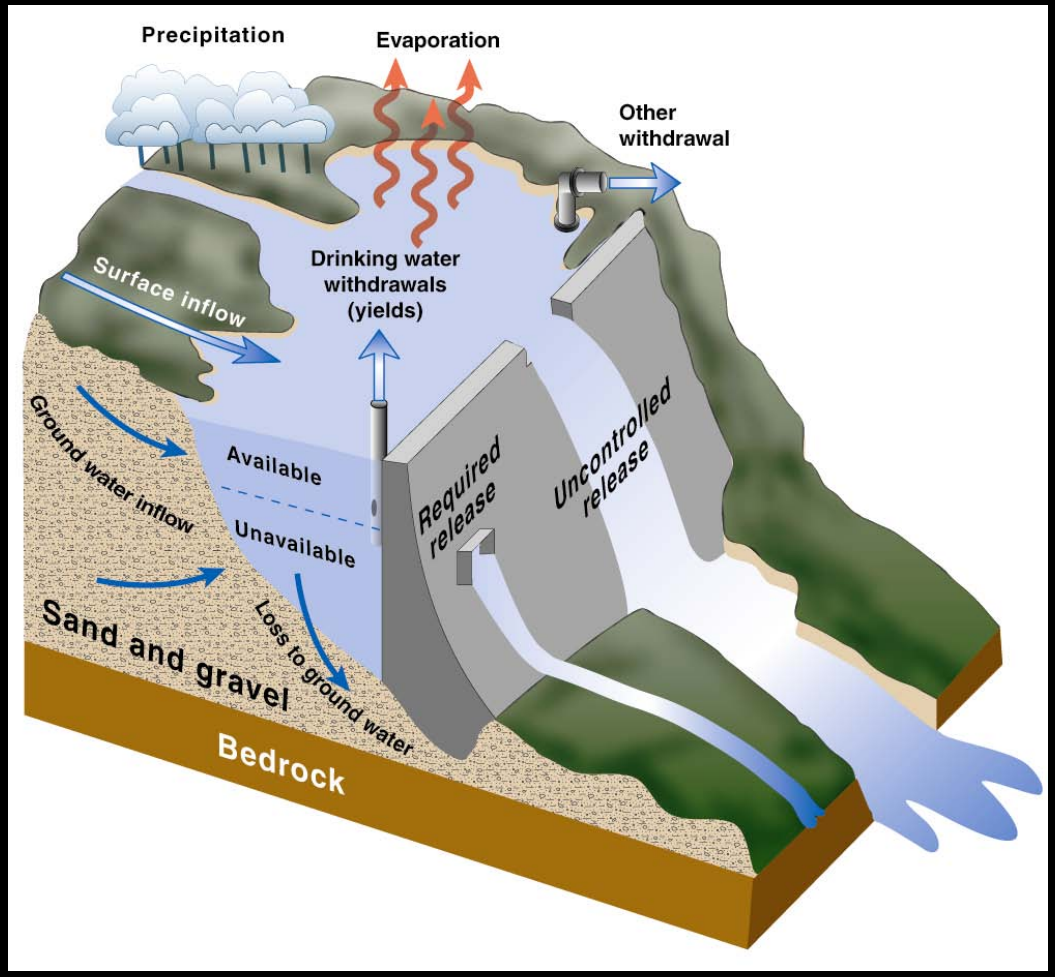
III. Results

IV. Conclusion and next steps

V. Additional work

USGS
science for a changing world

Introduction:
Reservoir Water Balance



$$\text{Water in storage}_t = \text{Inflows}_t - \text{Outflows}_t \qquad \text{Groundwater}_t - \text{Yield} + \text{Storage}_{t-1}$$

If $\text{Water in storage}_t < 0$,
then reservoir has failed

USGS science for a changing world

Illustration by C. Mendelsohn, USGS

Historical reservoir design

- The only time series available to estimate storage was the observed record
  - The worst drought in this time series is termed the *historical drought of record*
- A reservoir was built according to the maximum storage required to deliver the no-failure yield

  → This will occur during the worst drought
- Therefore, most reservoirs were designed according to the historical drought of record

Current methods to design and evaluate reservoirs

- Through the application of stochastic techniques to hydrology, we can create a synthetic time series of any length to use for reservoir design
  - A process called bootstrapping is used to extend and rearrange the historical record
- Reservoir design specifications can be determined from many time series of substantial record length
  - Historical record contains 1 record of length 40-60 years to evaluate the reservoir
  - Bootstrapped records can be repeated 100s of times with each record length greater than 1,000

Goal:

How reliable is a reservoir that was designed according to the drought of record?

- Because the reservoir design guaranteed the yield would be delivered without failure throughout the historical record, we can ask:

  1. What is the corresponding no-failure reservoir yield?

  2. How reliable is this yield if the reservoir were to experience alternative droughts other than the historical drought of record?

  3. Under what conditions is this or is this not a reliable method to design reservoirs?

USGS science for a changing world

Approach:
How do we answer these questions?

- Our dataset comprised 36 reservoirs in Massachusetts and 30 reservoirs across the U.S.

- We designed the following approach to answer our questions:

  1. *What is the corresponding no-failure reservoir yield?*

     → Computed the maximum yield that did not result in a reservoir failure throughout the historical period of record

USGS
science for a changing world

2. *How reliable is this yield if the reservoir were to experience droughts other than the historical drought of record?*

   → Used the bootstrap technique to create at least 100 synthetic records that were 12,000 months in length

   → For each synthetic record, counted the number of failures that resulted from the historical no-failure yield and determined reliability of the reservoir

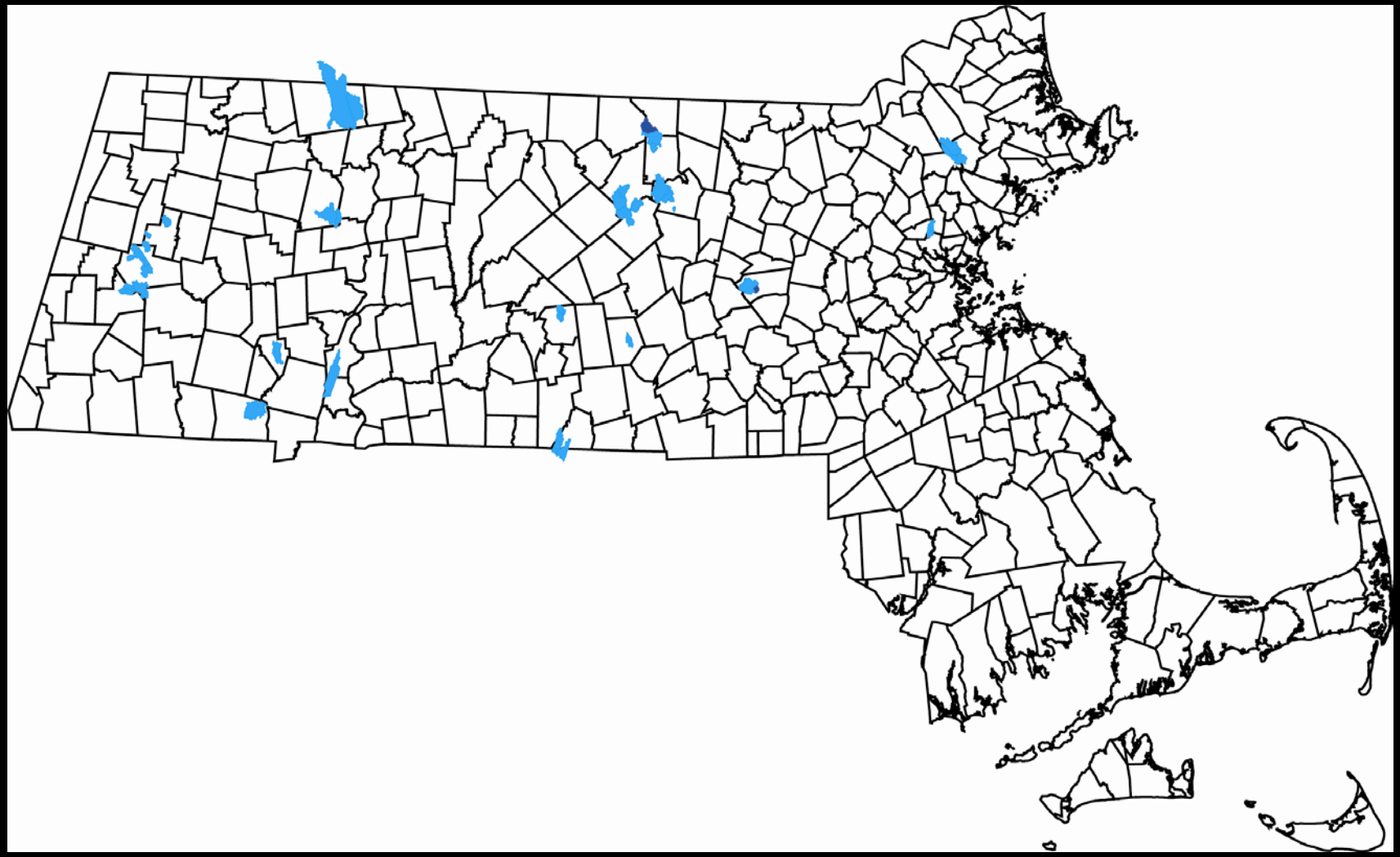
   → From the individual reliability estimates, we determined an average reliability

3. *Under what conditions is this or is this not a reliable method to design reservoirs?*

   → Compared average reliability to reservoir and streamflow characteristics

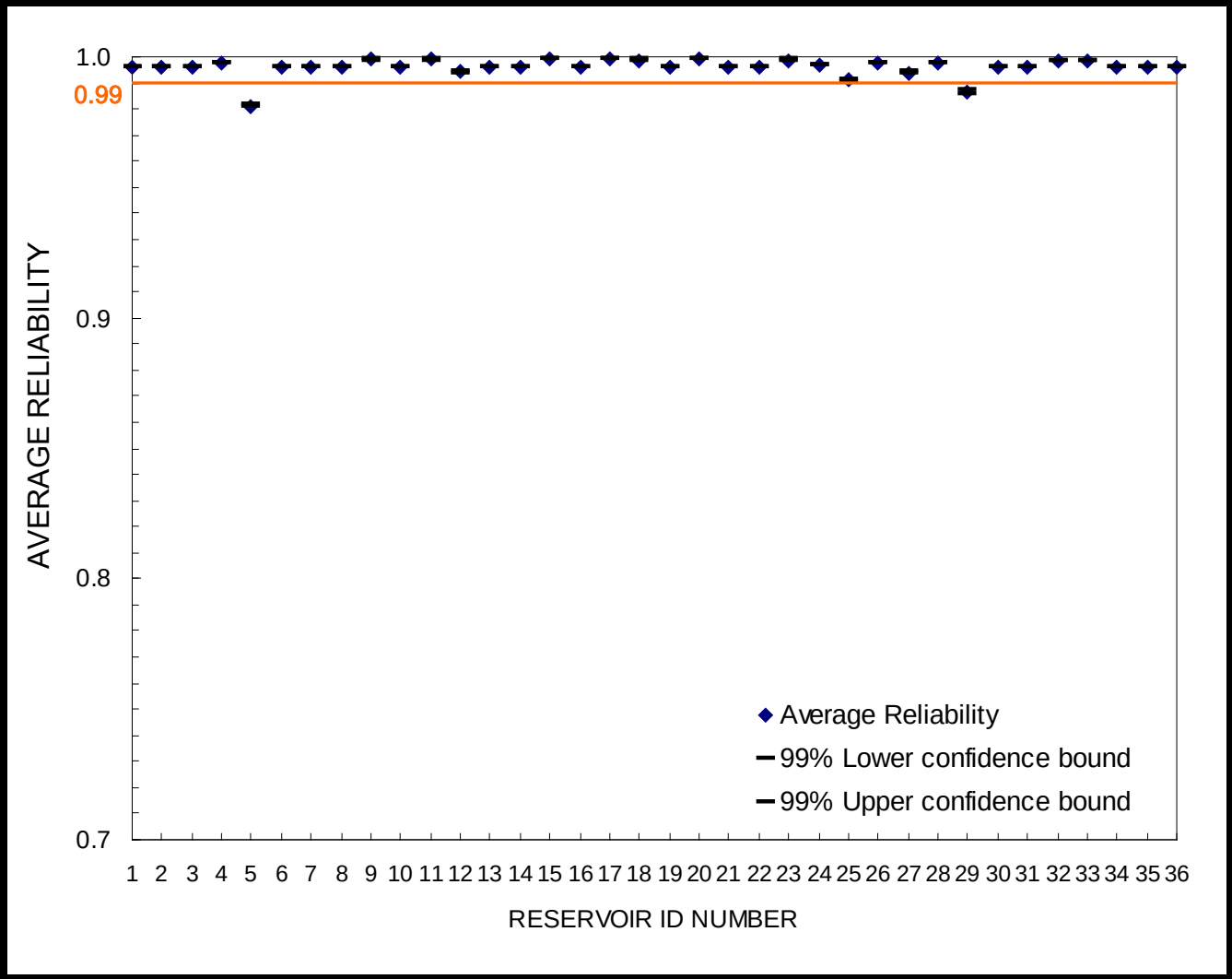
USGS
science for a changing world

Location of Study Reservoirs in Massachusetts



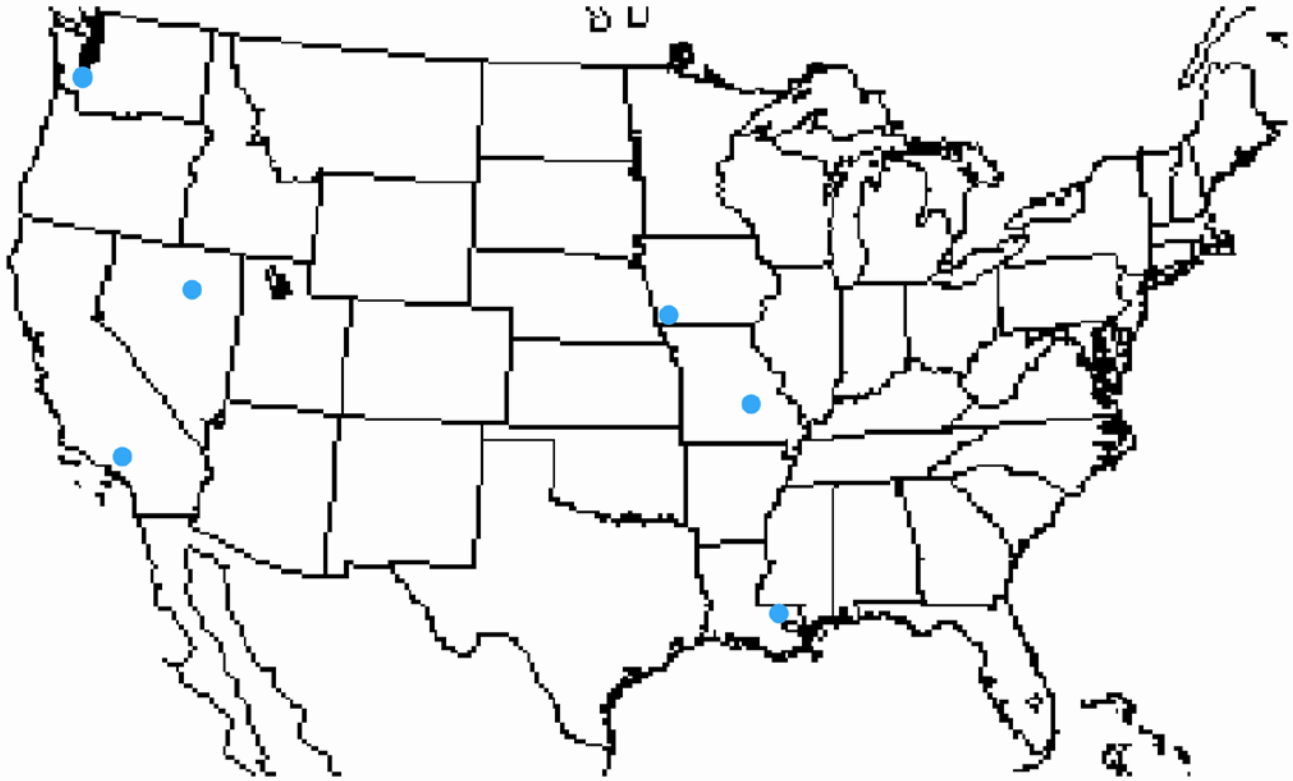
USGS
science for a changing world

Preliminary Results:
What is the reliability of the drought of record for reservoirs in Massachusetts?



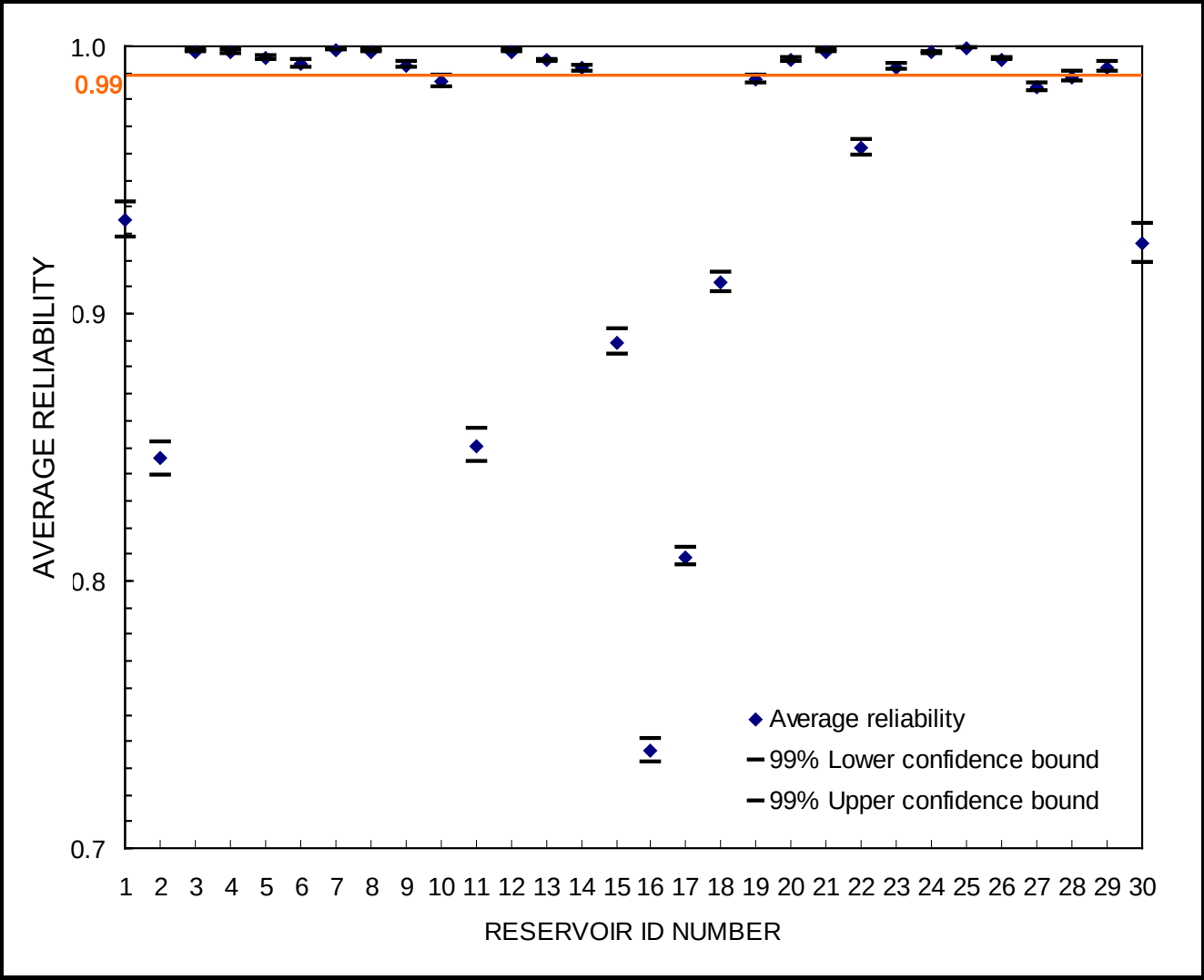
USGS
science for a changing world

Location of Study Reservoirs in the U.S.



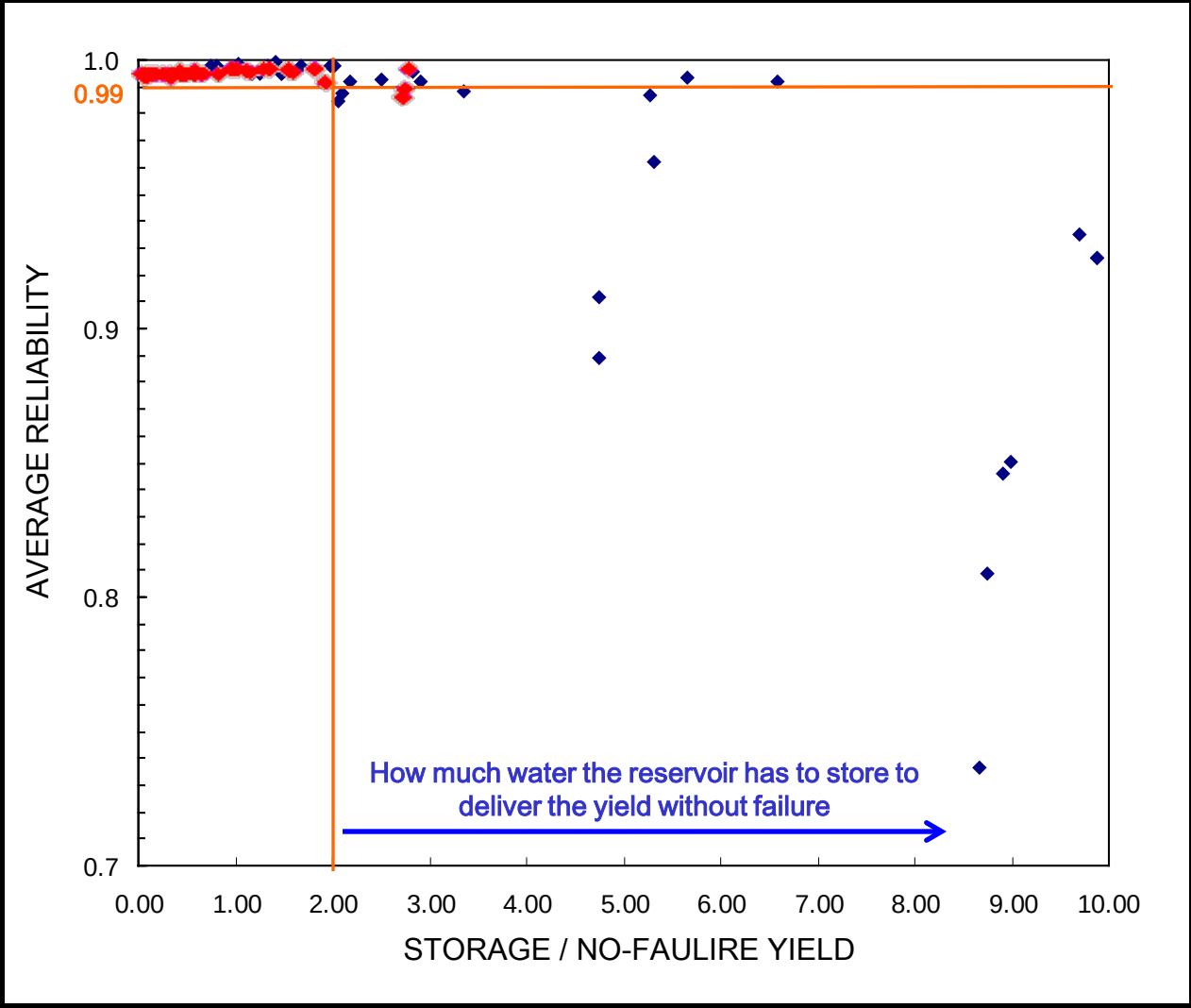
USGS
science for a changing world

Preliminary Results:
What is the reliability of the drought of record for reservoirs across the United States?



USGS science for a changing world

Preliminary Results:
What causes some reservoirs to be more reliable than others?



USGS science for a changing world

Preliminary Conclusions: Why does this matter?

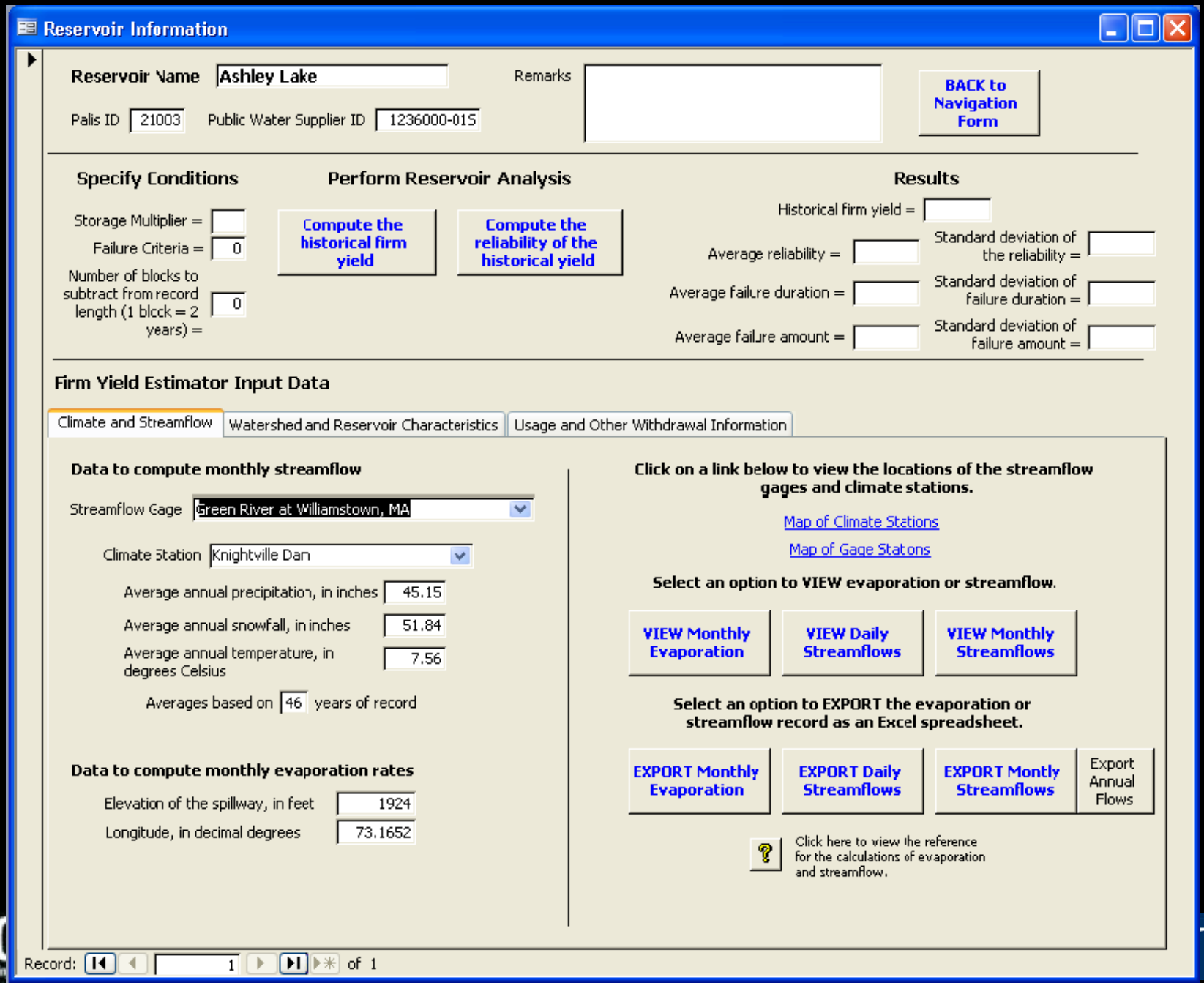
- Reservoirs designed on the basis of the drought of record are highly reliable if storage-yield ratio less than 2
  - Stochastic streamflow methods may not be needed to evaluate this class of reservoirs
- Establishing a reservoir classification scheme that provides *a priori* knowledge about the behavior of reservoirs designed on the basis of the drought of record

Next steps:
Future directions for this work

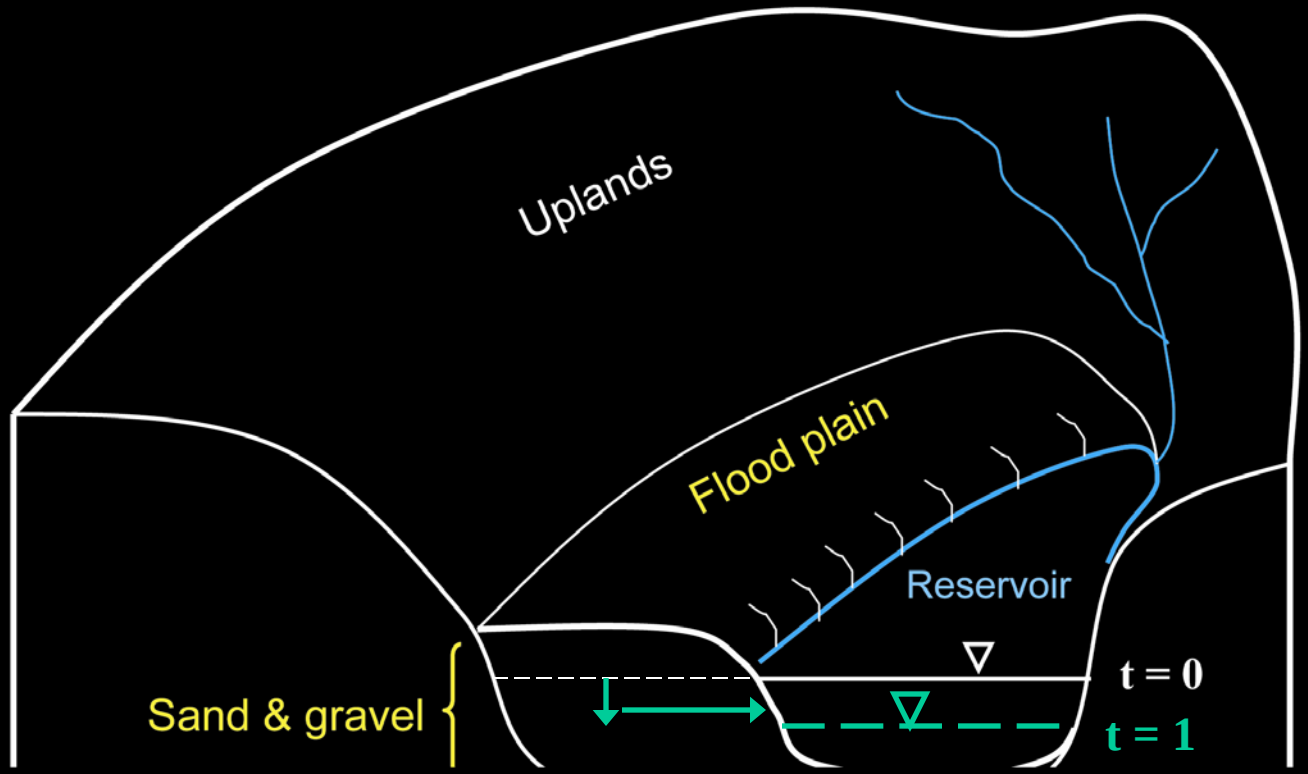
- What is the likelihood of the observed drought of record?
  - If we looked at another historical period of the same length, would our results change?
- What about other metrics of reservoir behavior, such as resilience and vulnerability?
- Add context to the reliability estimates
- Need to QA our methodology

USGS
science for a changing world

Additional work



Additional Work: Estimate ground-water component to reservoirs



USGS
science for a changing world