Salt Lake City Tree-Ring Workshop

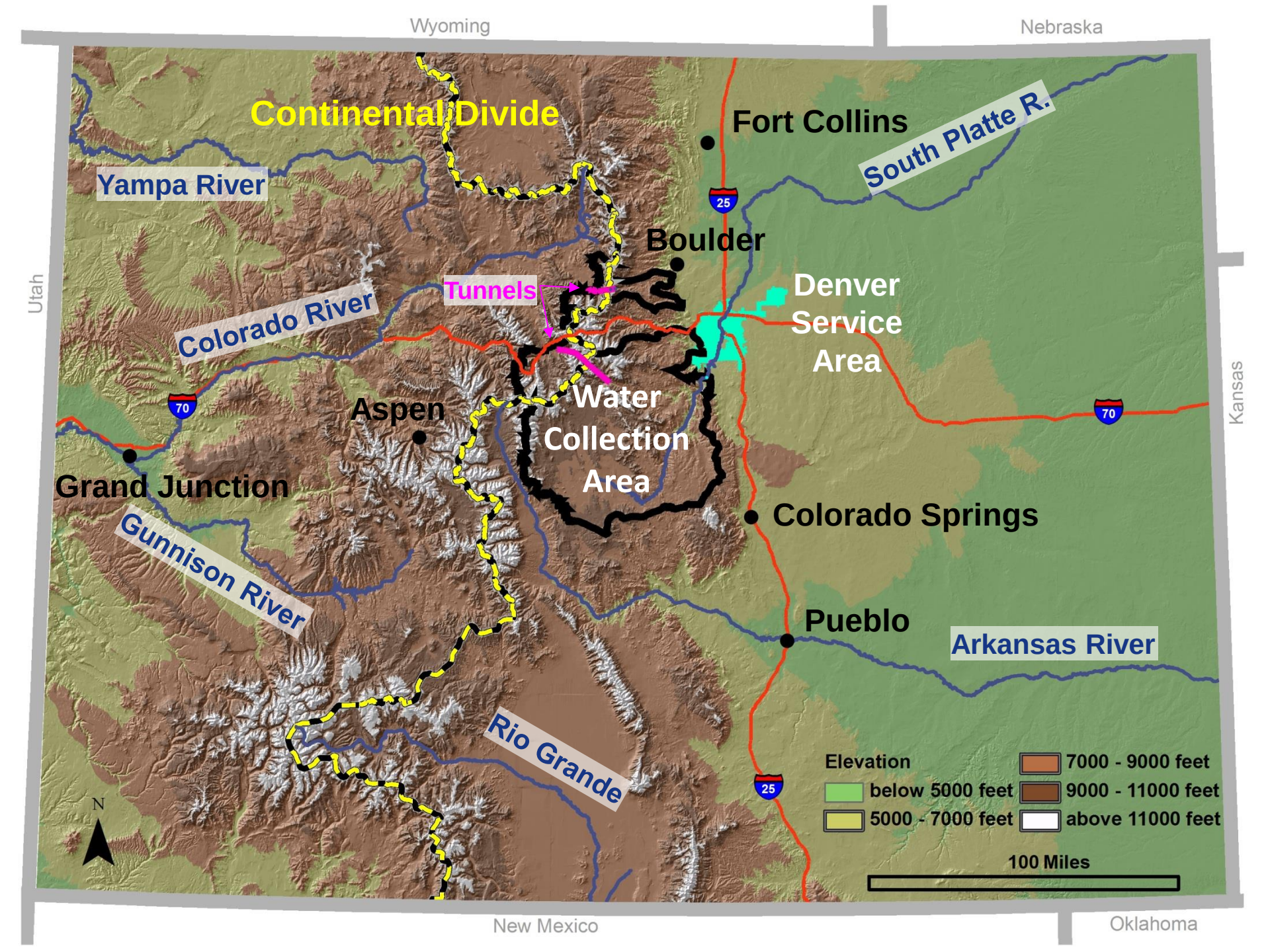
October 2, 2013

Denver Water's Use of Tree-Ring-based Stream Flow Reconstructions

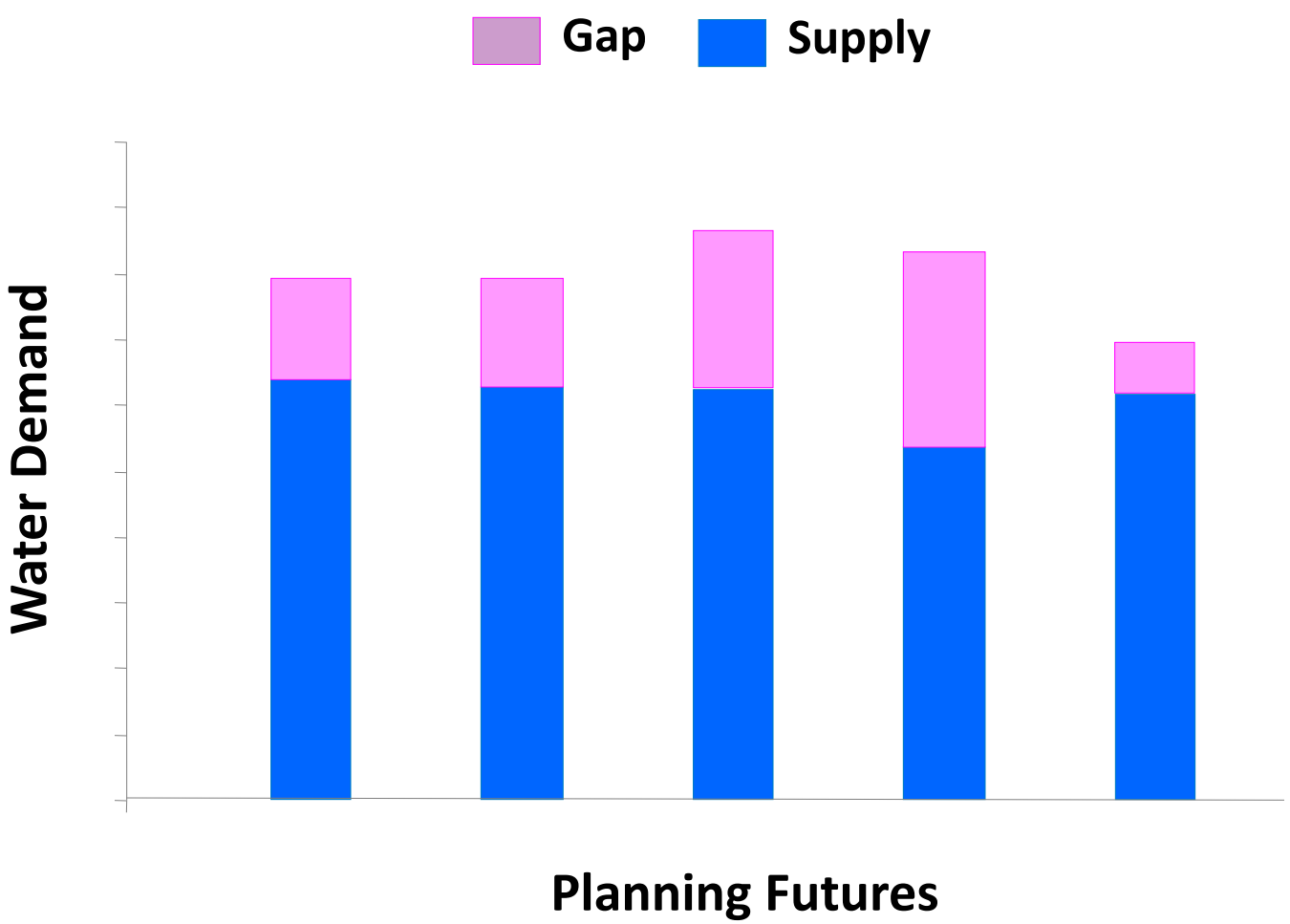
Steve.Schmitzer@DenverWater.org

303-628-6525

DENVER WATER


Wyoming
Nebraska
Utah
Kansas
New Mexico
Oklahoma
Continental Divide
Yampa River
Fort Collins
South Platte R.
Boulder
Tunnels
Colorado River
Denver
Service
Area
Aspen
Water
Collection
Area
Grand Junction
Gunnison River
Colorado Springs
Pueblo
Arkansas River
Rio Grande
25
70
N
Elevation
below 5000 feet
5000 - 7000 feet
7000 - 9000 feet
9000 - 11000 feet
above 11000 feet
100 Miles

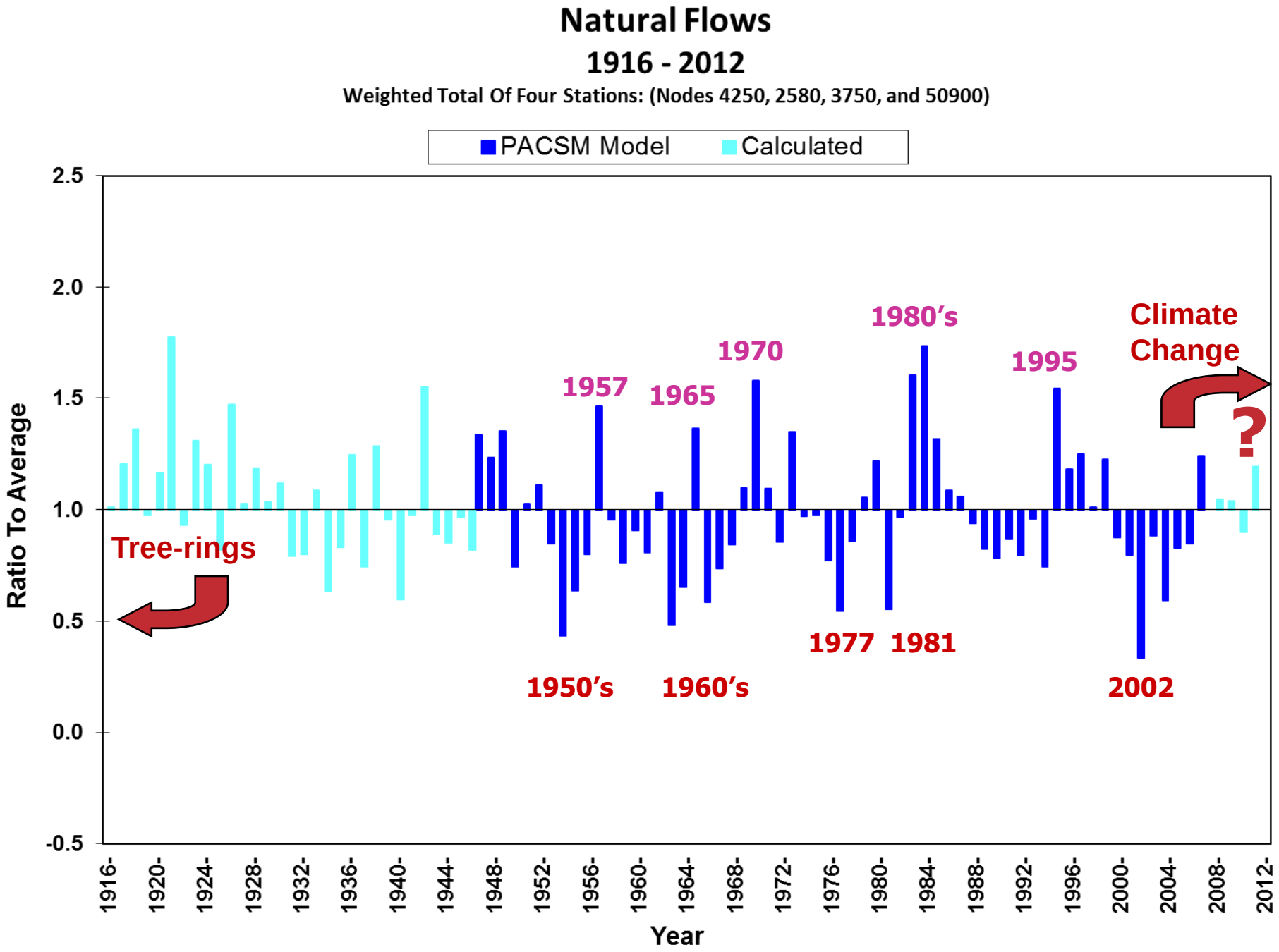
Gap Between Supply and Demand in 2050



Platte and Colorado Simulation Model PACSM

- **Integrated system of computer programs that simulate stream flows, reservoir operations and water supply in the South Platte and Colorado River basins.**
  - **Includes many water supply entities and systems, water demands, water rights and agreements.**

- **Hydrologic Study Period: 1947 – 1991 (provisional through 2007)**
  - **Includes the severe droughts and wet periods.**
  - **Daily data at approximately 500 locations on East and West Slopes.**


Natural Flows
1916 - 2012
Weighted Total Of Four Stations: (Nodes 4250, 2580, 3750, and 50900)
PACSM Model
Calculated
Ratio To Average
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Tree-rings
1950's
1957
1960's
1965
1970
1977
1980's
1981
1995
2002
Climate Change
?
1916-
1920-
1924-
1928-
1932-
1936-
1940-
1944-
1948-
1952-
1956-
1960-
1964-
1968-
1972-
1976-
1980-
1984-
1988-
1992-
1996-
2000-
2004-
2008-
2012-
Year

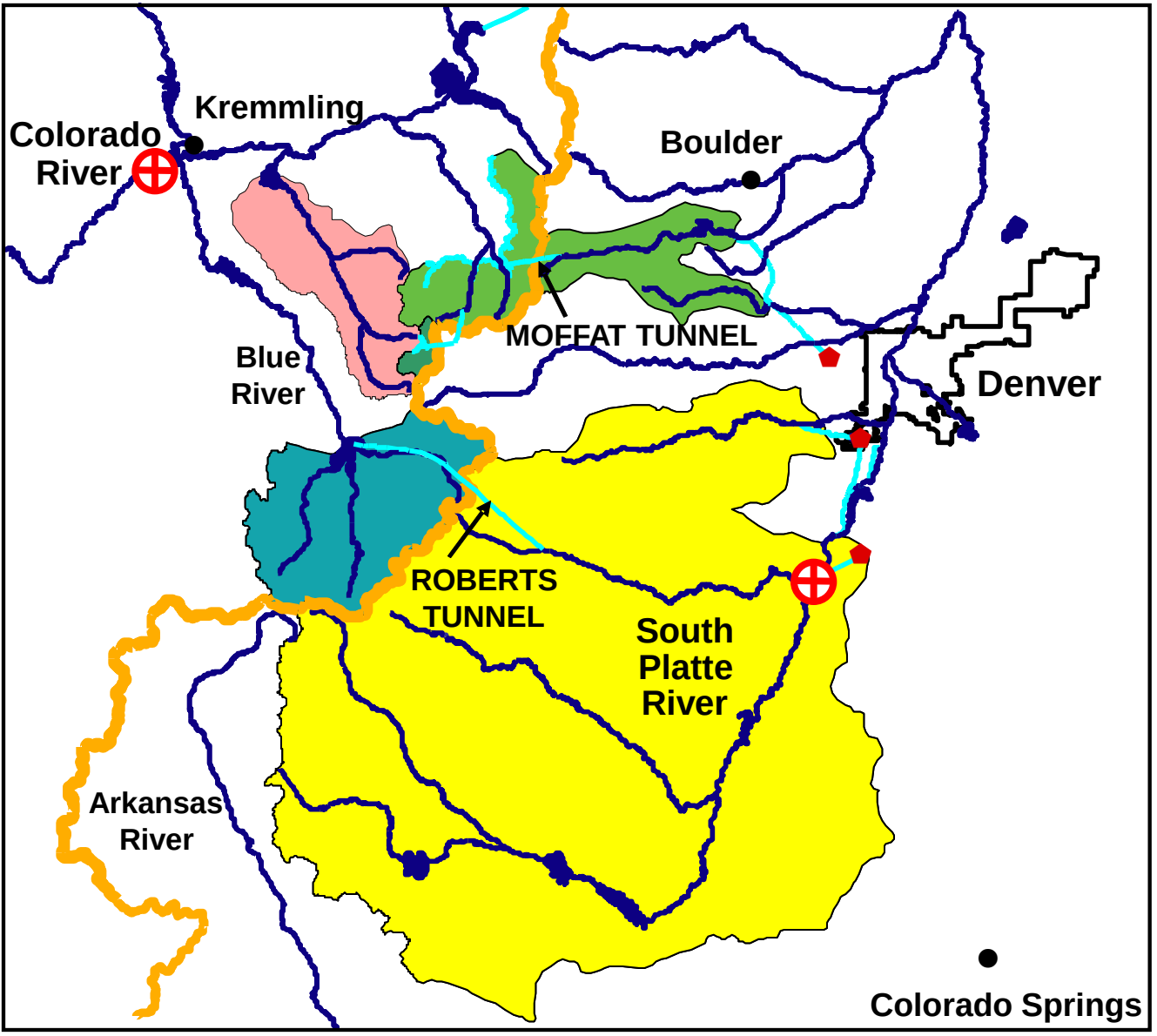
Tree-Ring-Based Stream Flow Reconstructions

- Uses East Slope and West Slope tree-ring-based stream flow reconstructions.
    1) South Platte River at South Platte
    2) Colorado River at Kremmling

- Tree-Ring Data 1634 – 1946
- Gage Data 1947 – 2007
- Modified PACSM to analyze the longer time frame

Denver Board of Water Commissioners

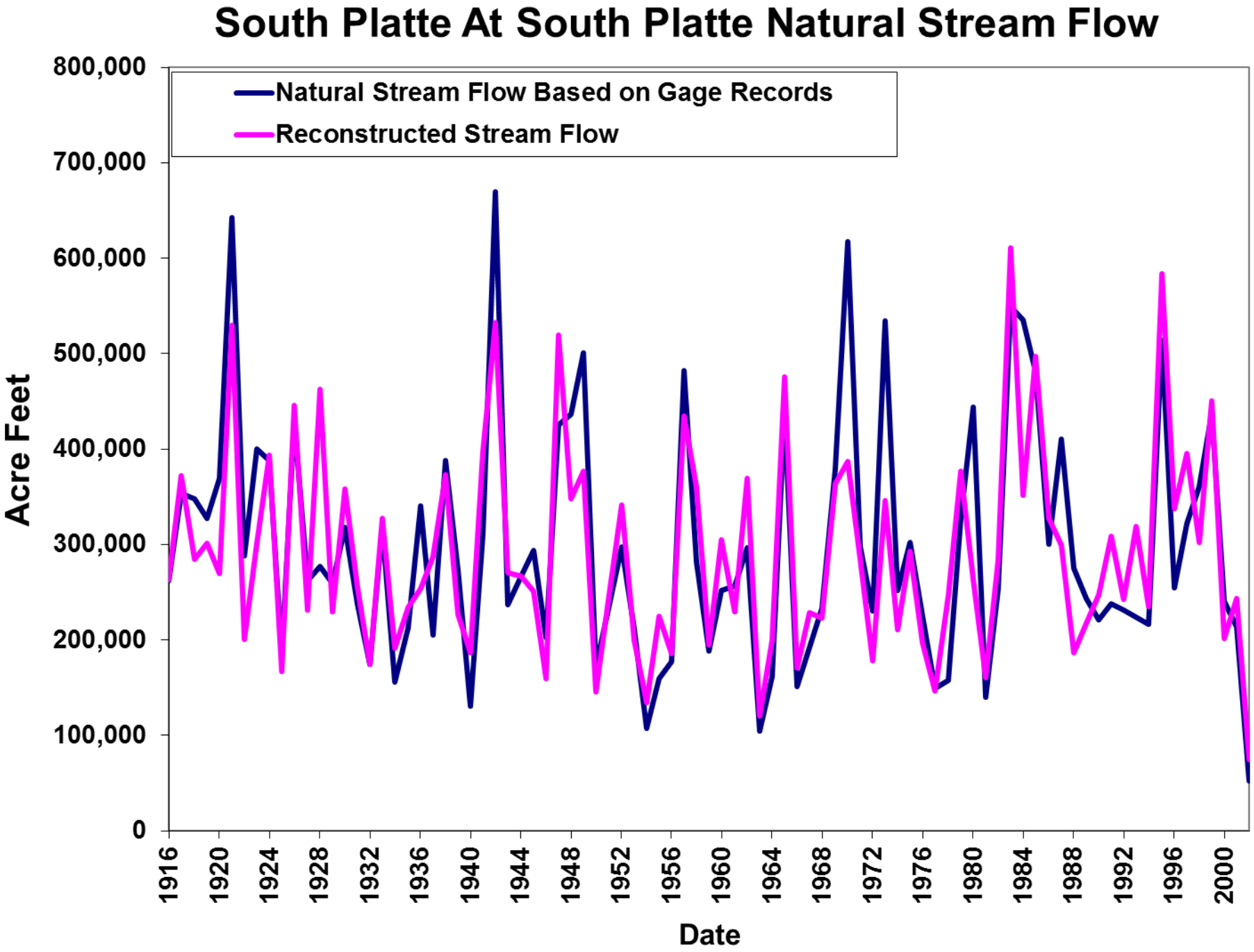
Water Collection System

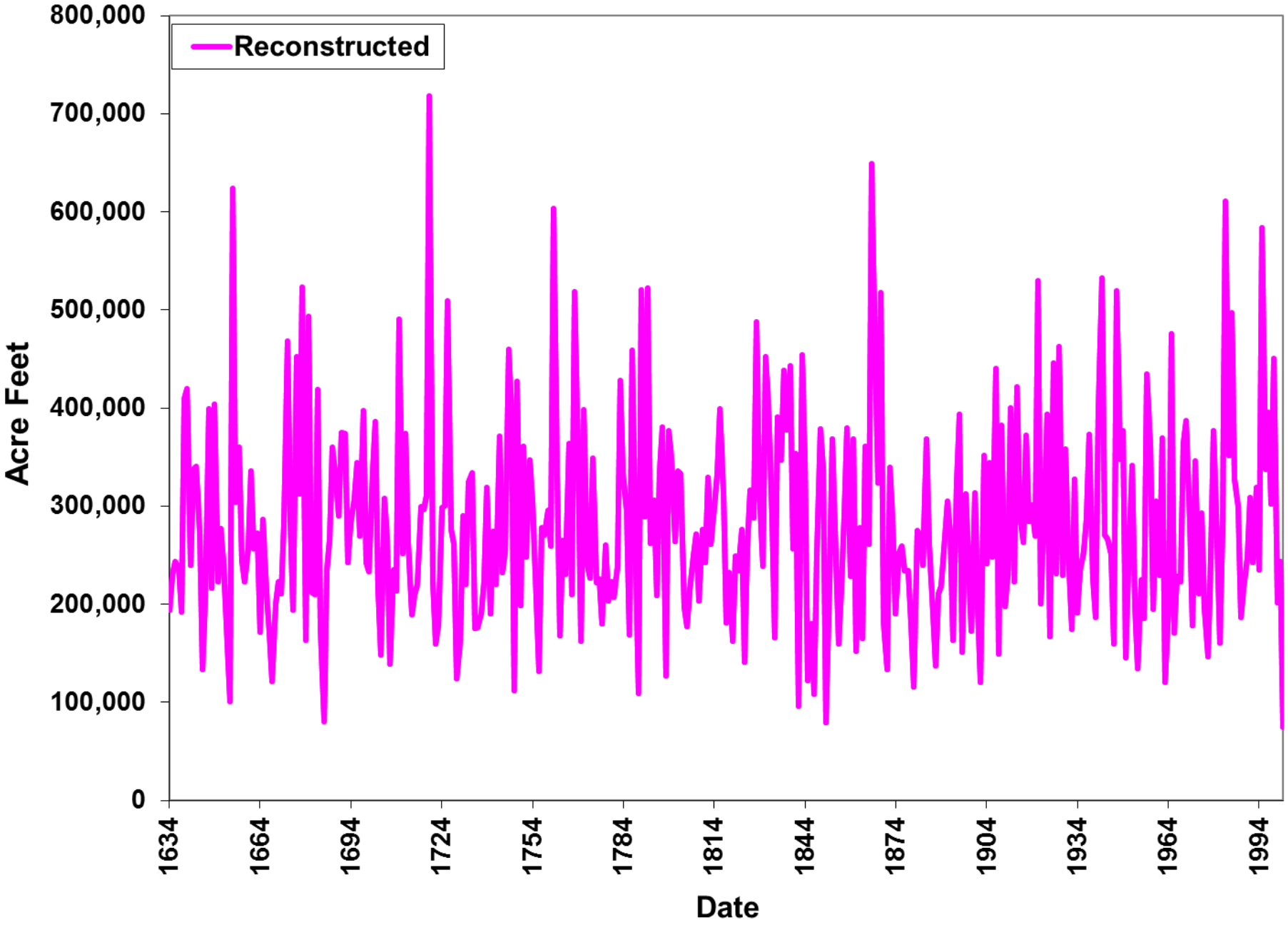


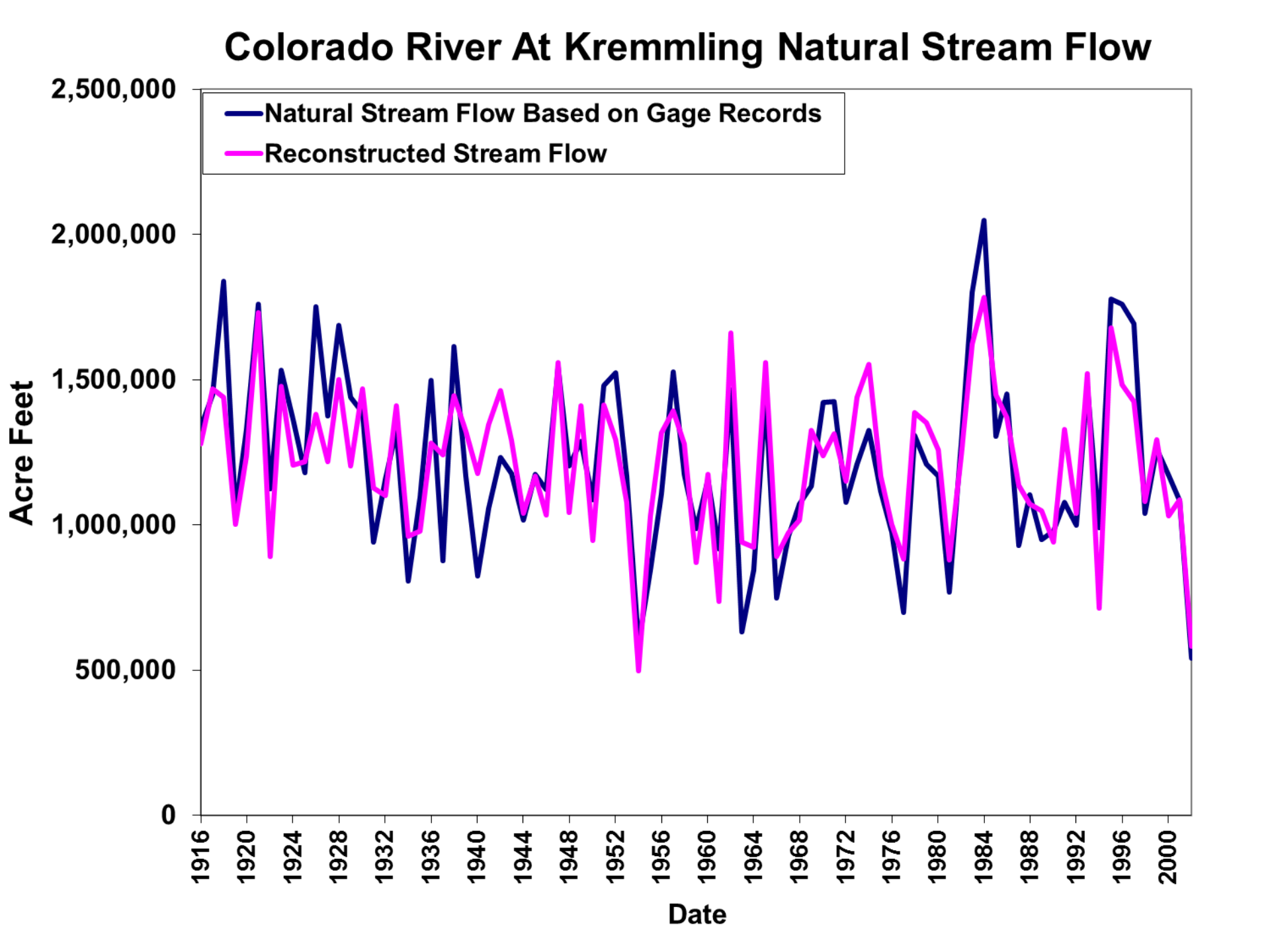
COLLECTION SYSTEMS

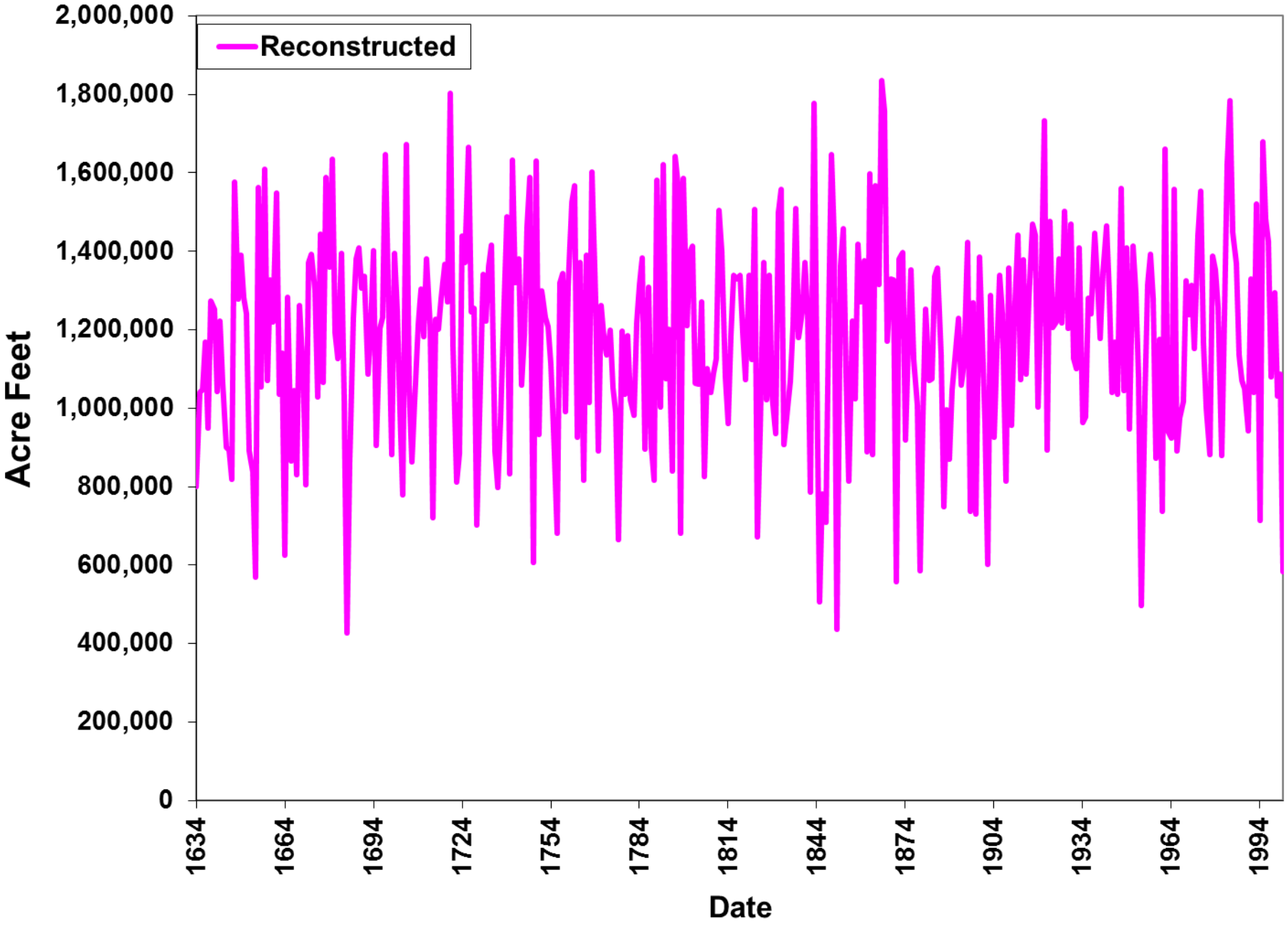
- SOUTH PLATTE
- MOFFAT TUNNEL
- ROBERTS TUNNEL
- WILLIAMS FORK WATERSHED

- TREATMENT PLANT
- CONTINENTAL DIVIDE
- STREAM OR RIVER
- TUNNEL, CANAL OR DITCH


South Platte At South Platte Natural Stream Flow
Natural Stream Flow Based on Gage Records
Reconstructed Stream Flow
Acre Feet
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Date


South Platte At South Platte Natural Stream Flow
Reconstructed
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Acre Feet
1634
1664
1694
1724
1754
1784
1814
1844
1874
1904
1934
1964
1994
Date

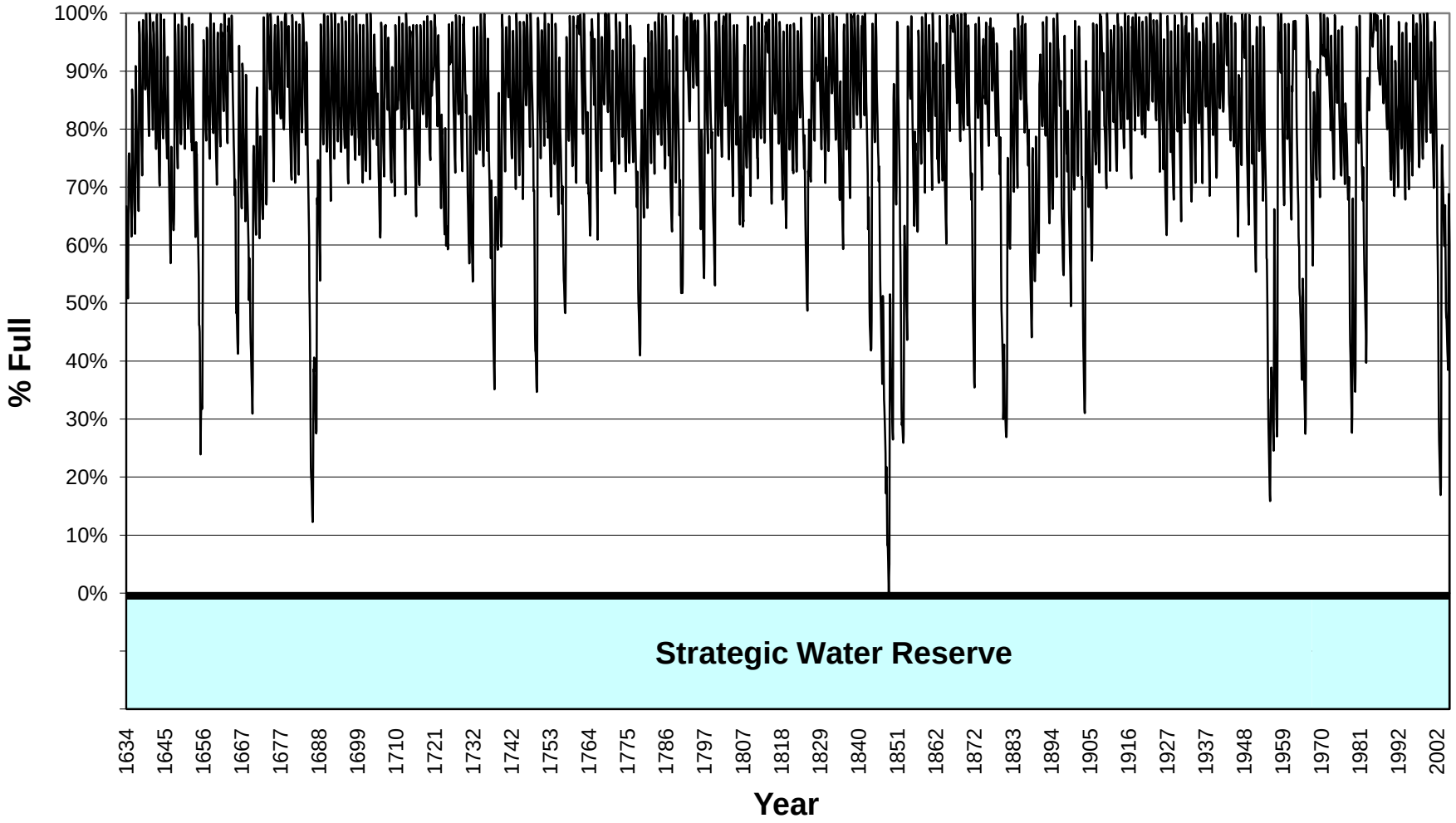

Colorado River At Kremmling Natural Stream Flow
Natural Stream Flow Based on Gage Records
Reconstructed Stream Flow
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Acre Feet
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Date


Colorado River At Kremmling Natural Stream Flow
Reconstructed
Acre Feet
2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1634
1664
1694
1724
1754
1784
1814
1844
1874
1904
1934
1964
1994
Date

Tree-Ring-Based Stream Flow Reconstructions

- **Match "Year Type" for East Slope and West Slope**
  - **Each tree-ring year prior to 1946 is represented by a model year with known daily natural stream flow (e.g., on the West Slope, 1877 annual tree-ring growth is similar to 1975, but on the East Slope it's similar to 1968).**
  - **Ratio down extreme tree-ring dry years from driest year in model period.**
  - **Ratio up extreme tree-ring wet years from wettest year in model period.**
- **Assemble data files as new sequences of model years.**
- **Use PACSM to simulate entire period (1634-2007).**
  - **Determine the level of demand that could be met during the entire model period without shortages, and the recurrence intervals of drought periods.**

Denver Water Reservoir Contents
(1634-2007)
Water Supply: 345,000 af
Includes 30,000 af Strategic Water Reserve and Drought Restrictions



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Tree-Ring-Based Stream Flow Reconstructions

Advantages

- **Enables planning for droughts more severe than indicated in the stream flow gage records.**
- **Better indication of the water supply system reliability in terms of the frequencies and durations that customers would be on various levels of drought restrictions.**

Limitations

- **Although tree-rings and stream flow correlations are generally good, reconstructions are not as sensitive in the extreme wet or dry years.**
- **Uses mean values for reconstructions; confidence intervals not used.**
- **From one number (annual flow) we assume an entire year of daily data.**
- **From one East Slope and one West Slope location, all 500 model nodes are adjusted.**
- **Slight changes to the tree-ring-based stream flow reconstructions can significantly alter the water supply analysis.**