

Computation and Analysis of the  
Instantaneous Discharge Record for  
the Colorado River at Lees Ferry,  
Arizona - May 8, 1921, through  
September 30, 2000

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U.S. Geological Survey

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PROFESSIONAL PAPER 1677



Data downloadable from  
the temporary site:

<ftp://ftpext.usgs.gov/pub/wr/az/flagstaff/GCMRC-water/>

# Objectives

- Evaluation of the natural hydrologic variability in the Upper Basin as measured in the discharge of the Colorado River at Lees Ferry (42-year period from May 1921 to March 1963; only 10-15% virgin flow depleted prior to 1963, mostly before 1921)
- Evaluation of the effects of the operation of Glen Canyon Dam on the discharge of the Colorado River in Grand Canyon National Park (37-year period from March 1963 through September 2000)
- Implications for sediment transport and storage in the reach between Lees Ferry and the Grand Canyon gaging station

# Chief analyses

- Flow duration (with sediment transport implications)
- Sub-daily discharge variability
- Flood frequency

# Main problem to overcome

Data were of differing precision during different time periods

- May 8, 1921 through June 12, 1921  
not published
- June 13, 1921, through September 30, 1986  
mean daily
- October 1, 1986, through May 31, 1998  
30 minutes
- After June 1, 1998  
15 minutes

Retrieve and compile digitally all raw data collected by the USGS at the Lees Ferry and Grand Canyon gaging stations

4 years of work

Lees Ferry - May 1921 through September 1986

35 boxes of data in the Federal Records Center

Grand Canyon - November 1922 through September 1986

-Construct a continuous record of instantaneous stage

-Enter staff gage data from May 8, 1921, through January 18, 1923

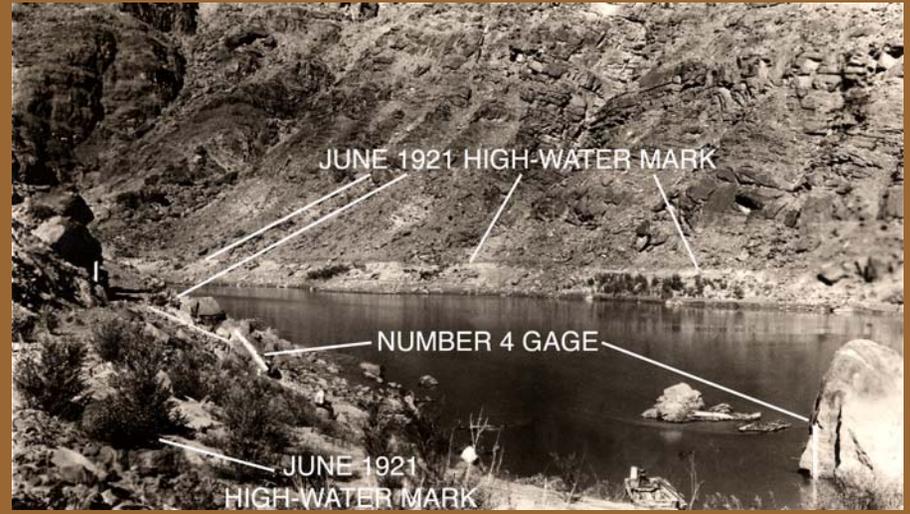
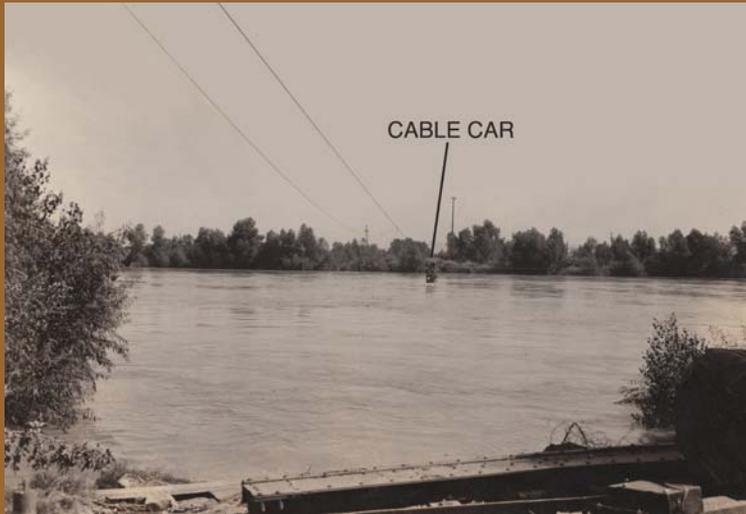
-Digitize strip-chart data from January 19, 1923, through September 30, 1986

-Enter digital-recorder data from February 2, 1967, through September 30, 1986

-Compute a continuous record of instantaneous discharge using the appropriate rating curves and shifts

-Quality control

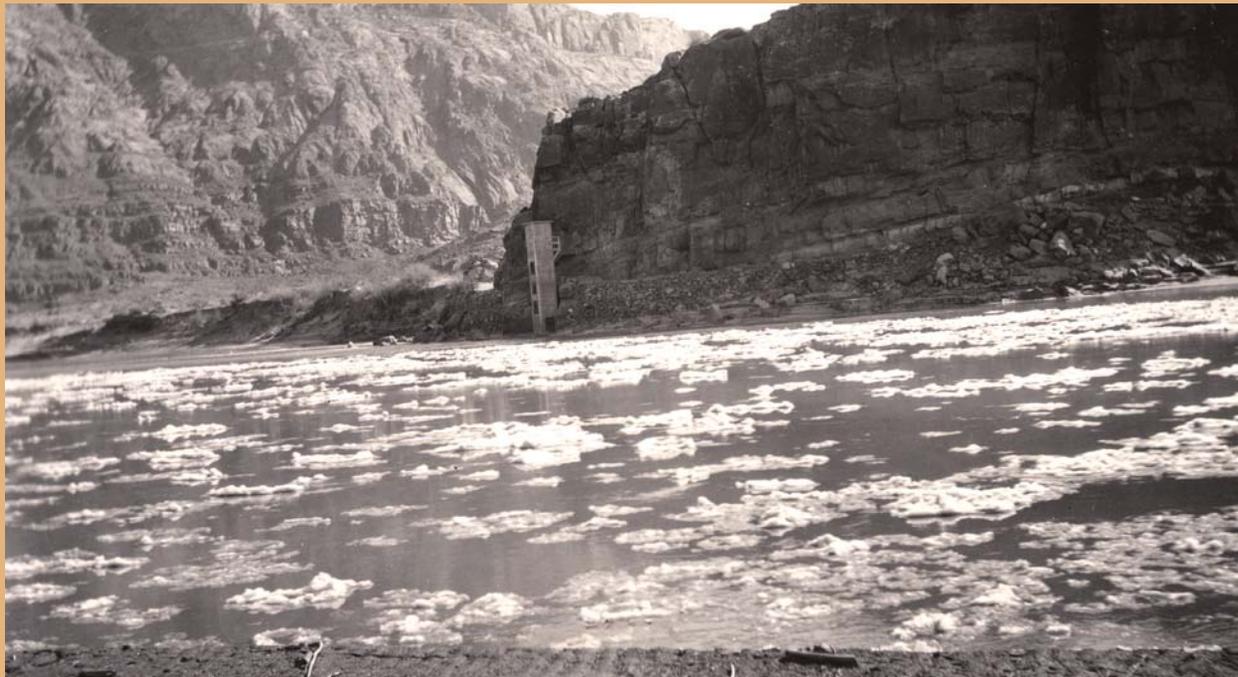
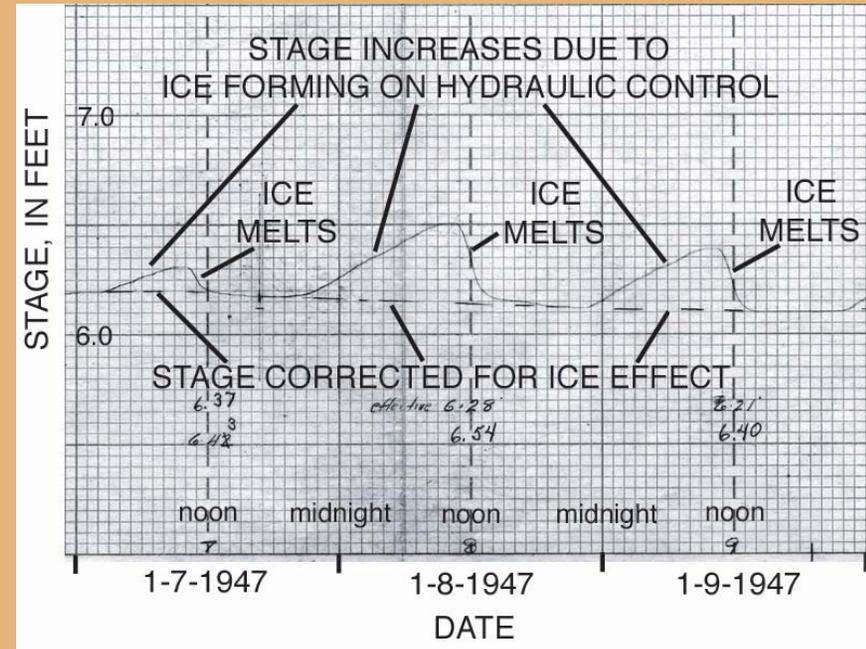
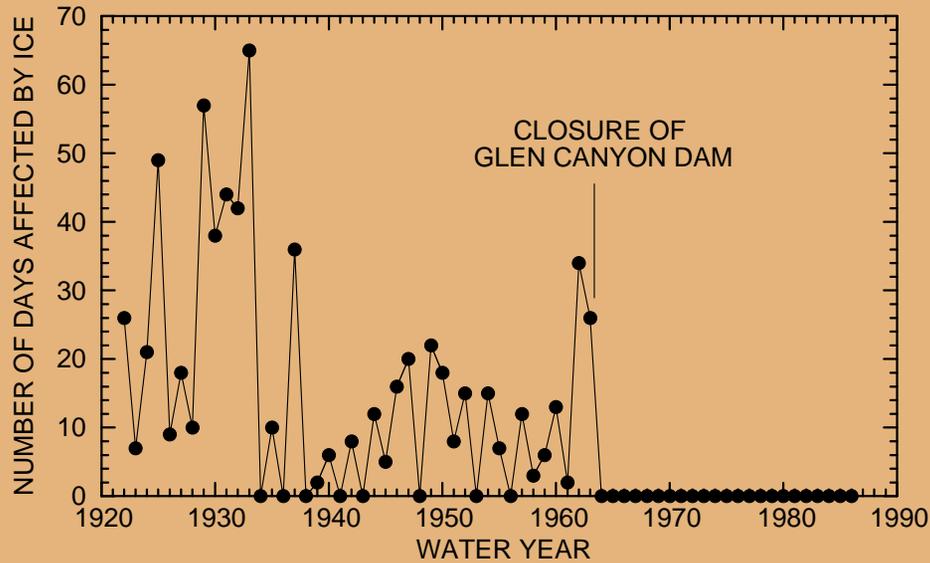
# Check and, if necessary, revise peak discharges of the largest pre-dam floods

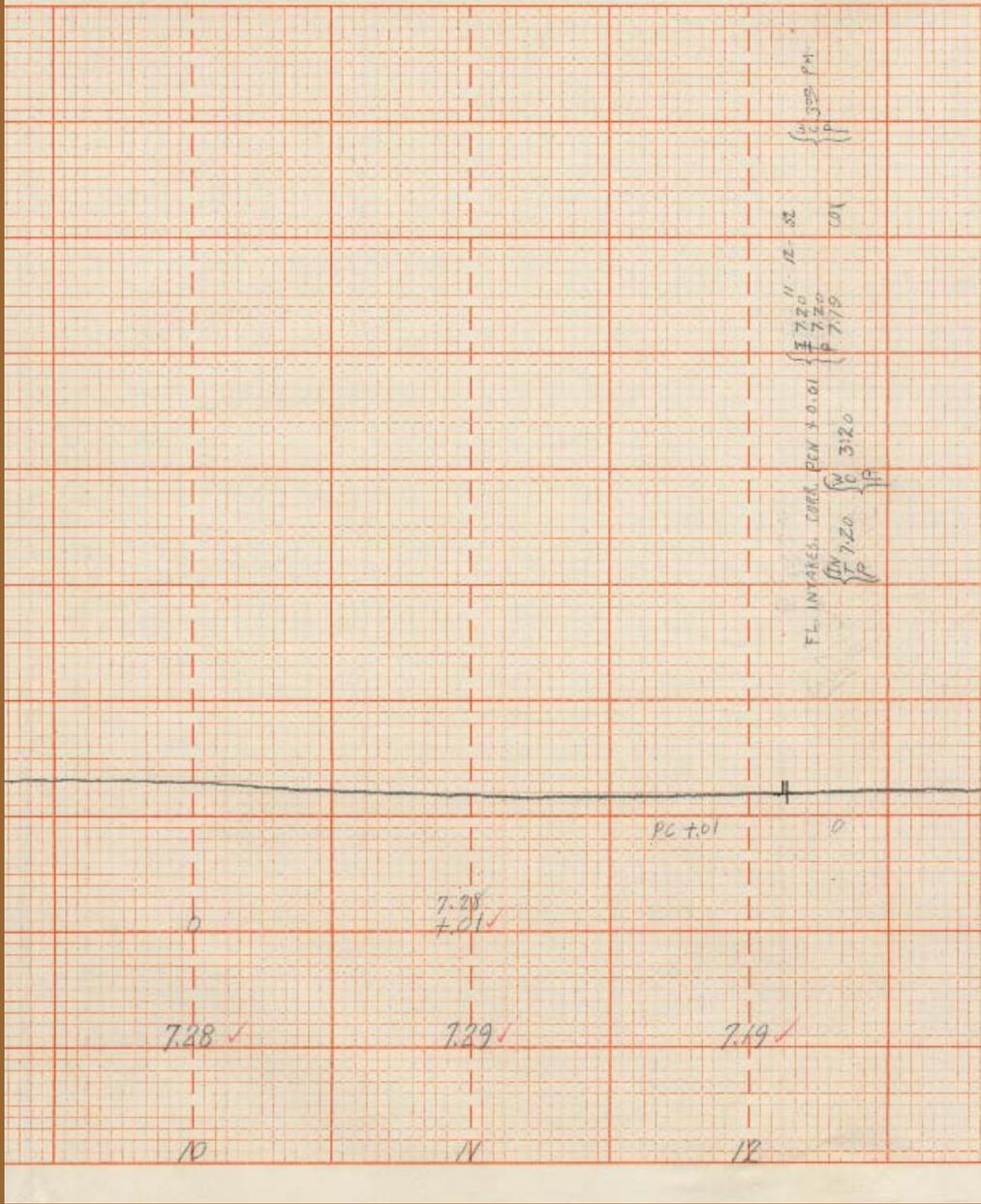


	Original value	1939 revision	This study
1921	174,000 ft <sup>3</sup> /s	220,000 ft <sup>3</sup> /s	170,000±20,000 ft <sup>3</sup> /s
1884	210,000-250,000 ft <sup>3</sup> /s	300,000 ft <sup>3</sup> /s	210,000±30,000 ft <sup>3</sup> /s

Largest flood within last 4,500 years occurred 1,200-1,600 years ago (O'Connor et al., 1994) ~ 300,000 ft<sup>3</sup>/s

# Ice effects

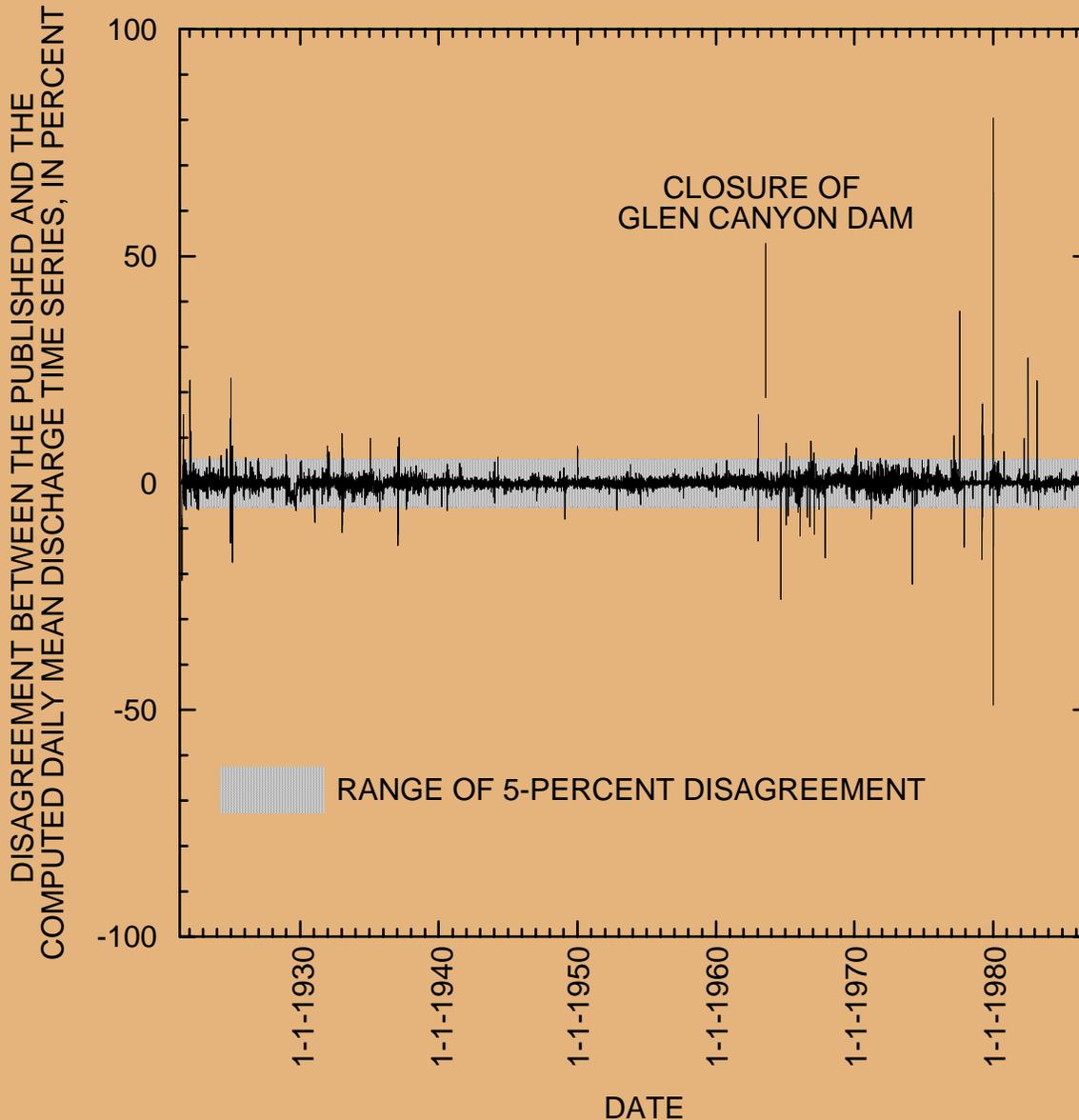




# Errors

Example: 11-11-52  
daily mean Stage  
incorrectly recorded as  
7.29' instead of 7.19'

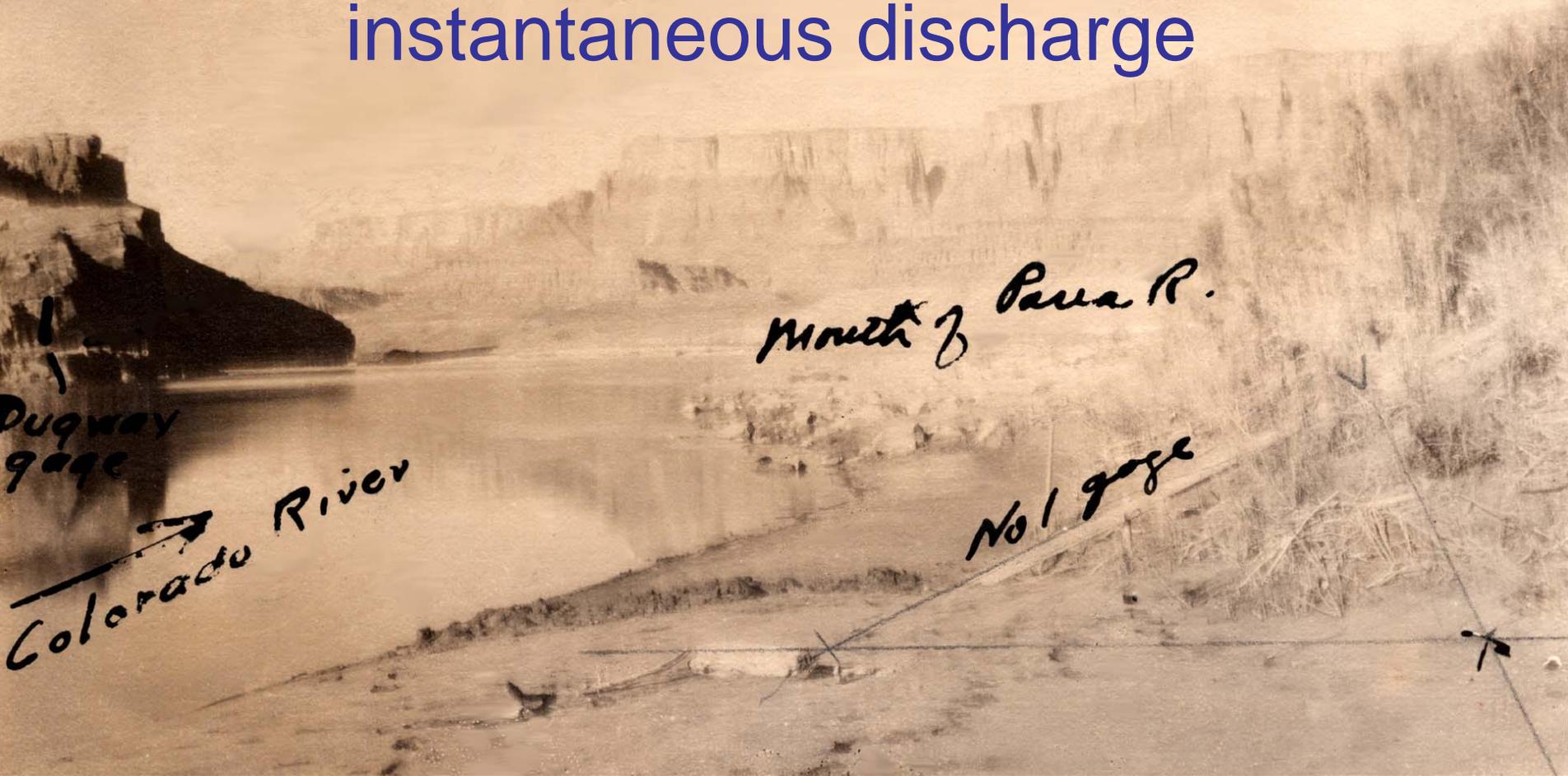
+6.0% discharge error



89 non-ice-affected days in the published daily mean discharge record were found to have errors in excess of 5%

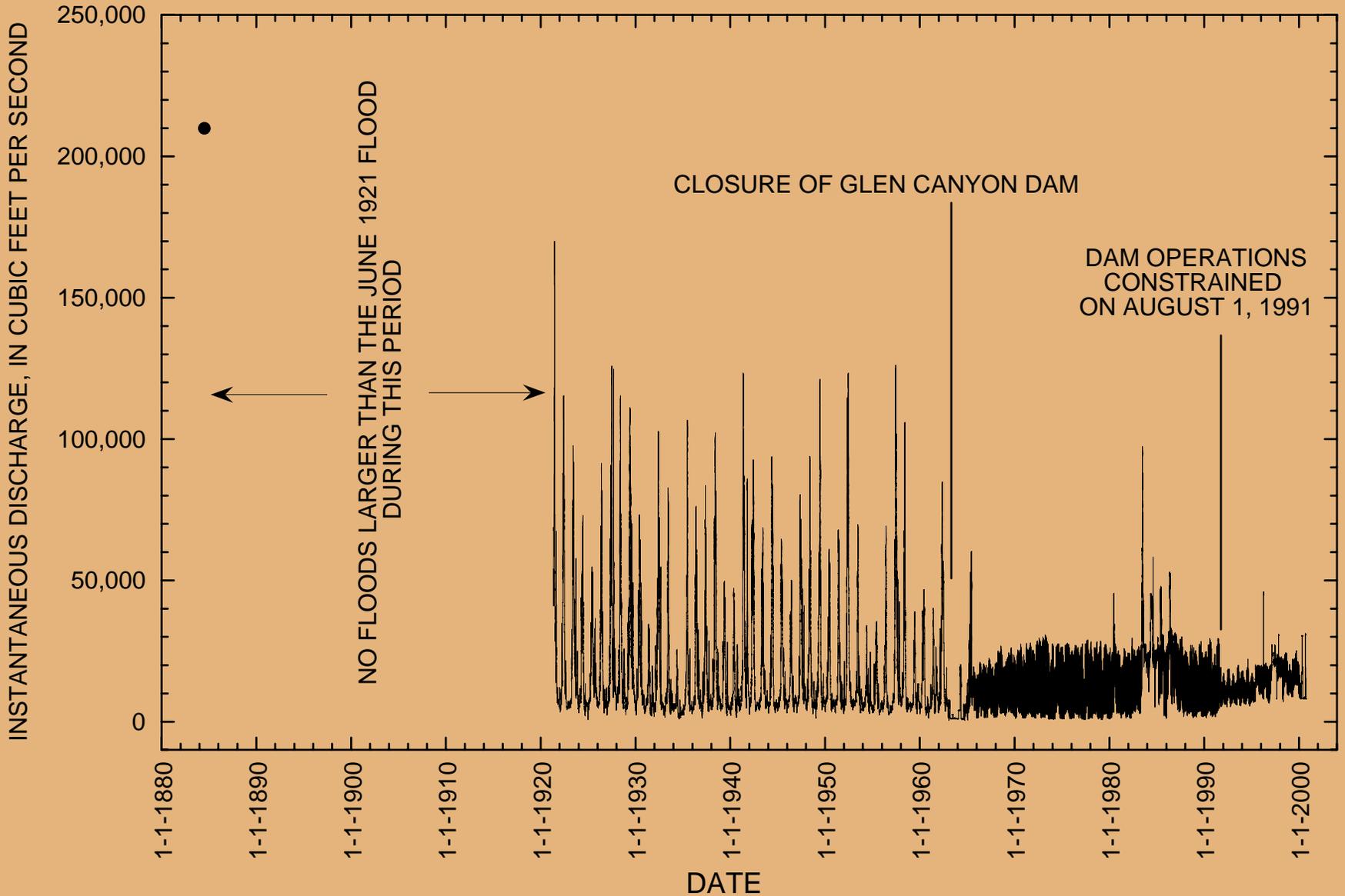
Mean disagreement = +0.055%

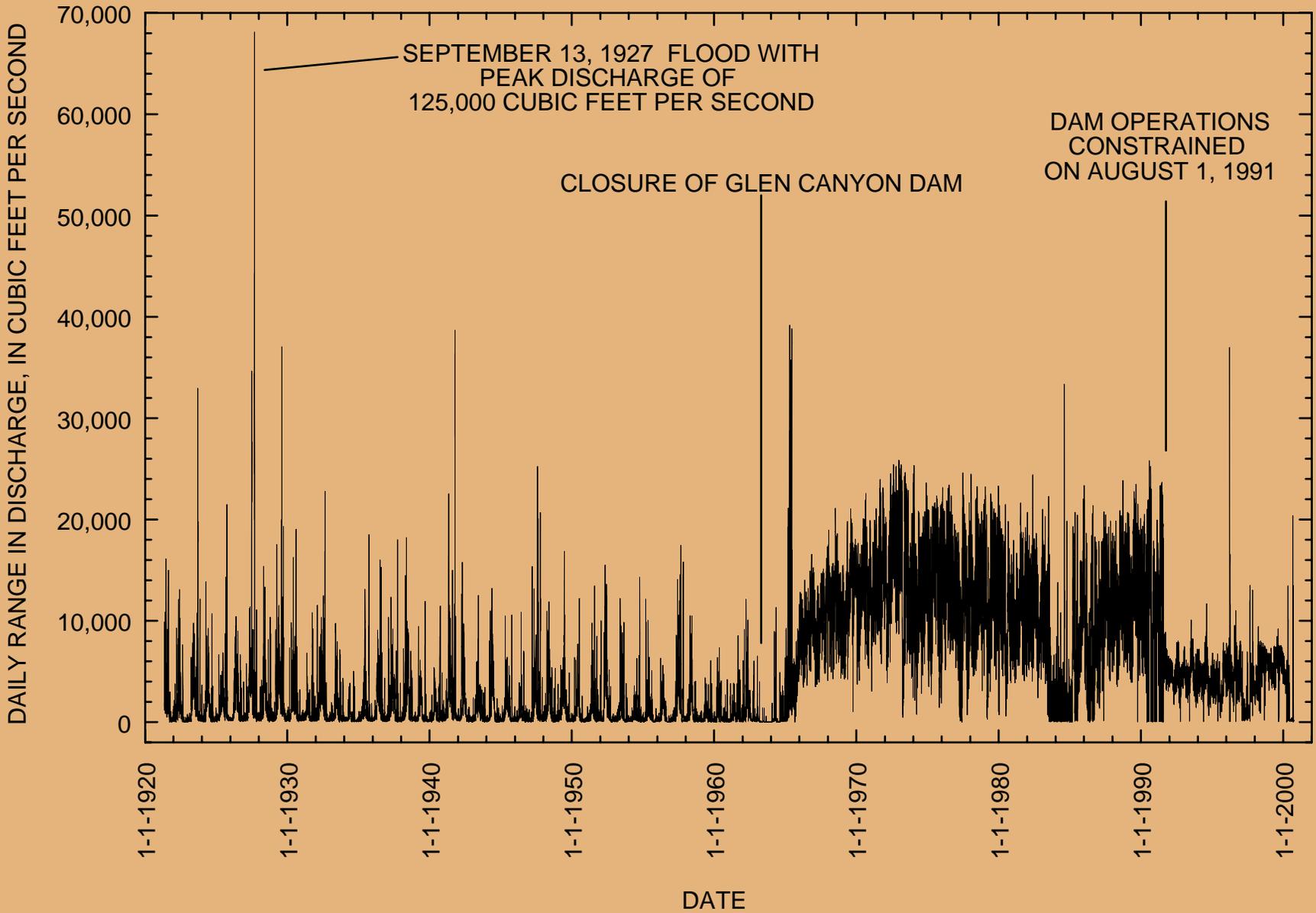
# The continuous record of instantaneous discharge



# EXPLANATION

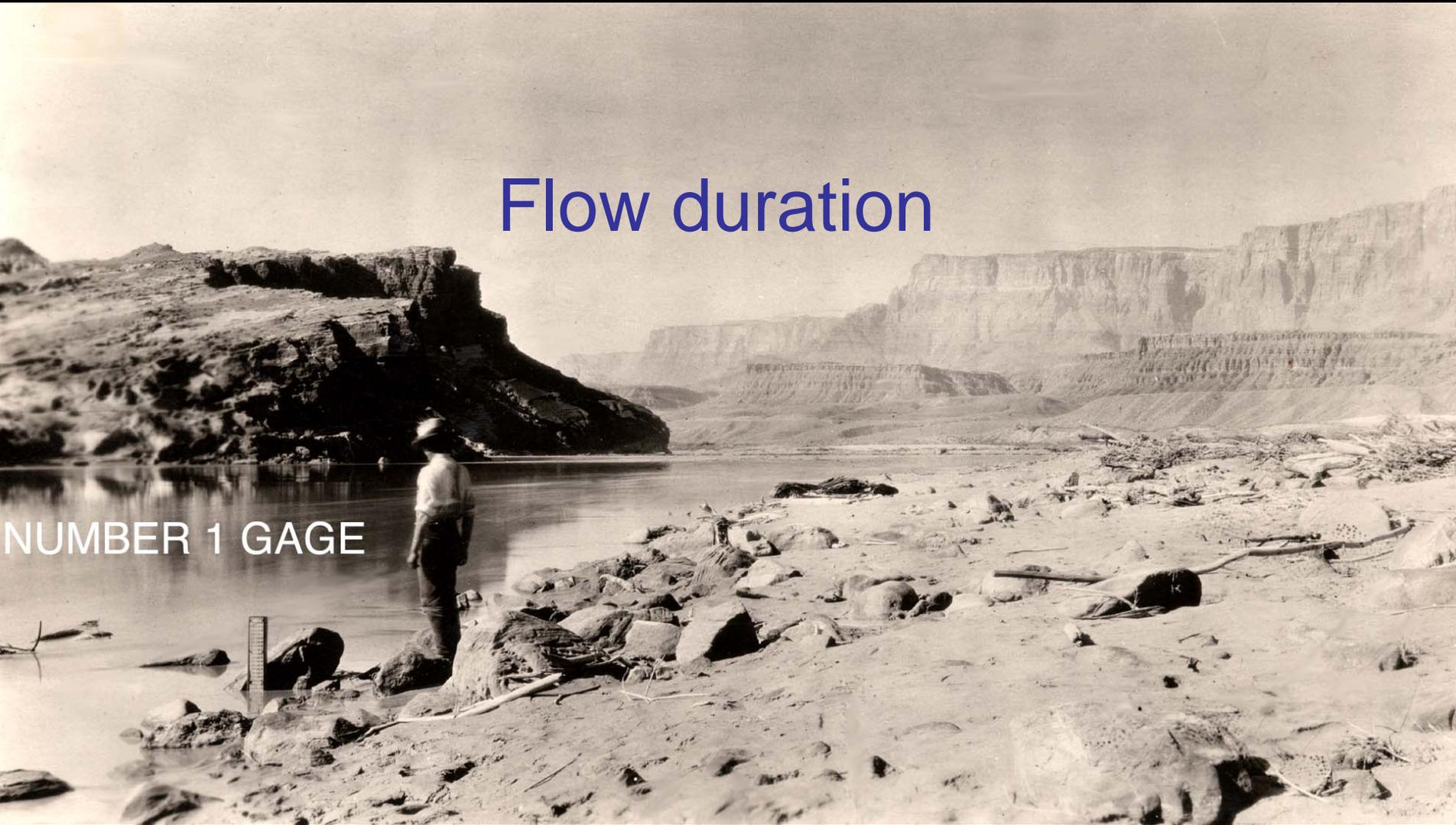
- MAY 8, 1921 - SEPTEMBER 30, 2000, CONTINUOUS RECORD OF INSTANTANEOUS DISCHARGE
- PEAK DISCHARGE OF THE 1884 FLOOD





# Flow duration

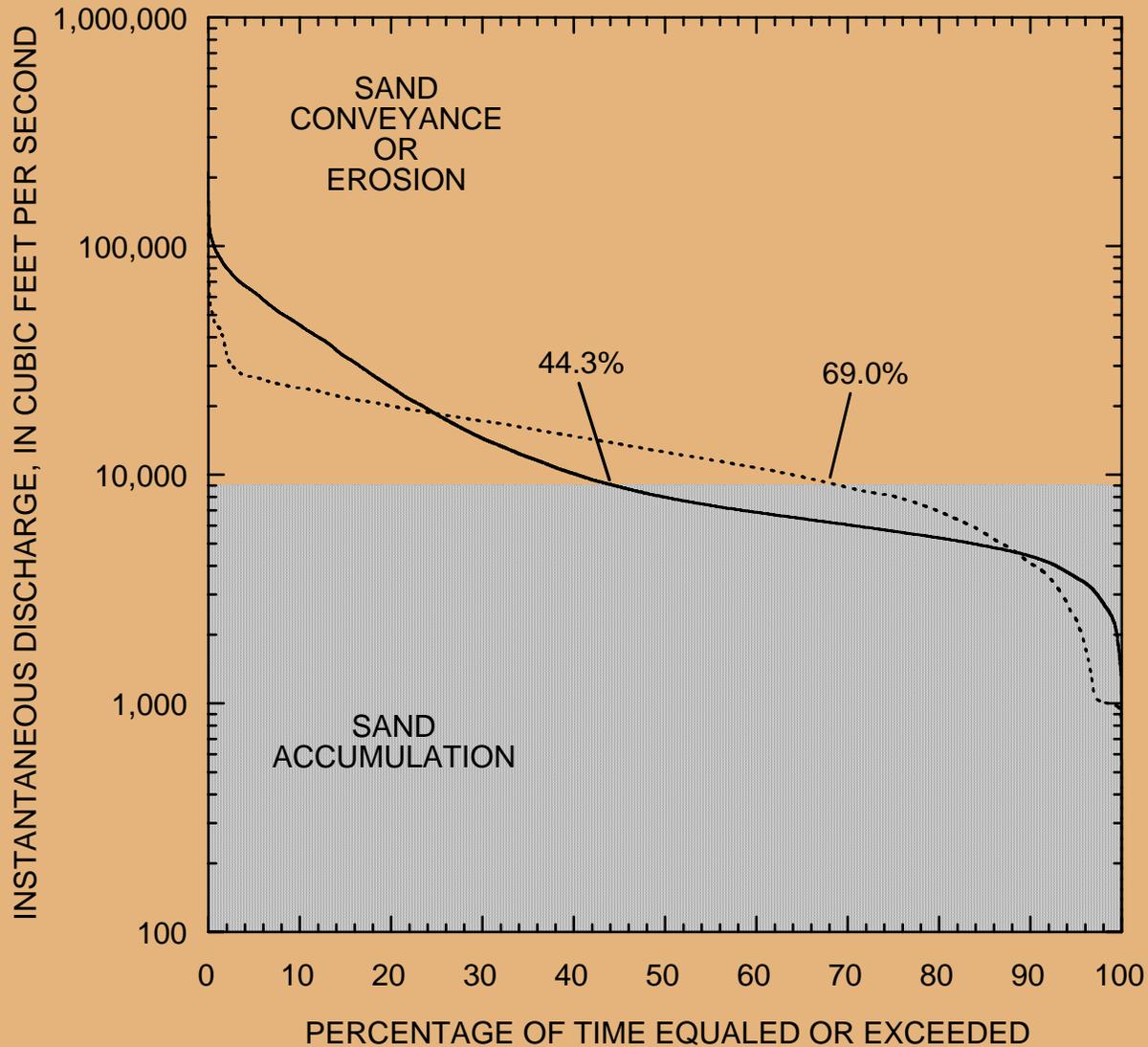
NUMBER 1 GAGE



# EXPLANATION

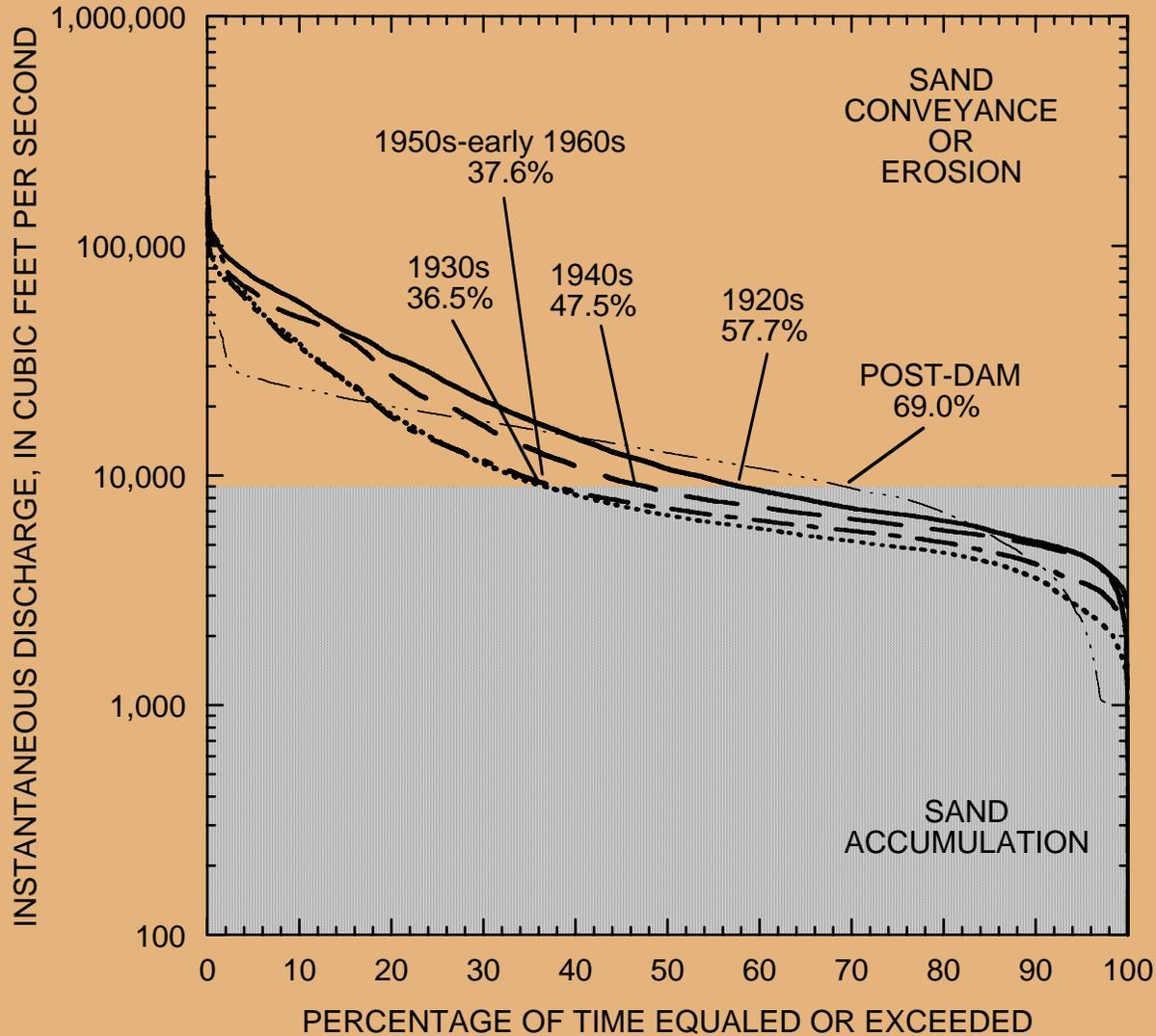
— PRE-DAM (May 8, 1921, through March 12, 1963)

..... POST-DAM (March 14, 1963, through September 30, 2000)



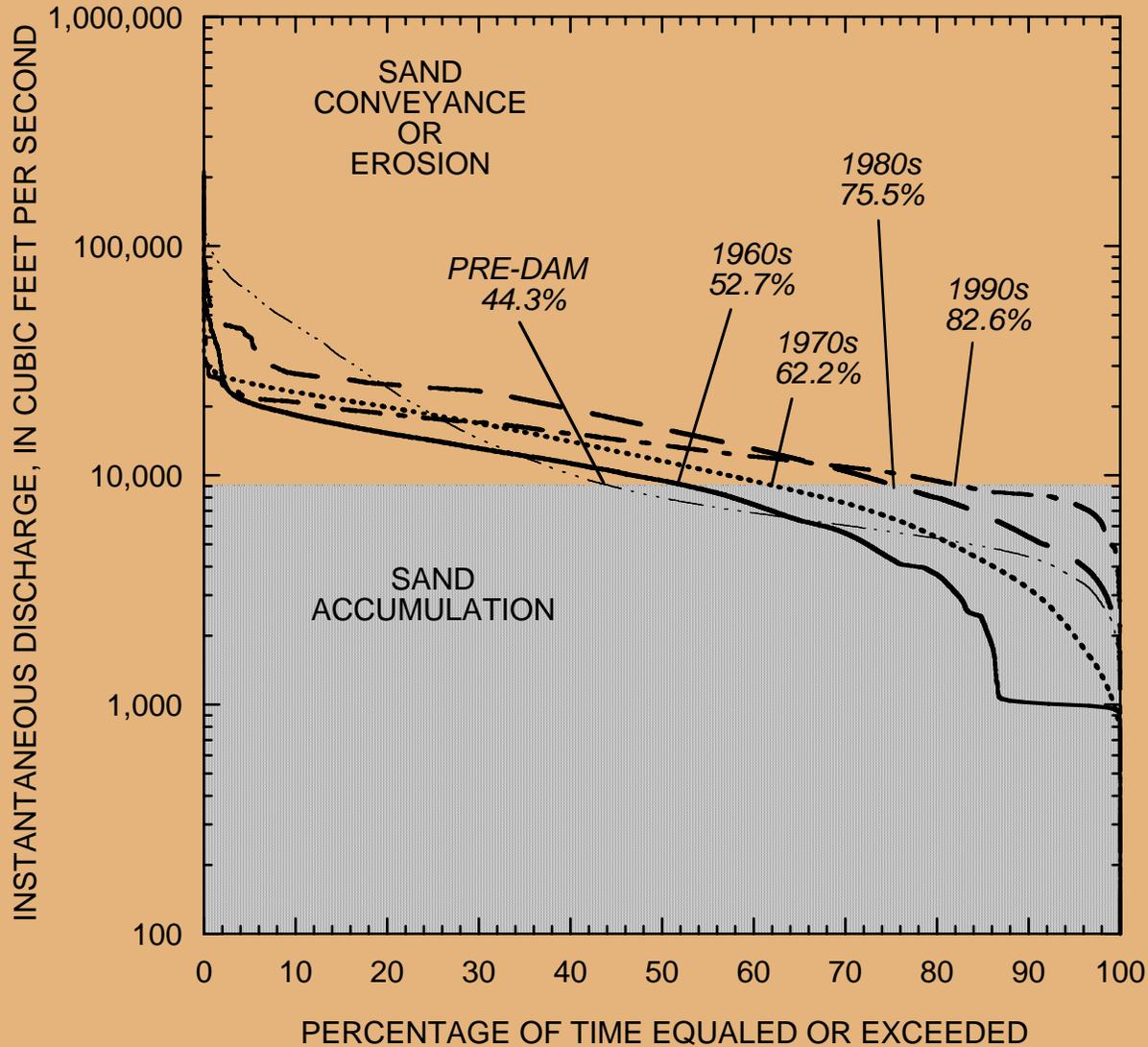
## EXPLANATION

- 1920s (May 8, 1921, through December 31, 1930)
- ..... 1930s (January 1, 1931, through December 31, 1940)
- - - 1940s (January 1, 1941, through December 31, 1950)
- - - 1950s-early 1960s (January 1, 1951, through March 12, 1963)
- · - · - POST-DAM (March 14, 1963, through September 30, 2000)



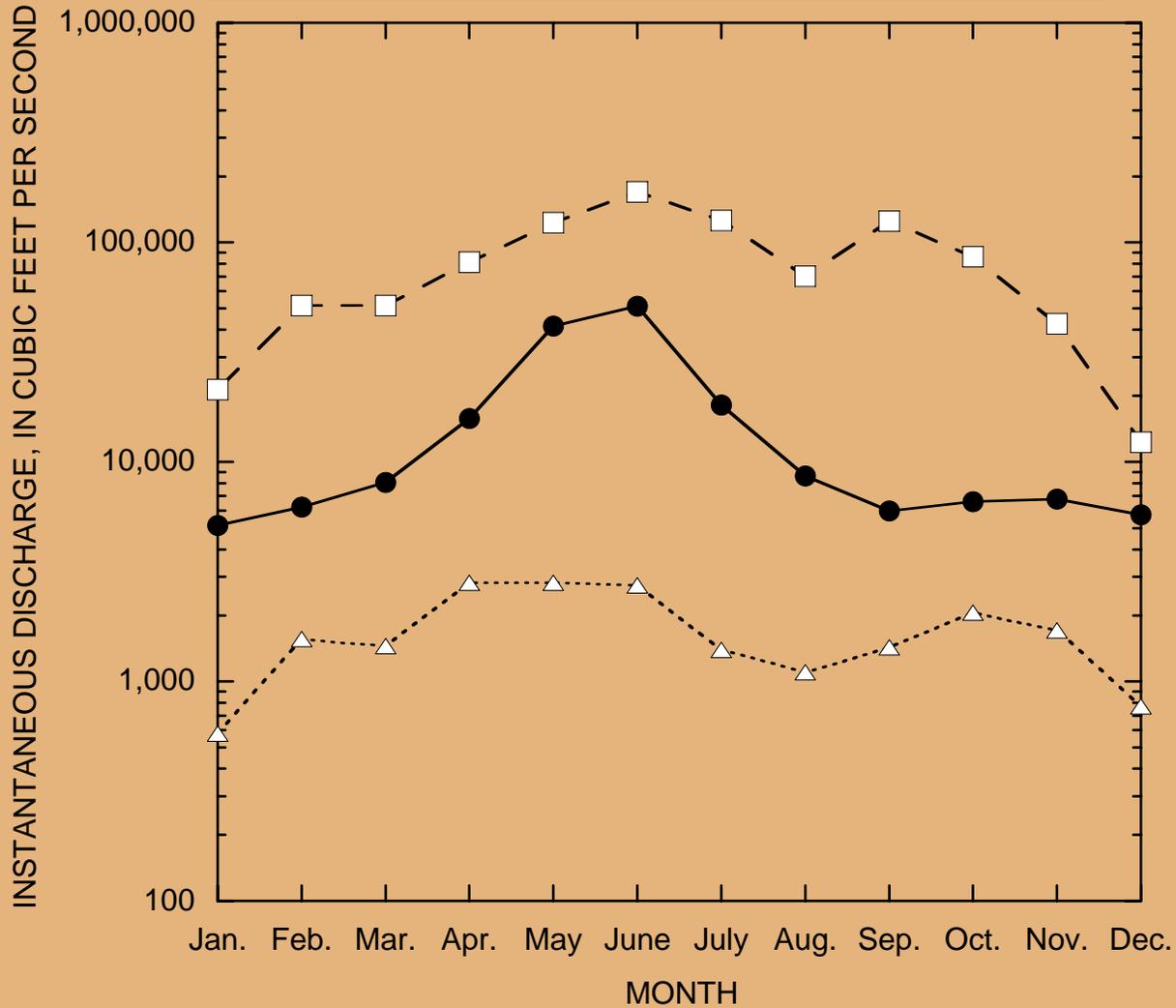
# EXPLANATION

- 1960s (March 14, 1963, through December 31, 1970)
- ..... 1970s (January 1, 1971, through December 31, 1980)
- - - 1980s (January 1, 1981, through December 31, 1990)
- - - 1990s (January 1, 1991, through September 30, 2000)
- · - · - PRE-DAM (May 8, 1921, through March 12, 1963)



# EXPLANATION

- PRE-DAM MONTHLY MEDIAN DISCHARGE
- ▲ PRE-DAM MONTHLY MINIMUM DISCHARGE
- PRE-DAM MONTHLY MAXIMUM DISCHARGE

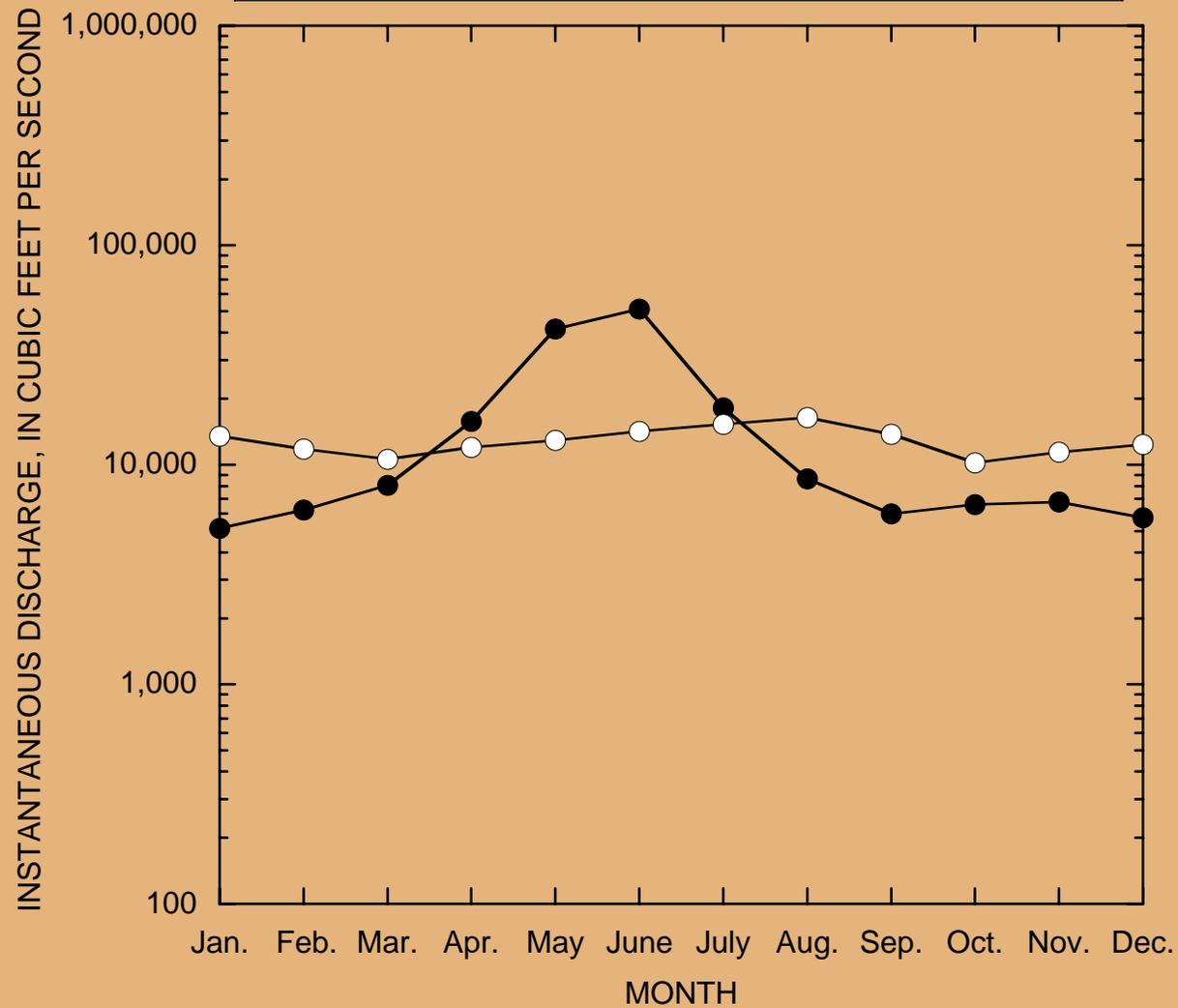


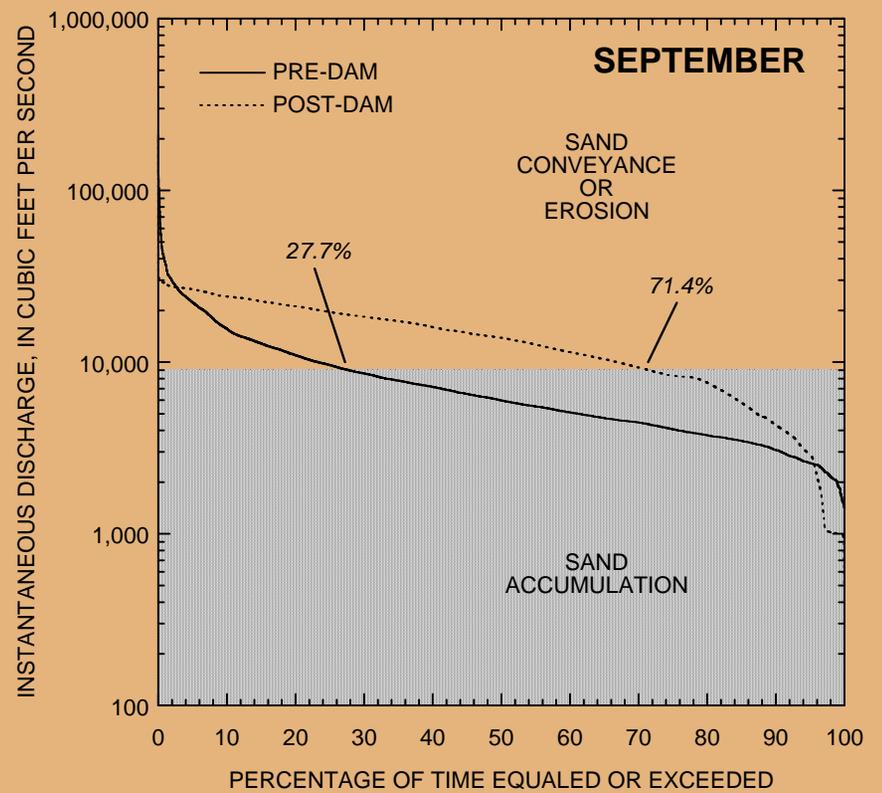
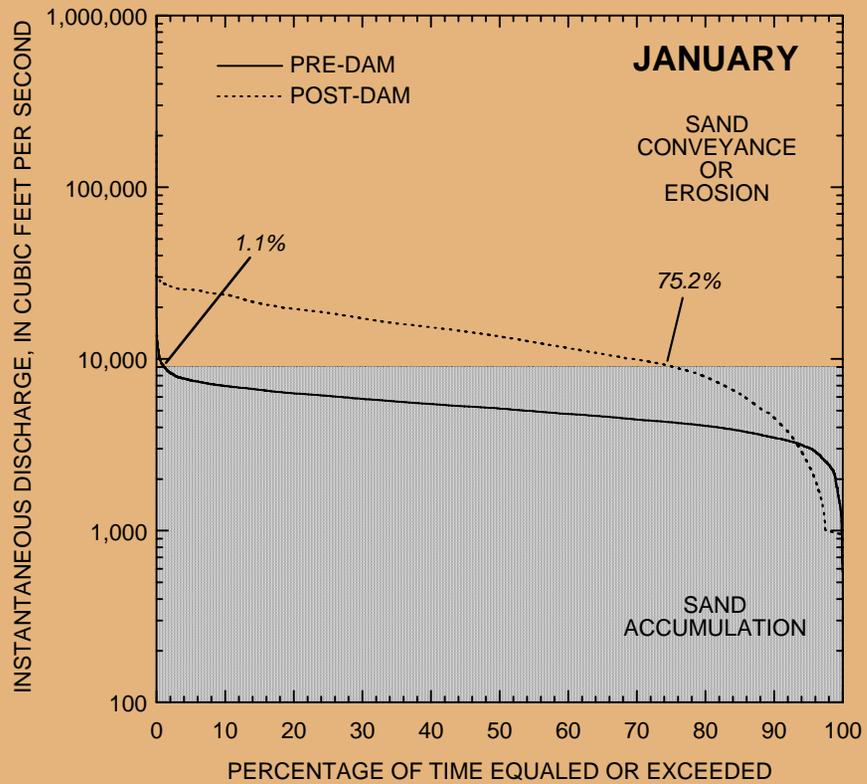
# EXPLANATION

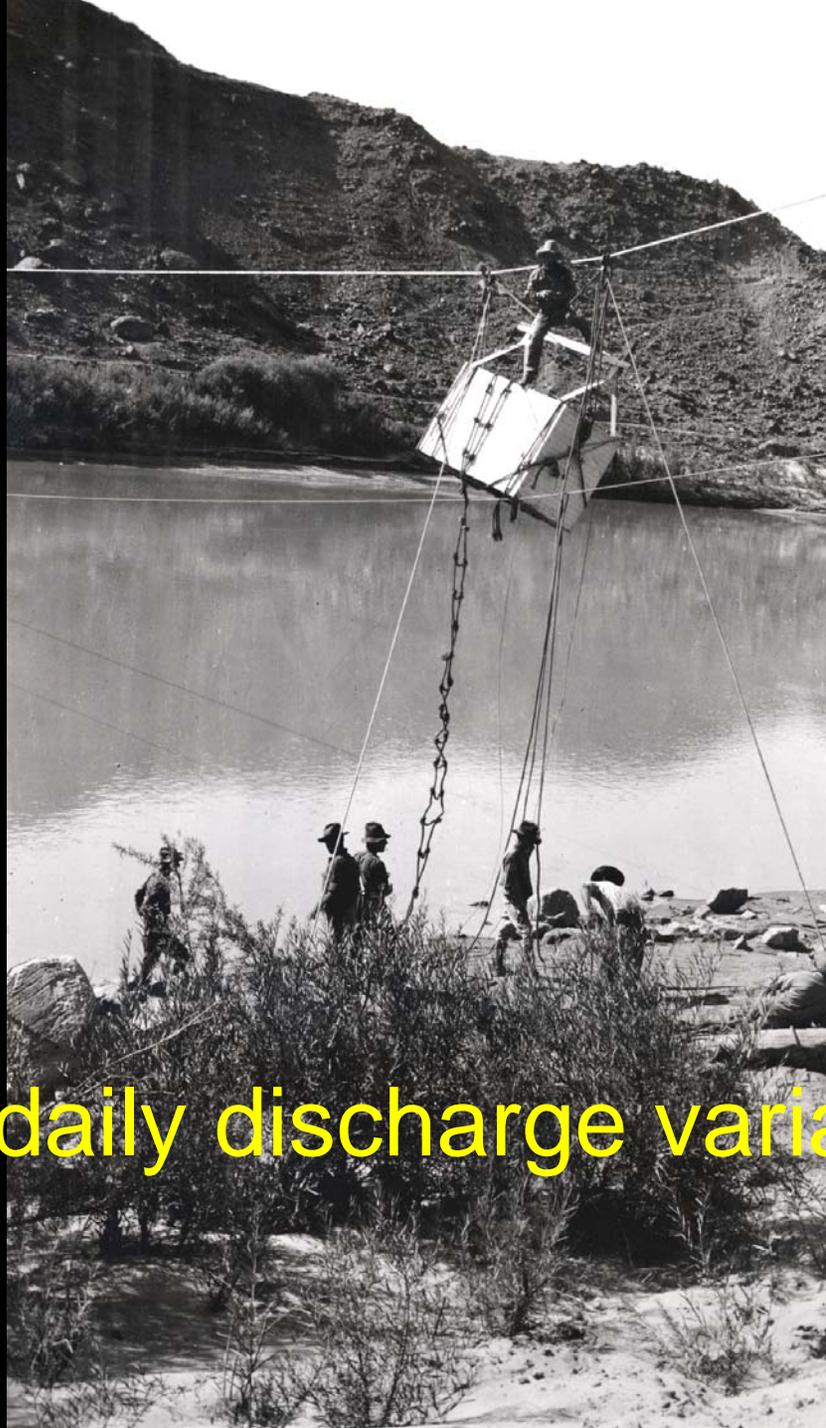
MONTHLY MEDIAN DISCHARGE

● PRE-DAM

○ POST-DAM





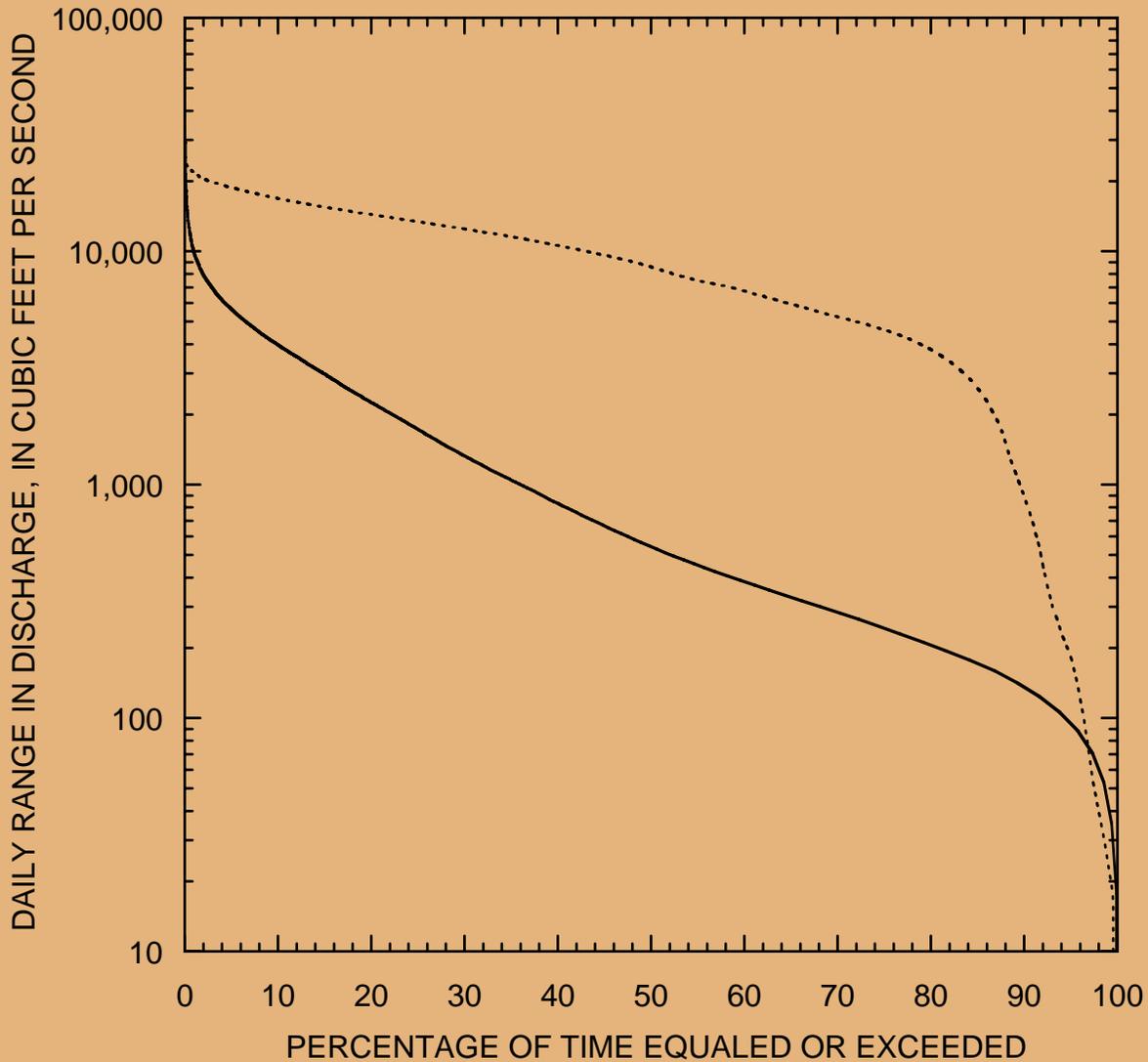


Sub-daily discharge variability

# EXPLANATION

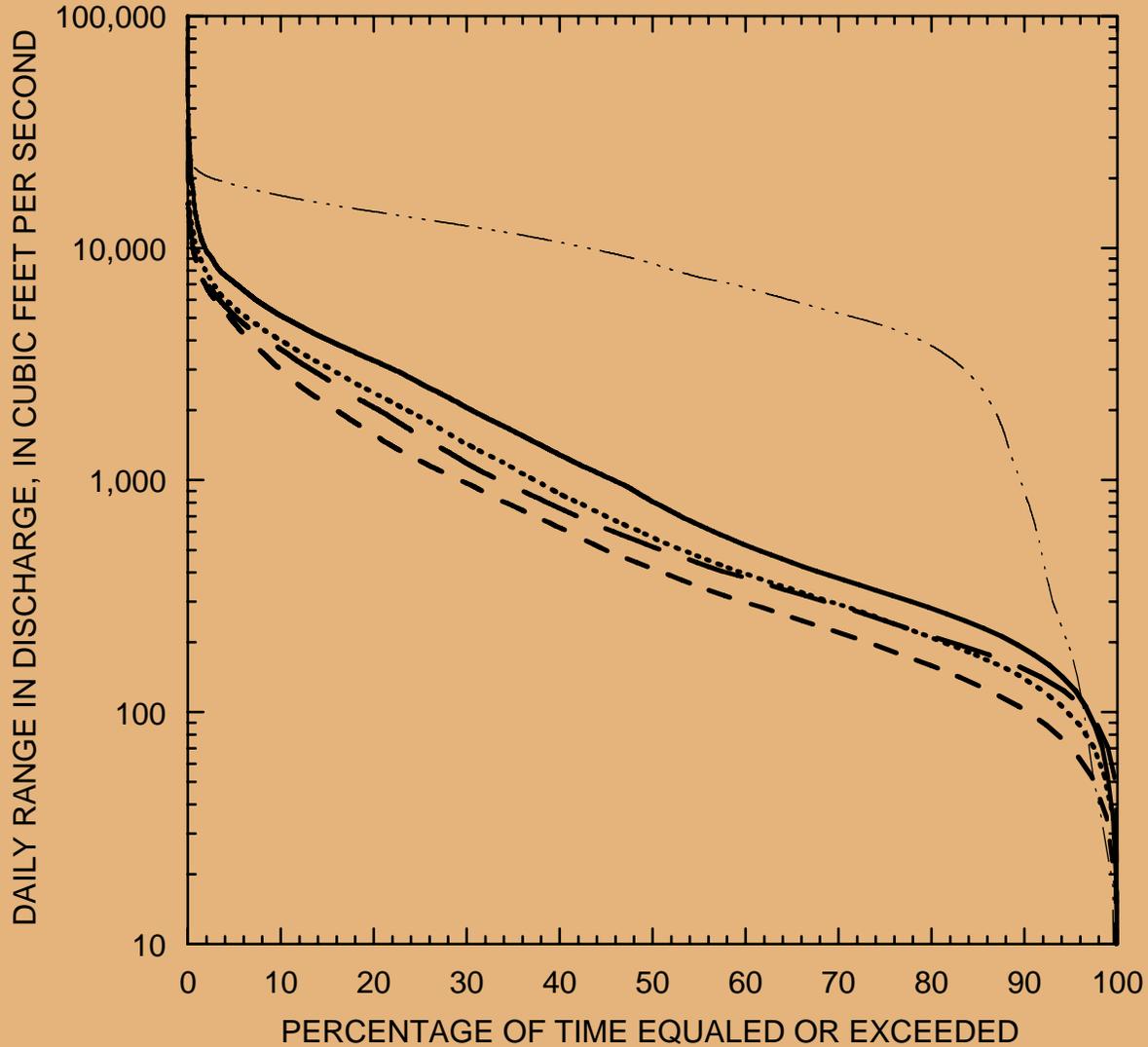
— PRE-DAM (May 8, 1921, through March 12, 1963)

⋯ POST-DAM (March 14, 1963, through September 30, 2000)



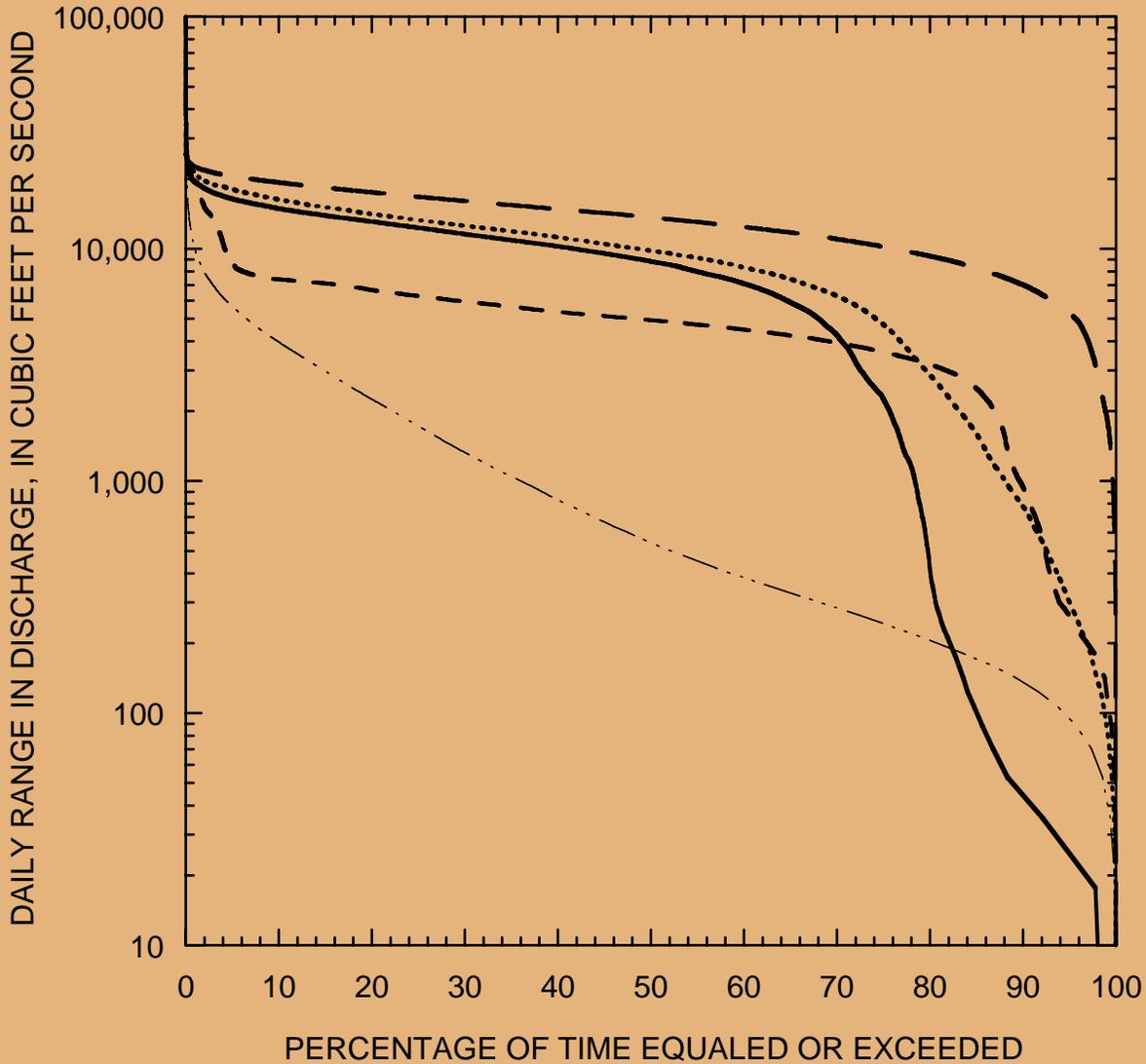
# EXPLANATION

- 1920s (May 8, 1921, through December 31, 1930)
- - 1930s (January 1, 1931, through December 31, 1940)
- ..... 1940s (January 1, 1941, through December 31, 1950)
- - - 1950s-early 1960s (January 1, 1951, through March 12, 1963)
- · - · POST-DAM (March 14, 1963, through September 30, 2000)



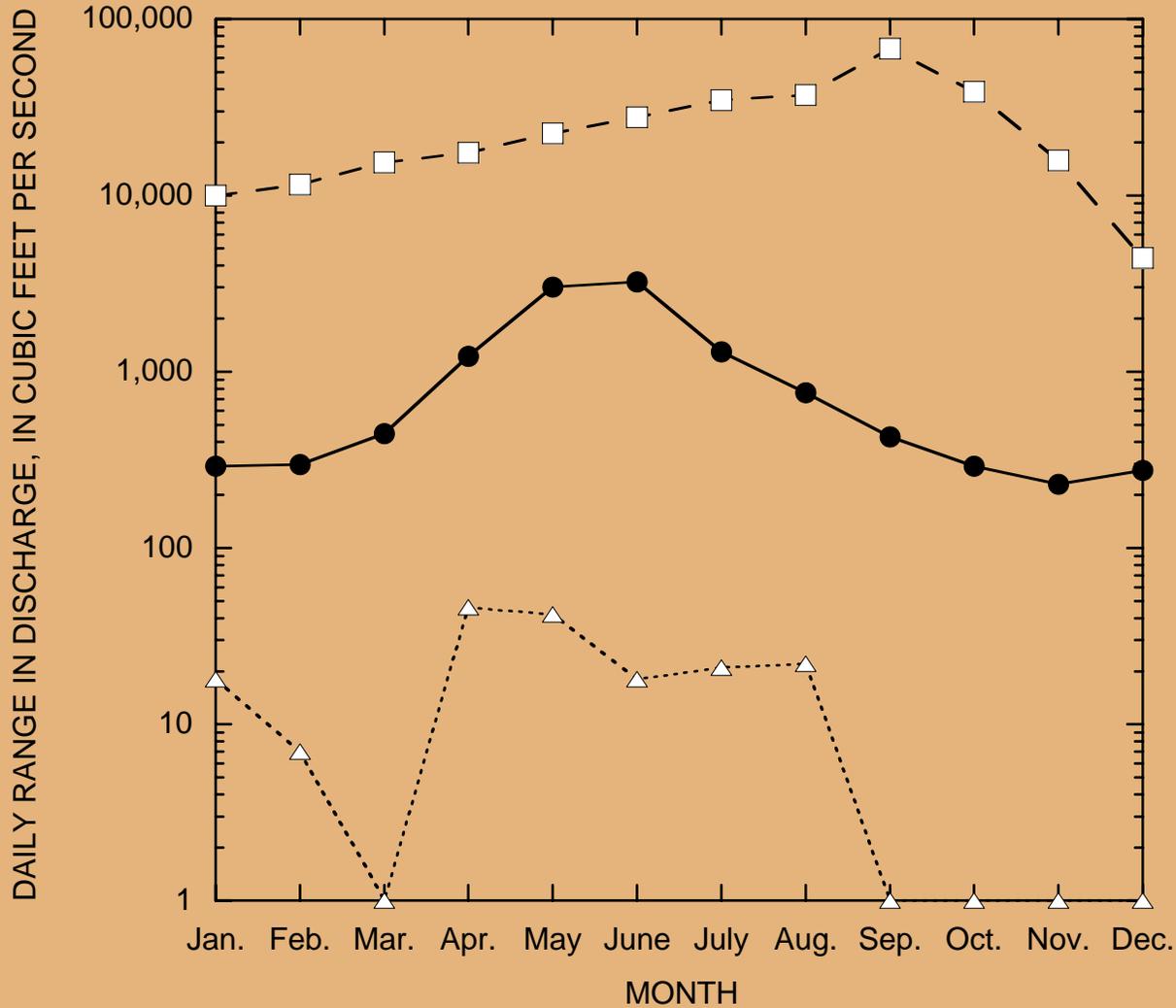
# EXPLANATION

- 1960s (March 14, 1963, through December 31, 1970)
- - - 1970s (January 1, 1971, through December 31, 1980)
- ..... 1980s (January 1, 1981, through December 31, 1990)
- - - 1990s (January 1, 1991, through September 30, 2000)
- · - · - PRE-DAM (May 8, 1921, through March 12, 1963)



# EXPLANATION

- PRE-DAM MONTHLY MEDIAN DAILY RANGE IN DISCHARGE
- ▲ PRE-DAM MONTHLY MINIMUM DAILY RANGE IN DISCHARGE
- PRE-DAM MONTHLY MAXIMUM DAILY RANGE IN DISCHARGE

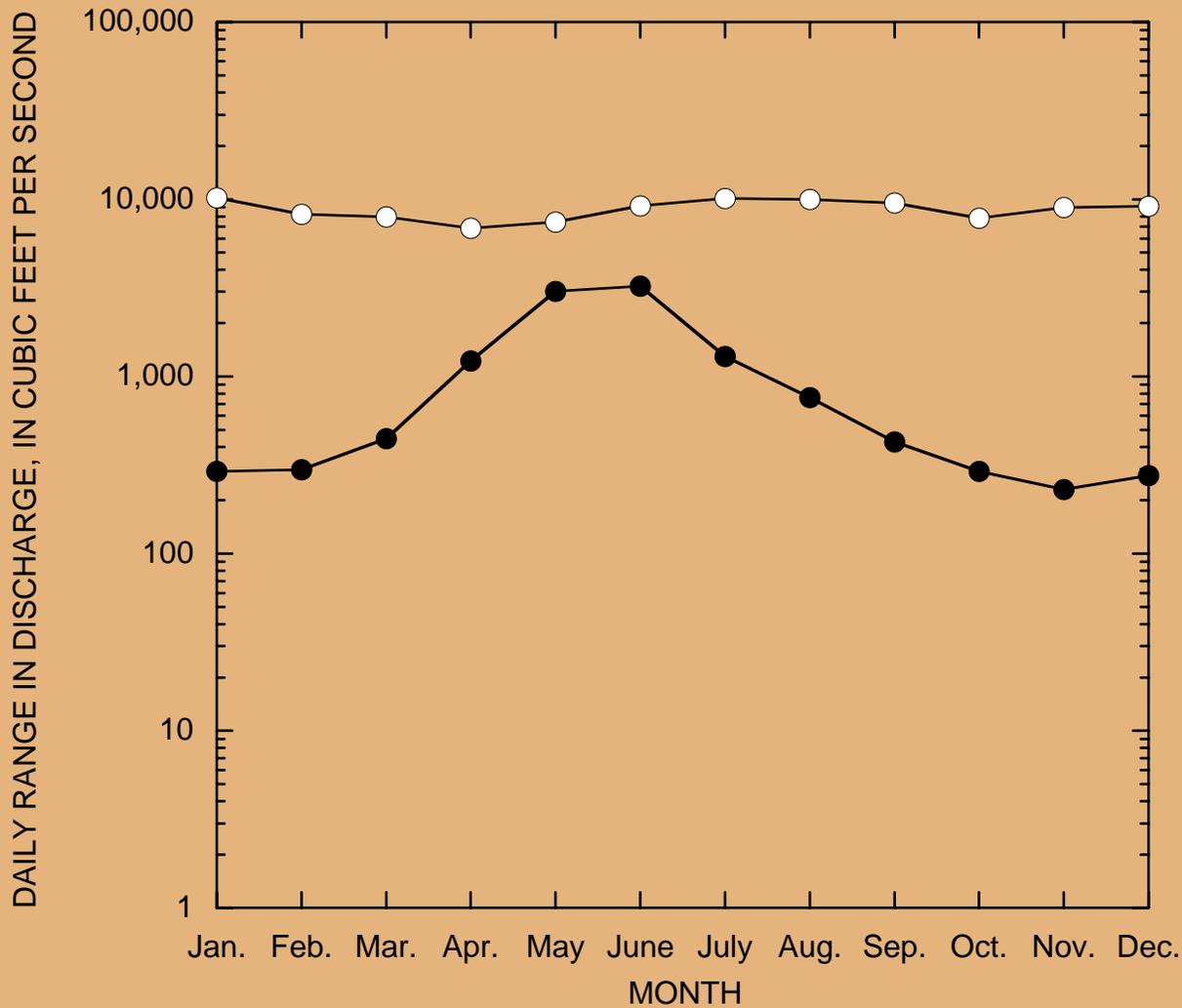


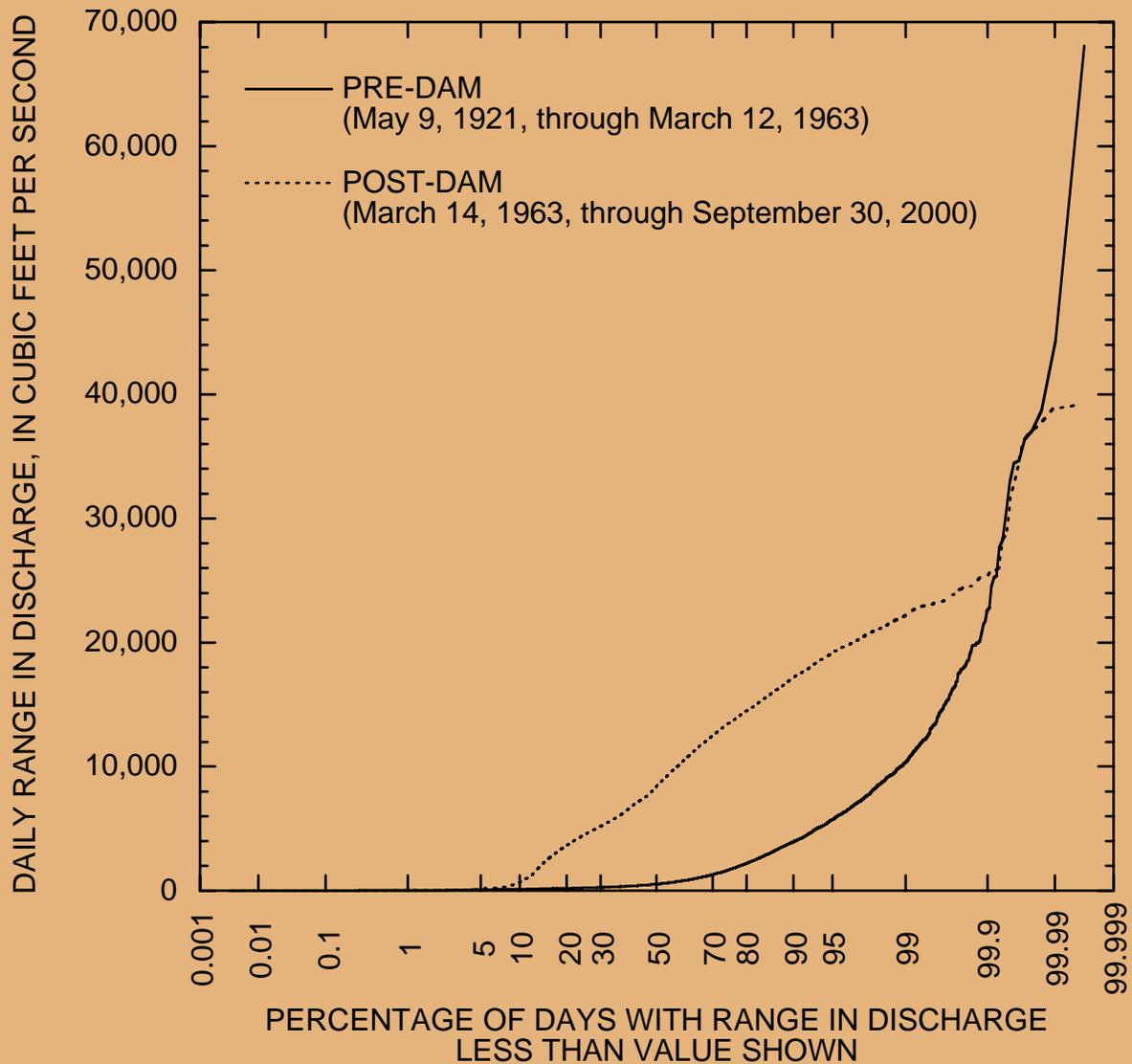
# EXPLANATION

MONTHLY MEDIAN DAILY RANGE IN DISCHARGE

—●— PRE-DAM

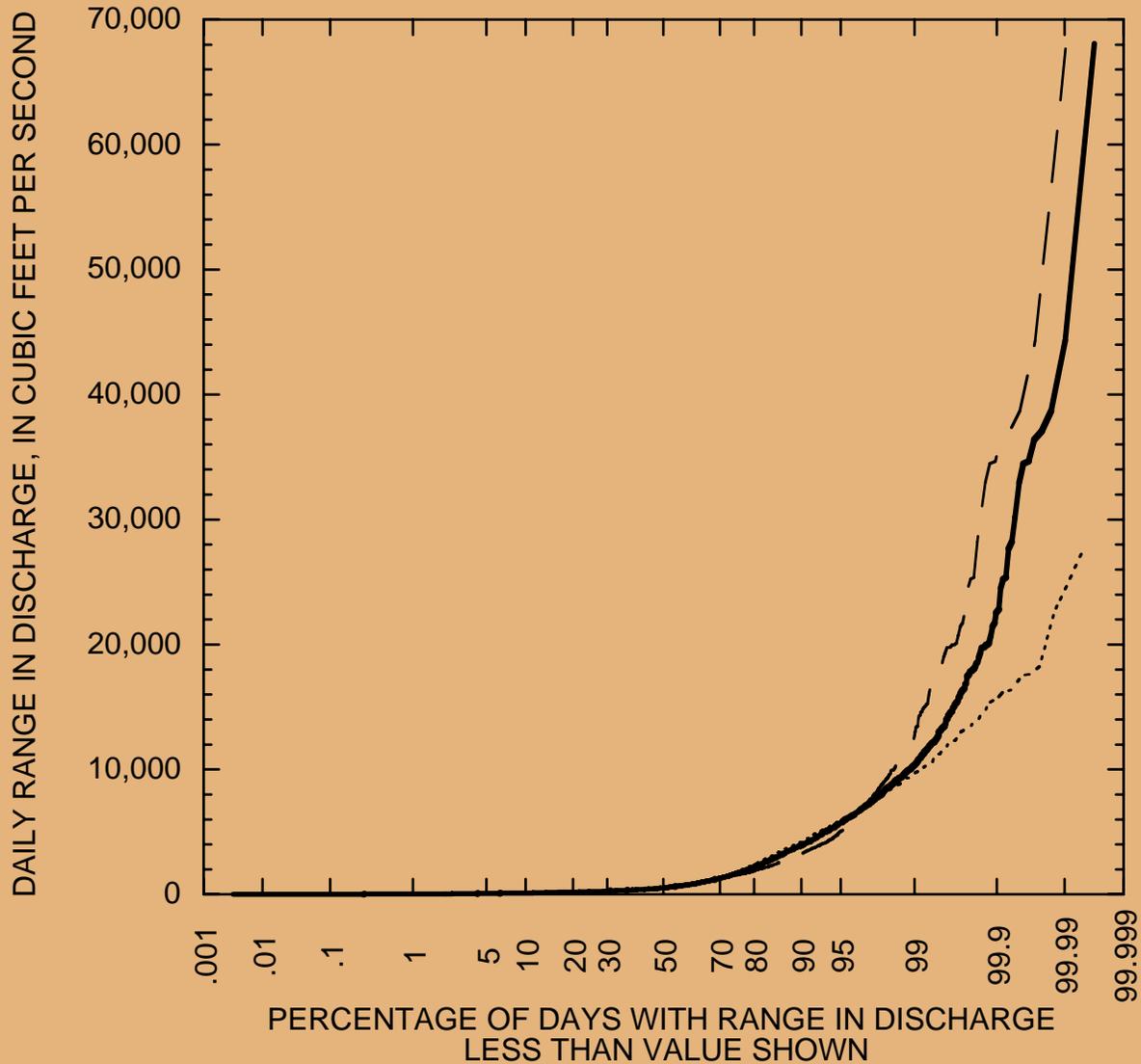
—○— POST-DAM

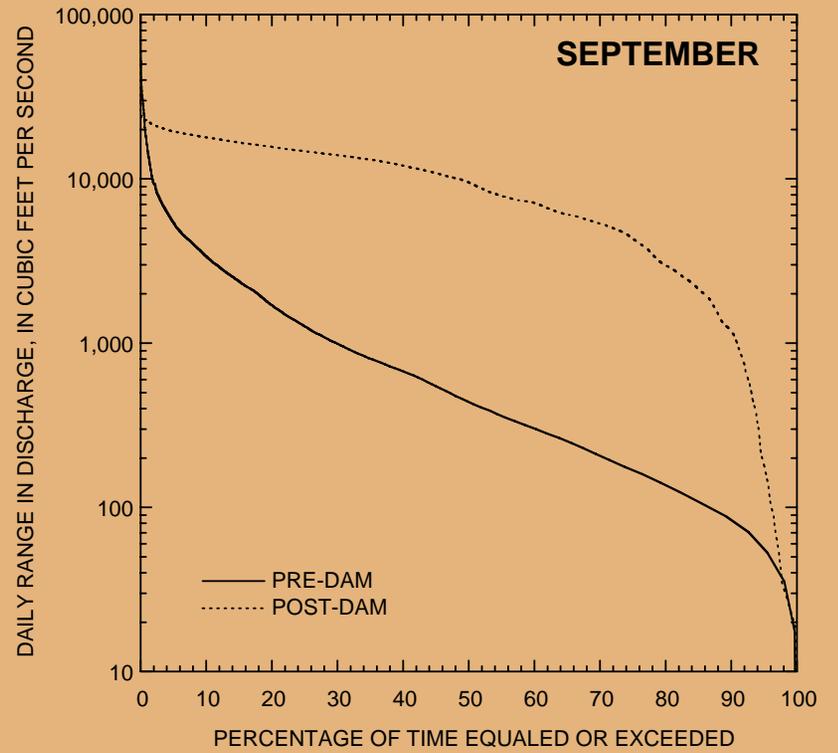
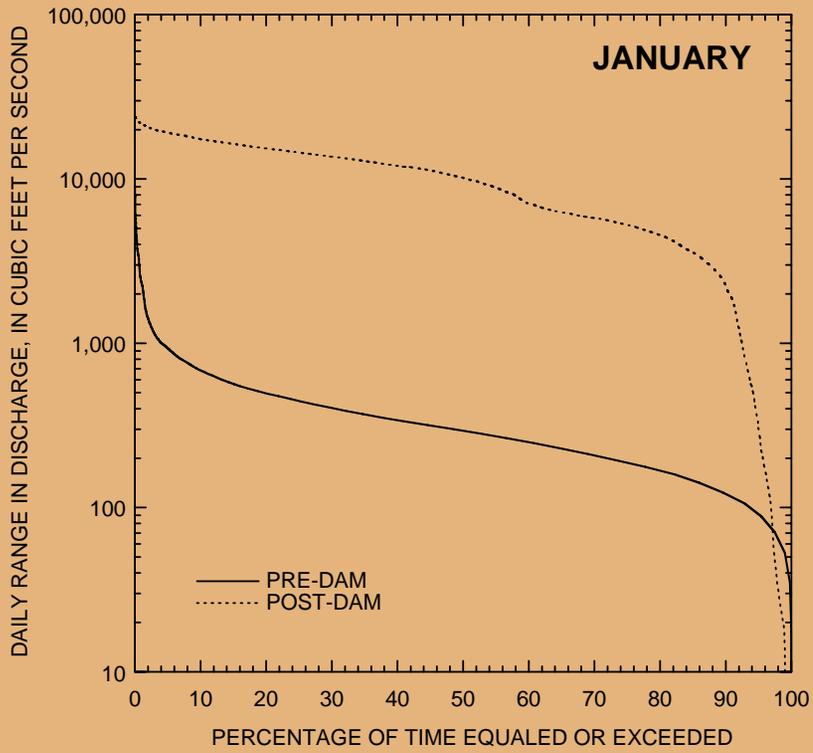




# EXPLANATION

- PRE-DAM ALL (May 9, 1921, through March 12, 1963)
- - PRE-DAM JULY THROUGH OCTOBER (summer thunderstorm season)
- ..... PRE-DAM NOVEMBER THROUGH JUNE

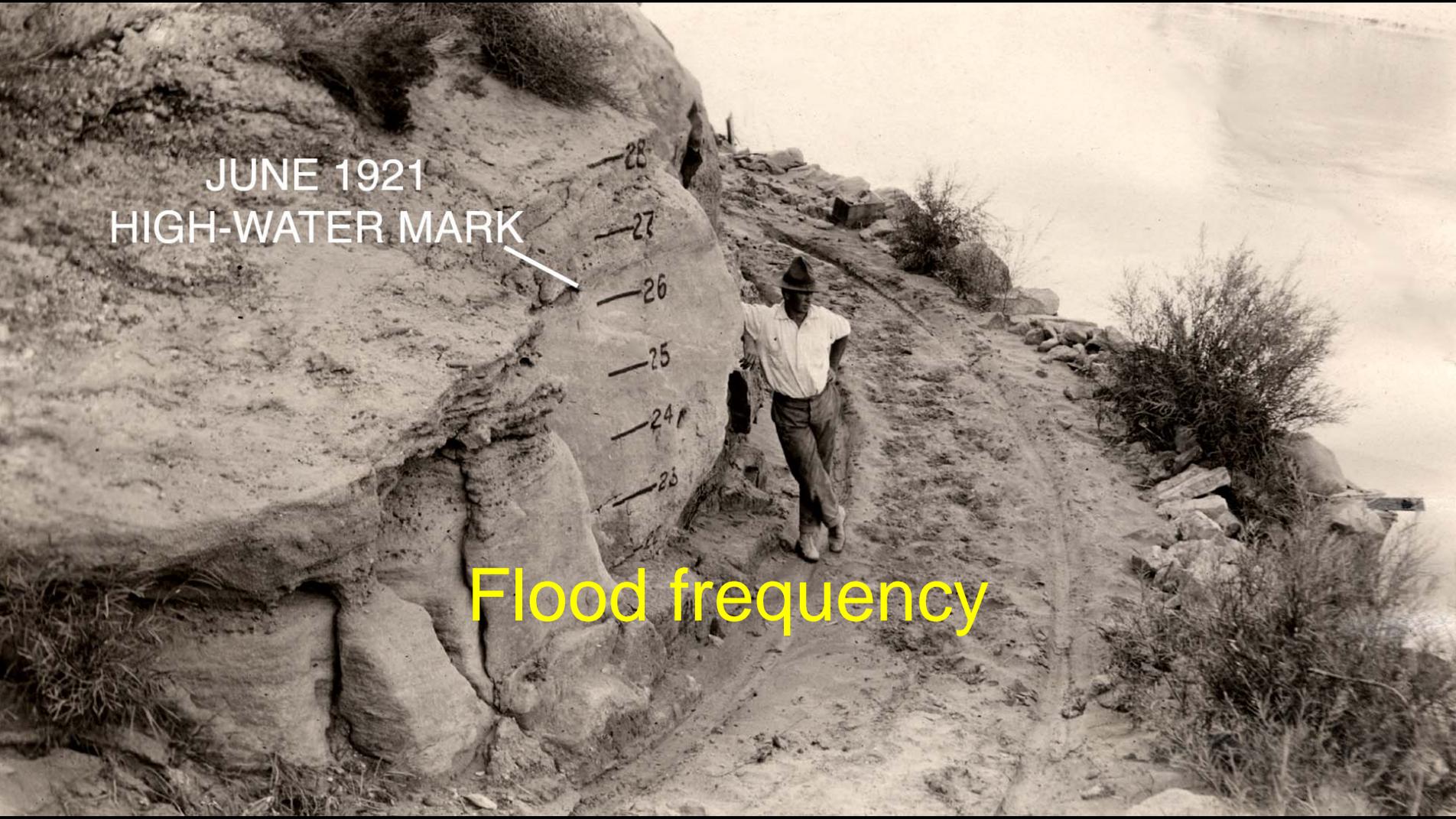


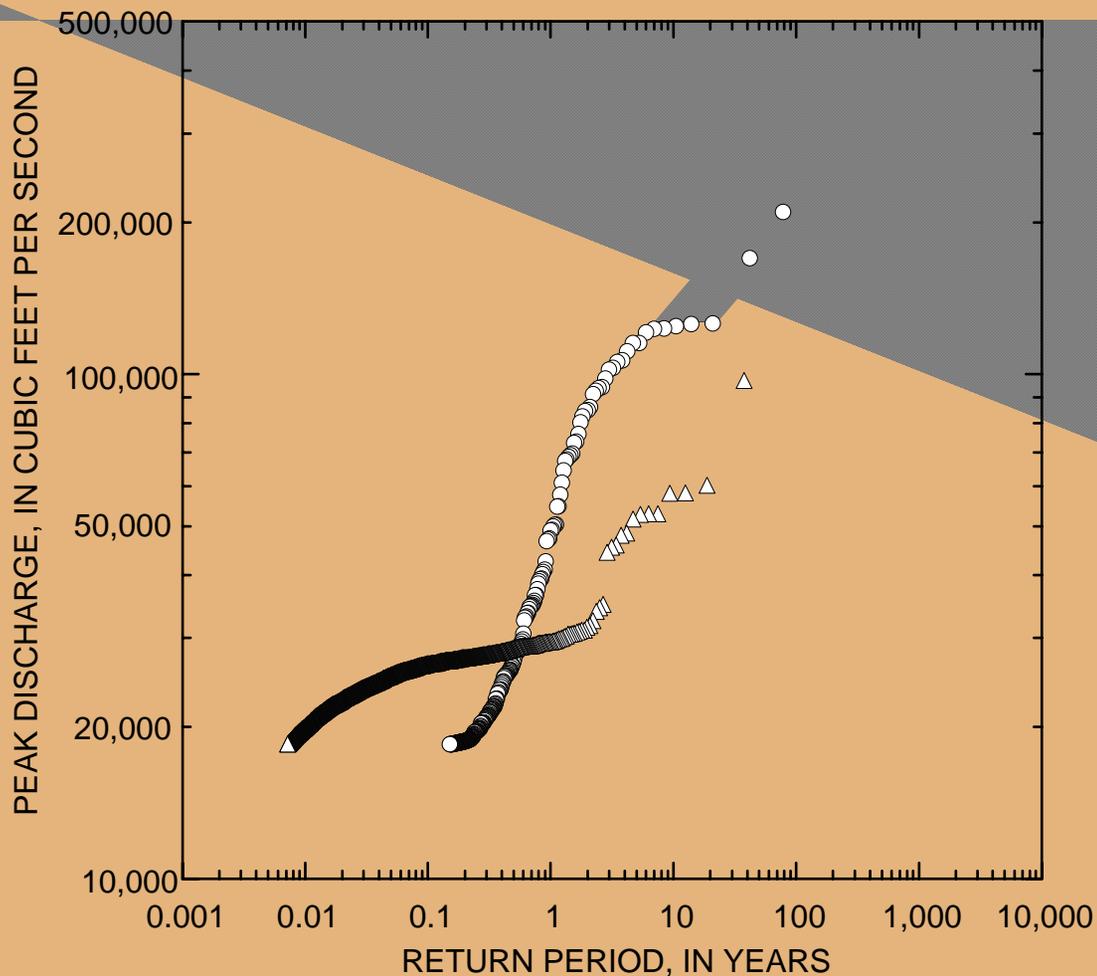


JUNE 1921  
HIGH-WATER MARK

—28  
—27  
—26  
—25  
—24  
—23

Flood frequency





**PRE-DAM**  
 1 yr - 50,000 ft<sup>3</sup>/s  
 2 yrs - 85,000 ft<sup>3</sup>/s  
 6 yrs - 120,000 ft<sup>3</sup>/s

**POST-DAM**  
 1 yr - 29,500 ft<sup>3</sup>/s  
 2 yrs - 31,500 ft<sup>3</sup>/s  
 6 yrs - 52,800 ft<sup>3</sup>/s

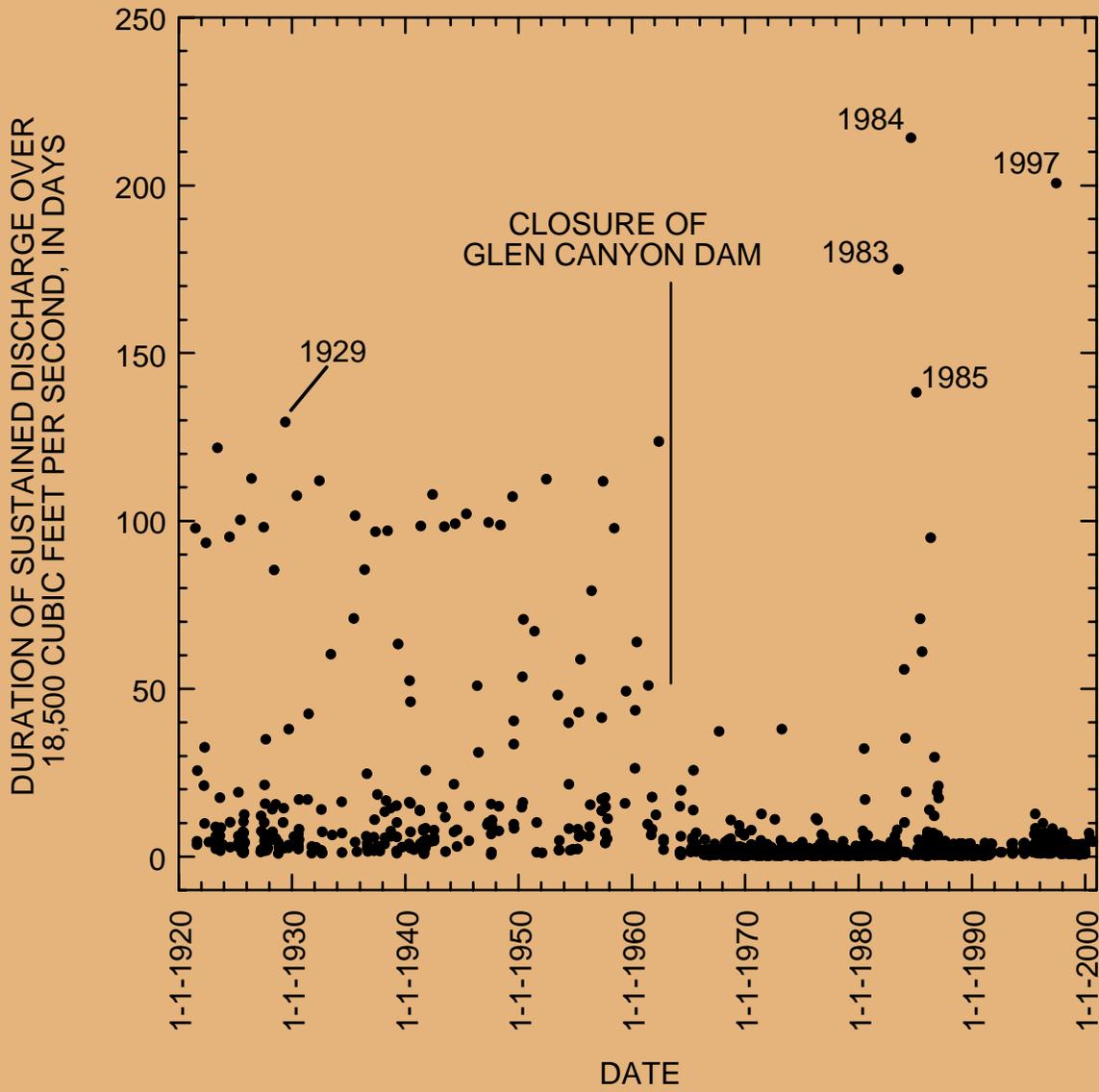
**PRE-DAM**  
 20,000 ft<sup>3</sup>/s - 97 days  
**POST-DAM**  
 20,000 ft<sup>3</sup>/s - 3.6 days

### EXPLANATION

- PRE-DAM PARTIAL-DURATION FLOOD SERIES
- △ POST-DAM PARTIAL-DURATION FLOOD SERIES
- UPWARD EXTENSION OF PRE-DAM PARTIAL-DURATION FLOOD SERIES BASED ON THE PALEOFLOOD DATA COMPUTED FROM THE REVISED DISCHARGES AND ADJUSTED RETURN PERIODS FROM THIS STUDY



Duration of sustained high flows



4 LONGEST PERIODS OF SUSTAINED HIGH DISCHARGE OCCURRED AFTER CLOSURE OF THE DAM

# Conclusions --- pre-dam

- Substantial natural variability existed in discharge and in the daily range in discharge over decadal timescales prior to construction of the dam
- Median discharge = 7,980 ft<sup>3</sup>/s
- Median daily range in discharge 542 = ft<sup>3</sup>/s
- Wettest decade---1920s---median discharge 10,700 ft<sup>3</sup>/s , median daily range in discharge 808 ft<sup>3</sup>/s
- Driest decade---1930s---median discharge 6,720 ft<sup>3</sup>/s , median daily range in discharge 516 ft<sup>3</sup>/s
- Flows conducive to sand accumulation occurred 55.7% of the time between 1921 and 1963, with the 1930s likely being the decade most dominated by sand accumulation
- Discharges in excess of 18,500 ft<sup>3</sup>/s occurred only 25% of the time pre-dam
- Daily ranges in discharge exceeded 10,000 ft<sup>3</sup>/s only during 1% of all pre-dam days and exceeded 30,000 ft<sup>3</sup>/s during 1 day every 3 years
- On average, floods with peak discharges of 50,000 ft<sup>3</sup>/s occurred every year, floods with peak discharges of 85,000 ft<sup>3</sup>/s occurred every 2 years, and floods with peak discharges of 120,000 ft<sup>3</sup>/s occurred every 6 years

# Conclusions --- post-dam

- Changes imposed on the hydrology by dam operations exceed anything in the quasi-natural pre-dam period of record; seasonality removed from both discharge and the daily range in discharge
- Median discharge -- 1960s = 9,490 ft<sup>3</sup>/s --- 1990s = 13,500 ft<sup>3</sup>/s
- Dam operations have largely eliminated base flows; pre-dam minimum discharge = 483 ft<sup>3</sup>/s; pre-dam discharges < 5,000 ft<sup>3</sup>/s 32.7% of the time
- Median daily range in discharge has increased by a factor of 15.8 relative to pre-dam; post-dam median daily range (8,580 ft<sup>3</sup>/s ) exceeds pre-dam median discharge (7,980 ft<sup>3</sup>/s )
- Post-dam daily range in discharge exceeds pre-dam daily range in discharge except during 0.1% of all pre-dam days
- Flows conducive to sand accumulation have progressively disappeared; discharge exceeded 9,000 ft<sup>3</sup>/s --in 1960s, 52.7% of the time--in 1970s, 62.2% of the time--in 1980s, 75.5% of the time--in 1990s, 82.6% of the time
- Dam operations have maintained the frequency of floods with peak discharges of 29,000 ft<sup>3</sup>/s, have decreased the frequency of floods with larger peak discharges, and have greatly increased the frequency of “smaller” floods
- Pre-dam 2-year flood = 85,000 ft<sup>3</sup>/s ; post-dam 2-year flood = 31,500 ft<sup>3</sup>/s
- Recurrence interval of 20,000 ft<sup>3</sup>/s flood -----97 days pre-dam, 3.6 days post-dam (factor of 27 increase)
- Longest 4 periods of sustained high discharge all post-date the dam: 1984, 1997, 1983, 1985

# More that could be done

- Analyses of quasi-daily temperature data at the Lees Ferry and Grand Canyon gaging stations; not all data from Lees Ferry have been analyzed; none from Grand Canyon (pre-dam river at these 2 sites was different with respect to temperature)
- Analyses of decadal, annual, seasonal, and daily variability in turbidity (1925 through 1972 at the Grand Canyon gaging station); note HBC were listed in 1967