Examination of Direct Discharge Measurement Data and Historic Daily Data for Selected Gages on the Middle Mississippi River, 1861-2008

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U.S. Geological Survey

Background

- US Geological Survey has assisted US Army Corps of Engineers with stage and discharge data collection on the Middle Mississippi River since 1930s
- In recent years, some researchers have found what appear to be trends of rising stage for a given discharge
- USACE AREC asked USGS to examine measurement data for possible trends, and discuss cause-and-effect mechanisms

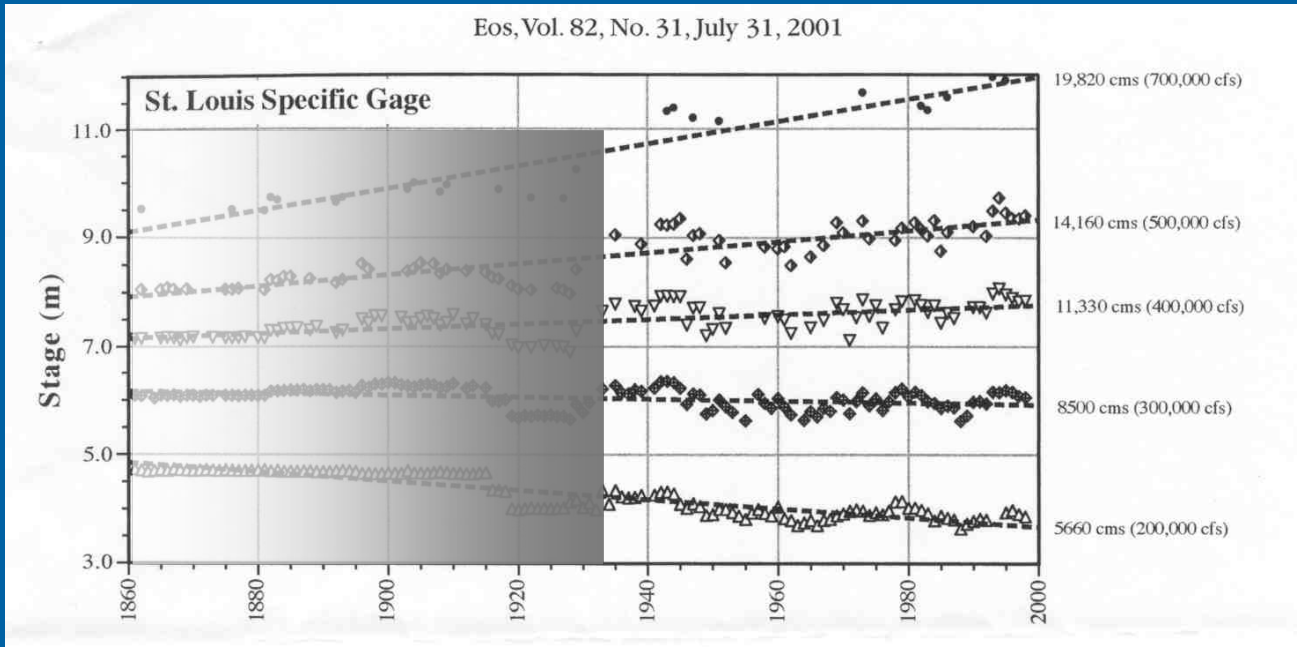

Fig. 2. Trends in stage over time are shown at the St. Louis gage of the Mississippi River using the specific-gage technique. Each line indicates stages associated with a fixed discharge, so that changes in stage over time indicate changes in the conveyance capacity of this section of the river.

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Factors Affecting Stage & Discharge

- In-channel structures
  - Dikes, bendway weirs, chevrons
- Floodplain structures
  - Levees, floodwalls, roadways
- Water Temperature
  - Cold water-> higher Q for given stage
- Seasonal variations in vegetation thickness
  - Thicker vegetation at end of growing season-> lower Q for given stage
- Timing of measurement
  - Rising limb of hydrograph-> higher Q for given stage
- Errors in measurement

All must be considered when evaluating changes in stage or discharge with time—Small changes might just as likely be caused by natural phenomena as by human impacts

USGS

Location

- Middle Mississippi River (MMR)

- Primarily examined data from gages at St. Louis & Chester

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Mississippi River at St. Louis, Missouri

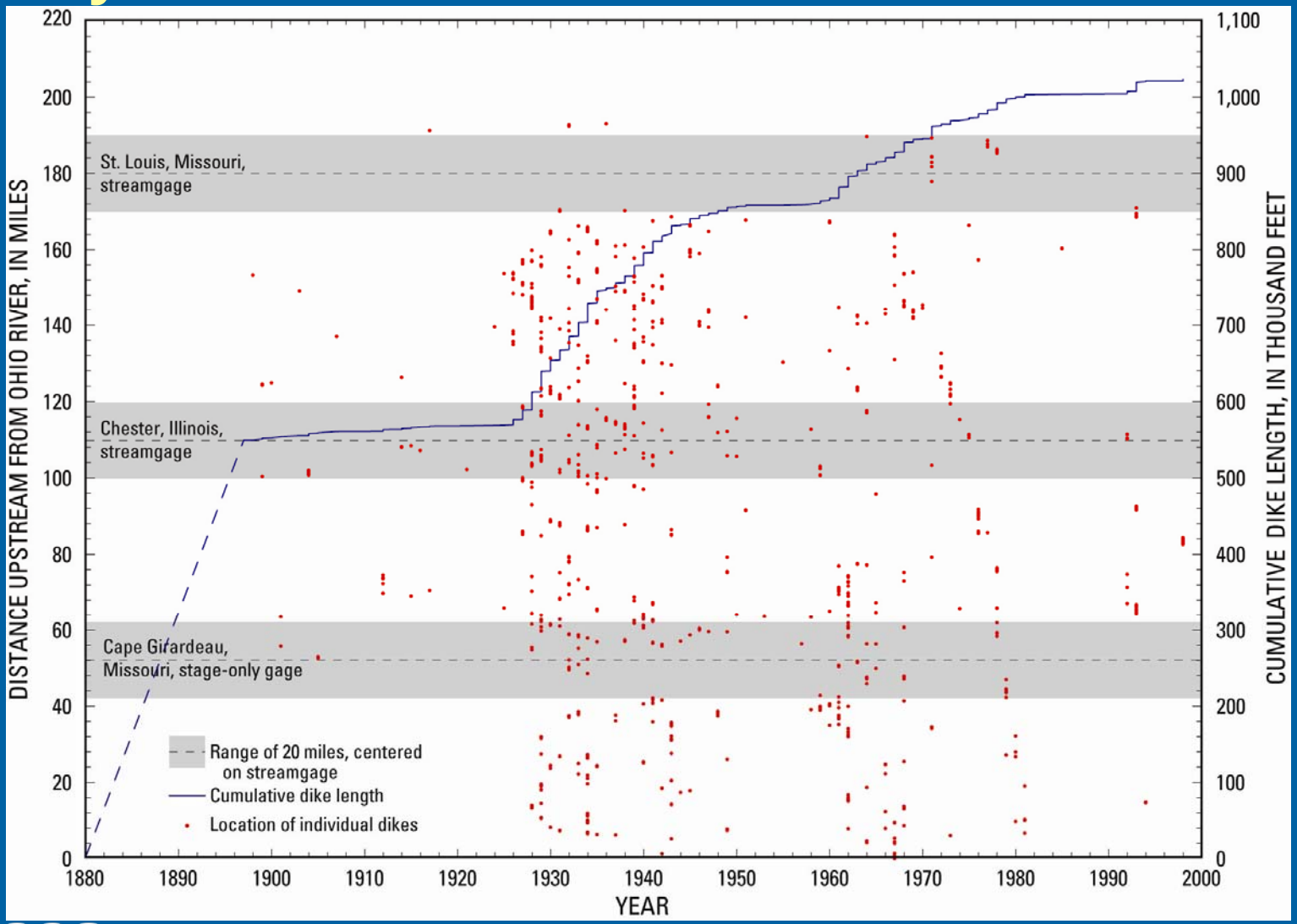
- Daily stage and discharge values from 1861 at St. Louis staff gage in database
- USGS began operating in 1933, continuous stage-discharge data, Eads Bridge
- Measurement methods
  - 1933-2003 Price AA
  - 1998-2003 transition
  - 1998-> ADCP
- Measurement location
  - 1933-1968 Municipal/ MacArthur Bridge
  - 1968-2003 Poplar Street

Mississippi River at Chester, Illinois

- Daily stage values from 1891 in database
- USGS began operating in 1942, continuous stage-discharge data
- Measurement methods
  - 1942-2003 Price AA
  - 1997-2003 transition
  - 1997-> ADCP
- Measurement location
  - 1942-2003 Chester Bridge
  - 1944-1946 boat

USGS

History of Dikes on MMR



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History of Floods on MMR (from St. Louis gage)

- Historic Peak: June 1844, 41.32 ft stage
  Estimated Discharge: 1,000,000 cfs

Before USGS Operation			Since USGS Operation		
Date	**Stage**	**Discharge**	**Date**	**Stage**	**Discharge**
May 1881	33.65	822,000	May 1943	38.94	840,000
June 1883	34.80	863,000	April 1944	39.14	844,000
May 1892	36.17	926,000	July 1947	40.26	783,000
June 1903	38.00	1,020,000	July 1954	40.28	782,000
June 1908	34.95	850,000	April 1973	43.23	852,000
July 1909	35.25	861,000	Aug 1993	49.58	1,070,000
April 1922	33.95	786,000	May 1995	41.89	800,000
April 1927	36.10	889,300			

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Data Examined for Period of USGS Operation

- Stage-Discharge Relation (Rating) for Measurements
- Stage from Rating Curves
- Measured Top-Width from Measurements
- Average Velocity from Measurements
- Average Bed Elevation
- Cross Sections from Measurements

Data Examined for Historic Period of Record

- Difference in Water-Surface Elevation
- Daily Data at St. Louis, Missouri, since 1861

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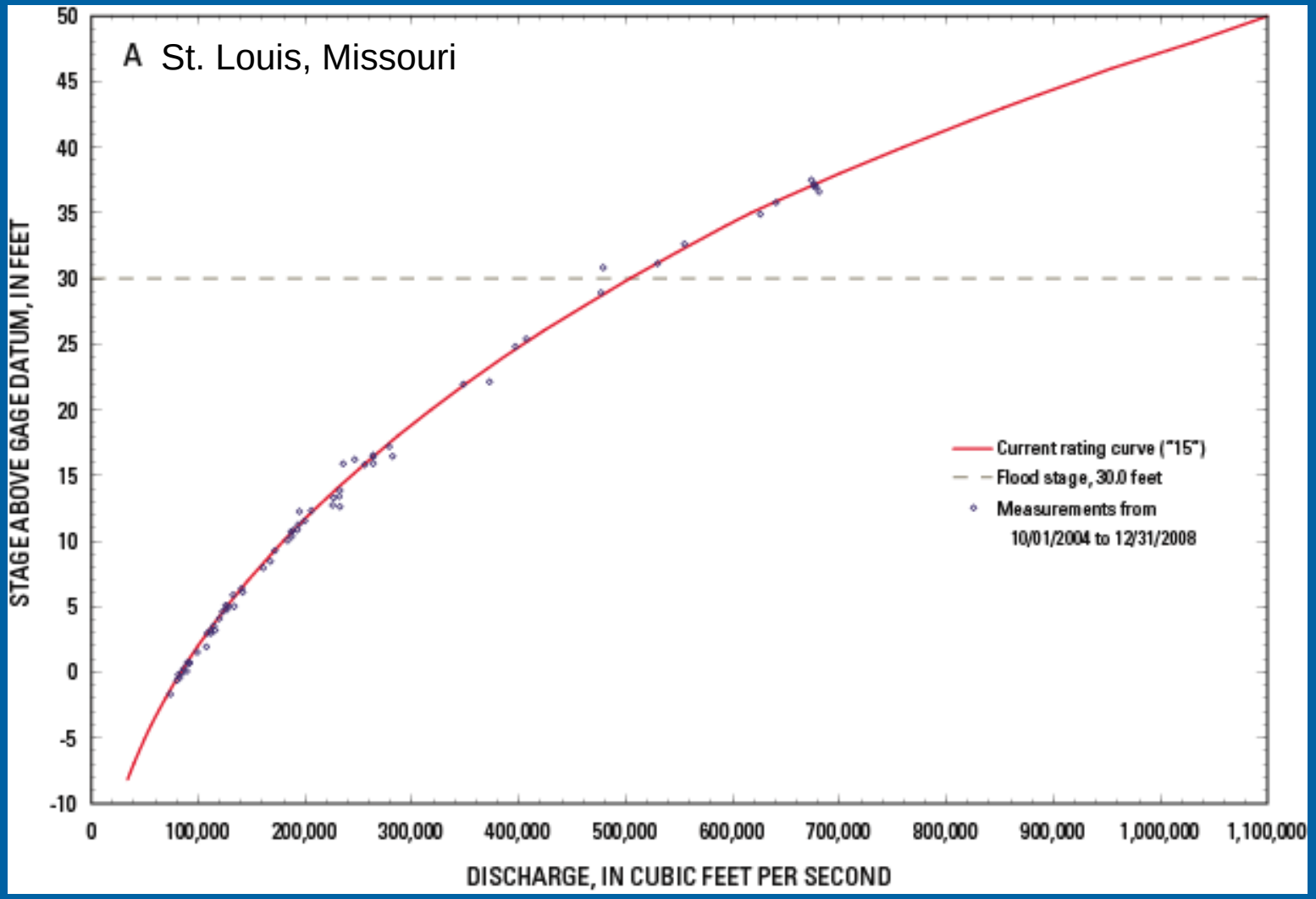
Stage-Discharge Relation (Rating)



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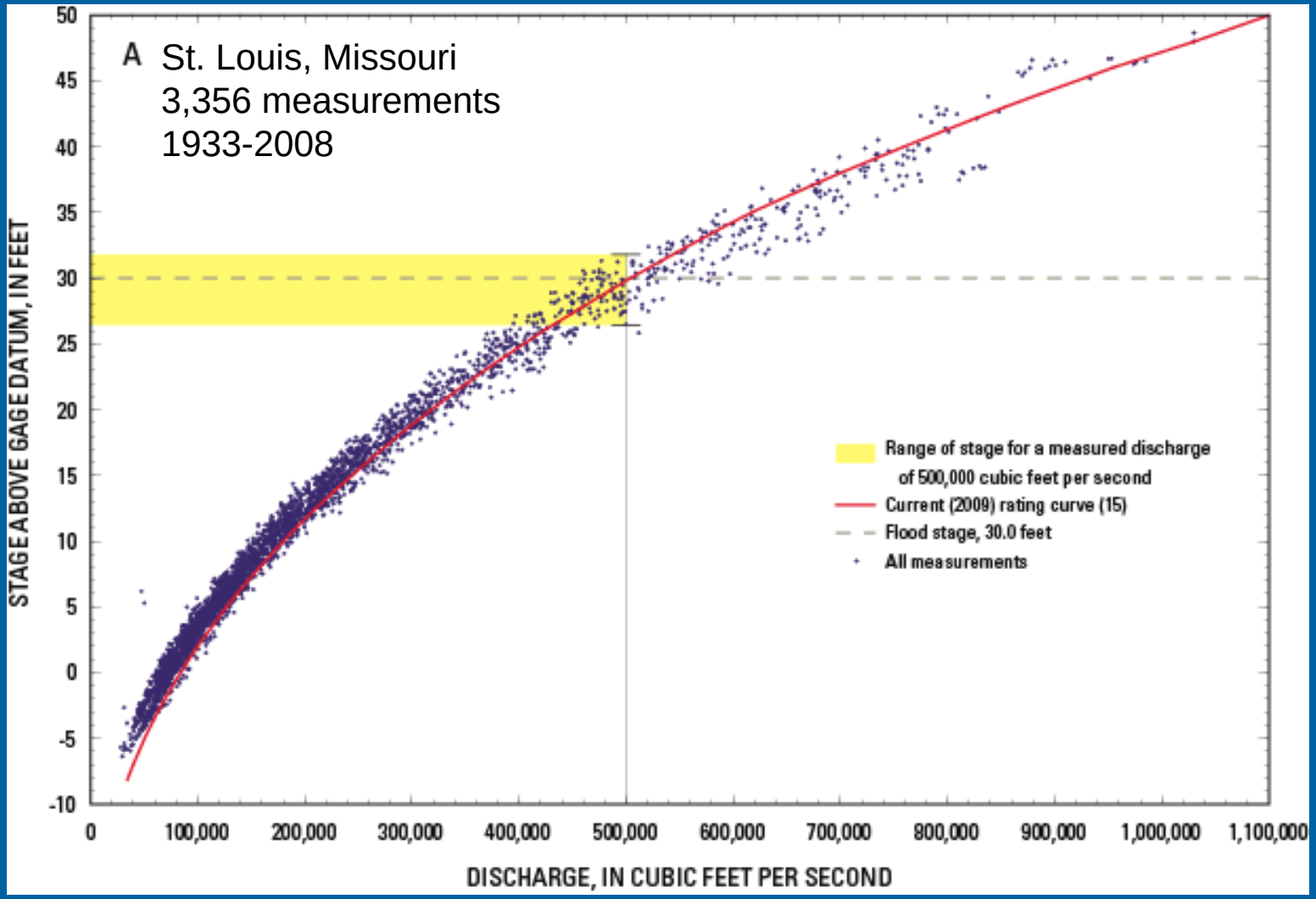

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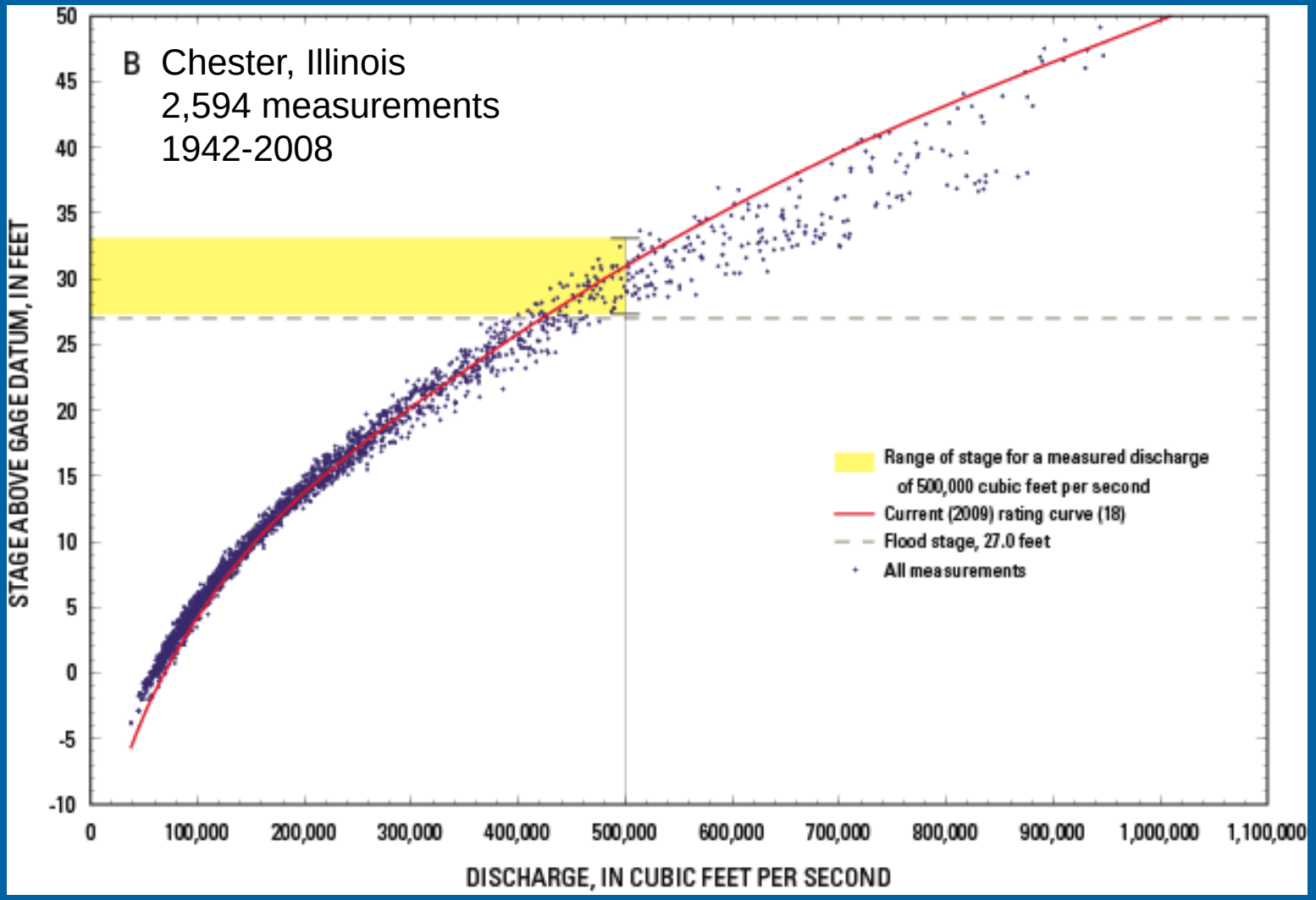

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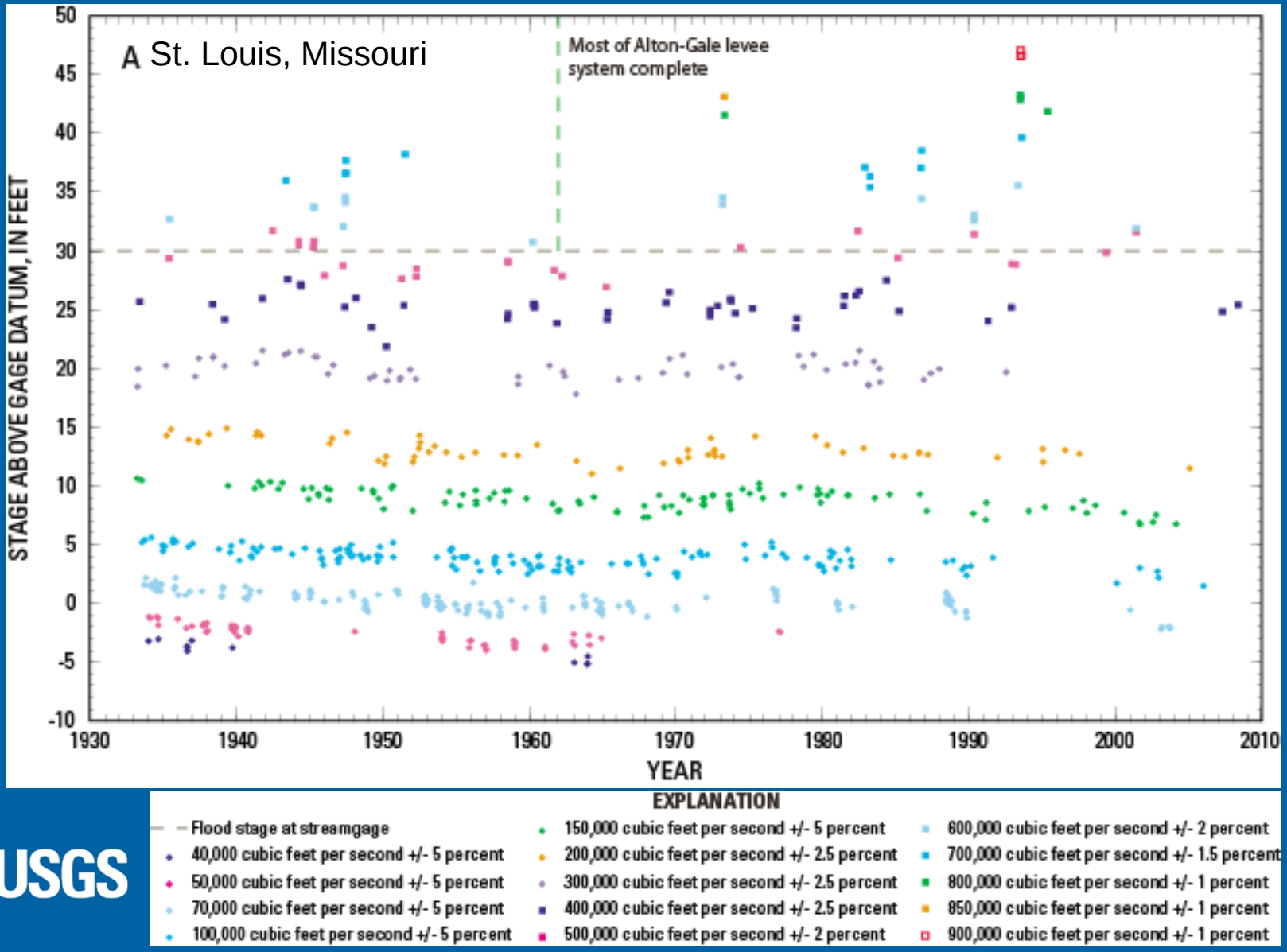

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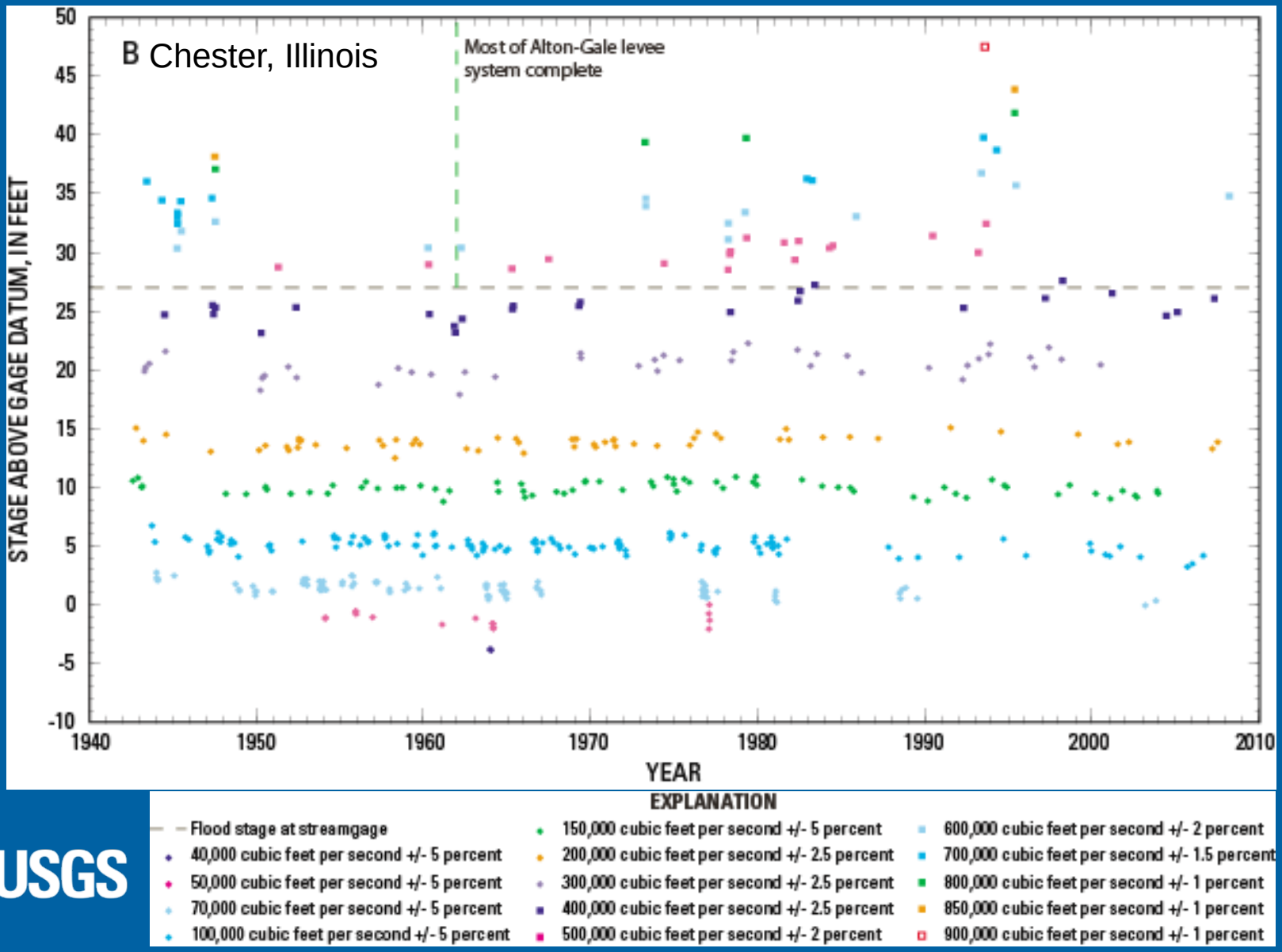

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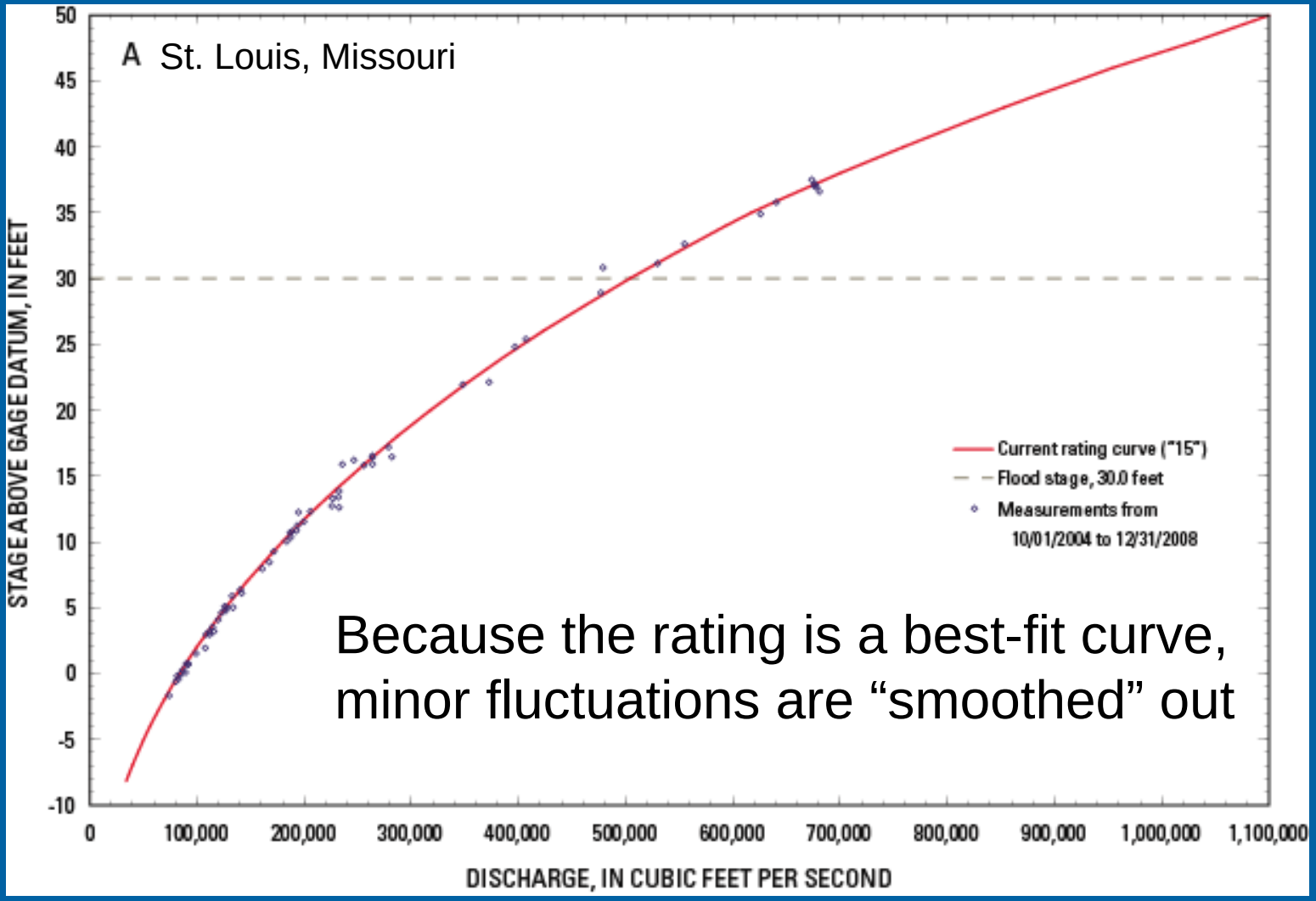
Stage from Rating



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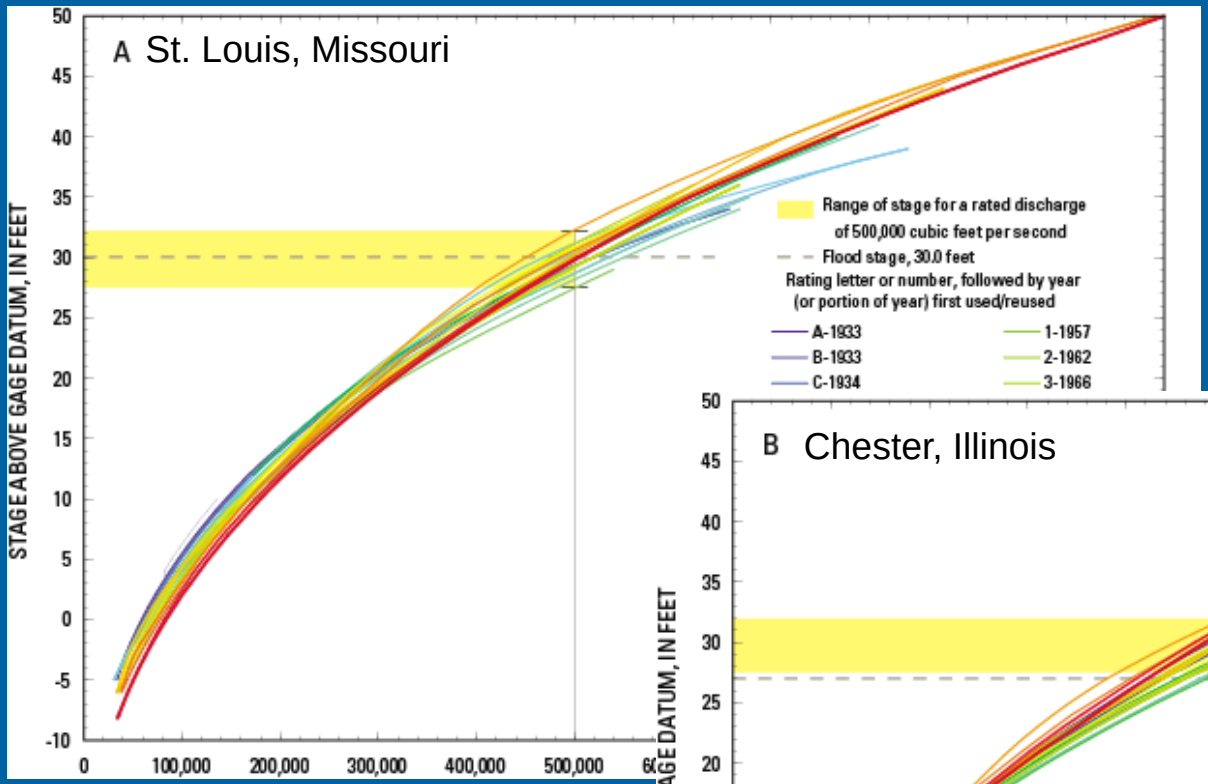
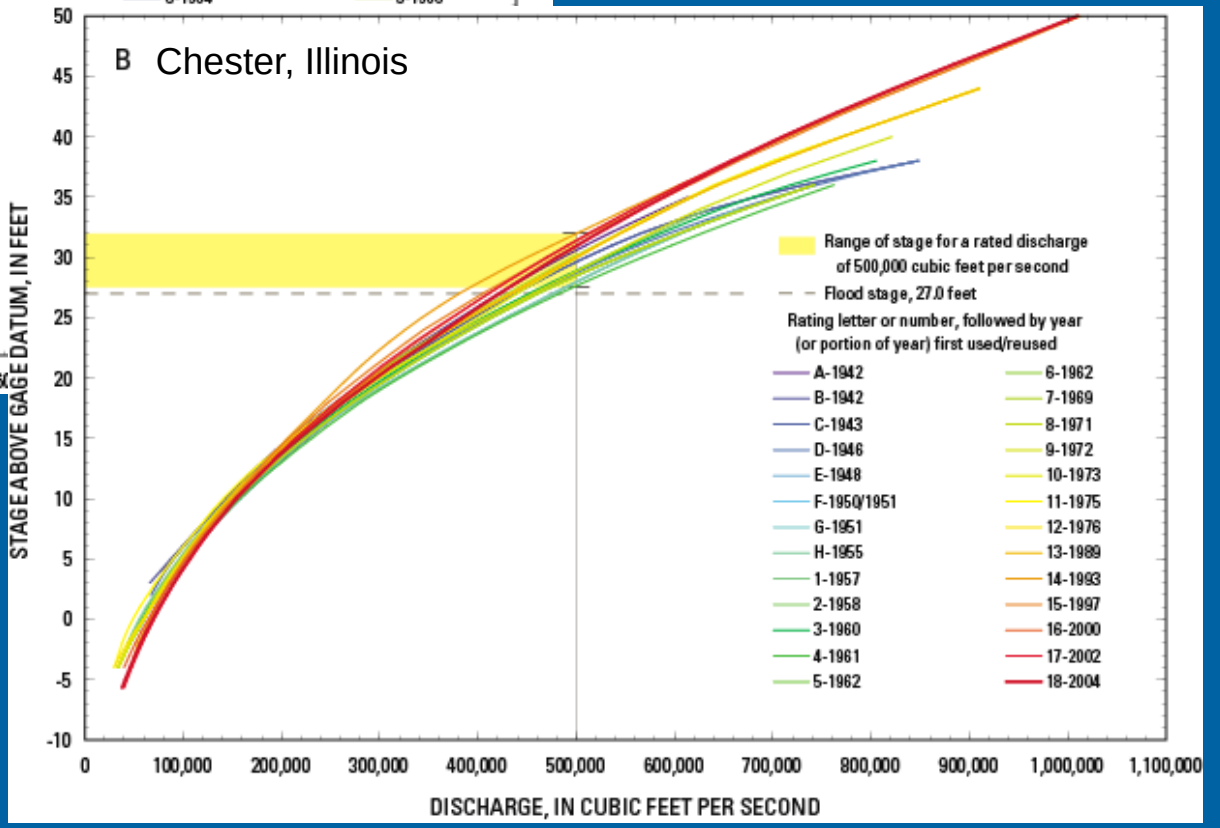
Stage from Ratings





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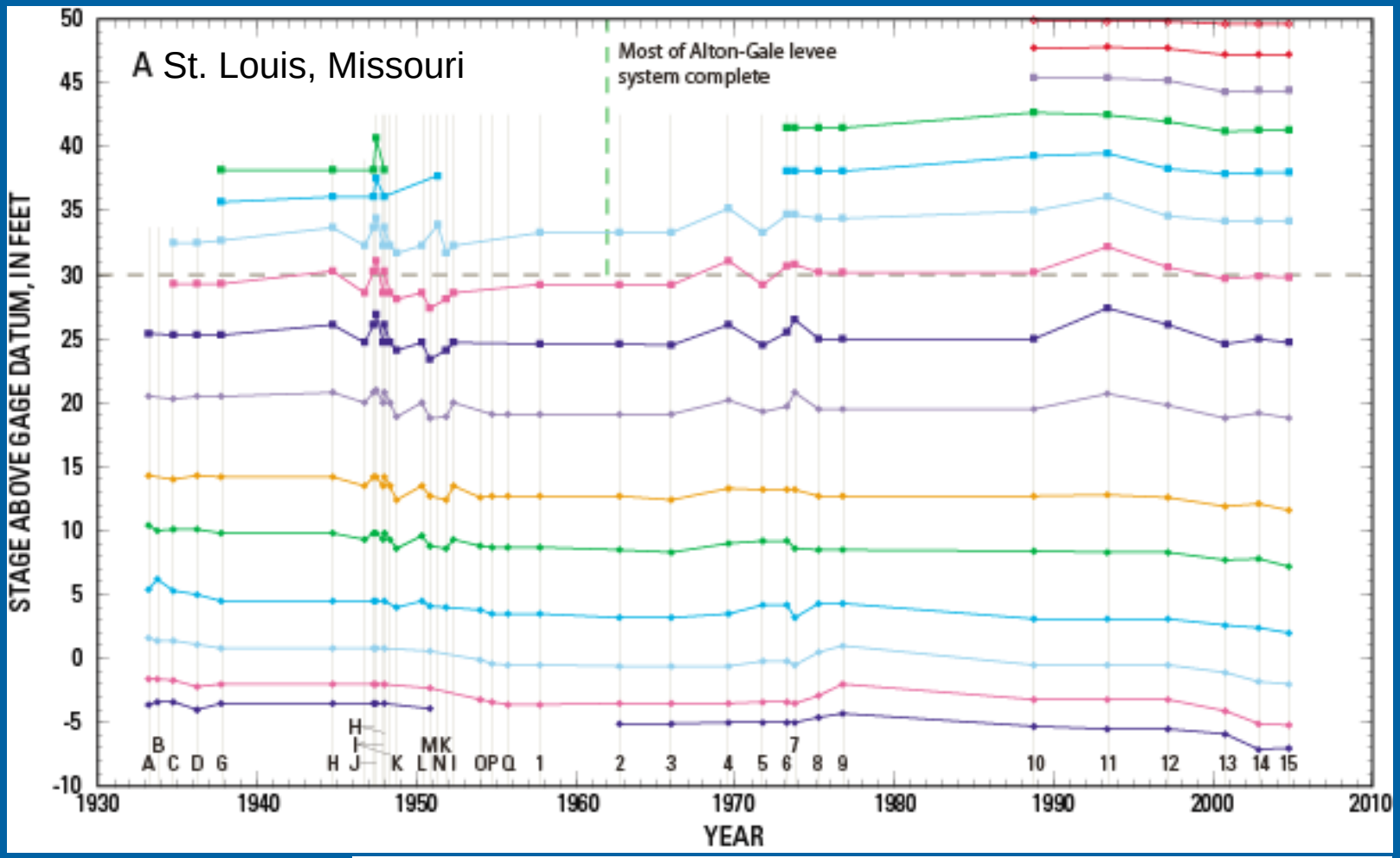

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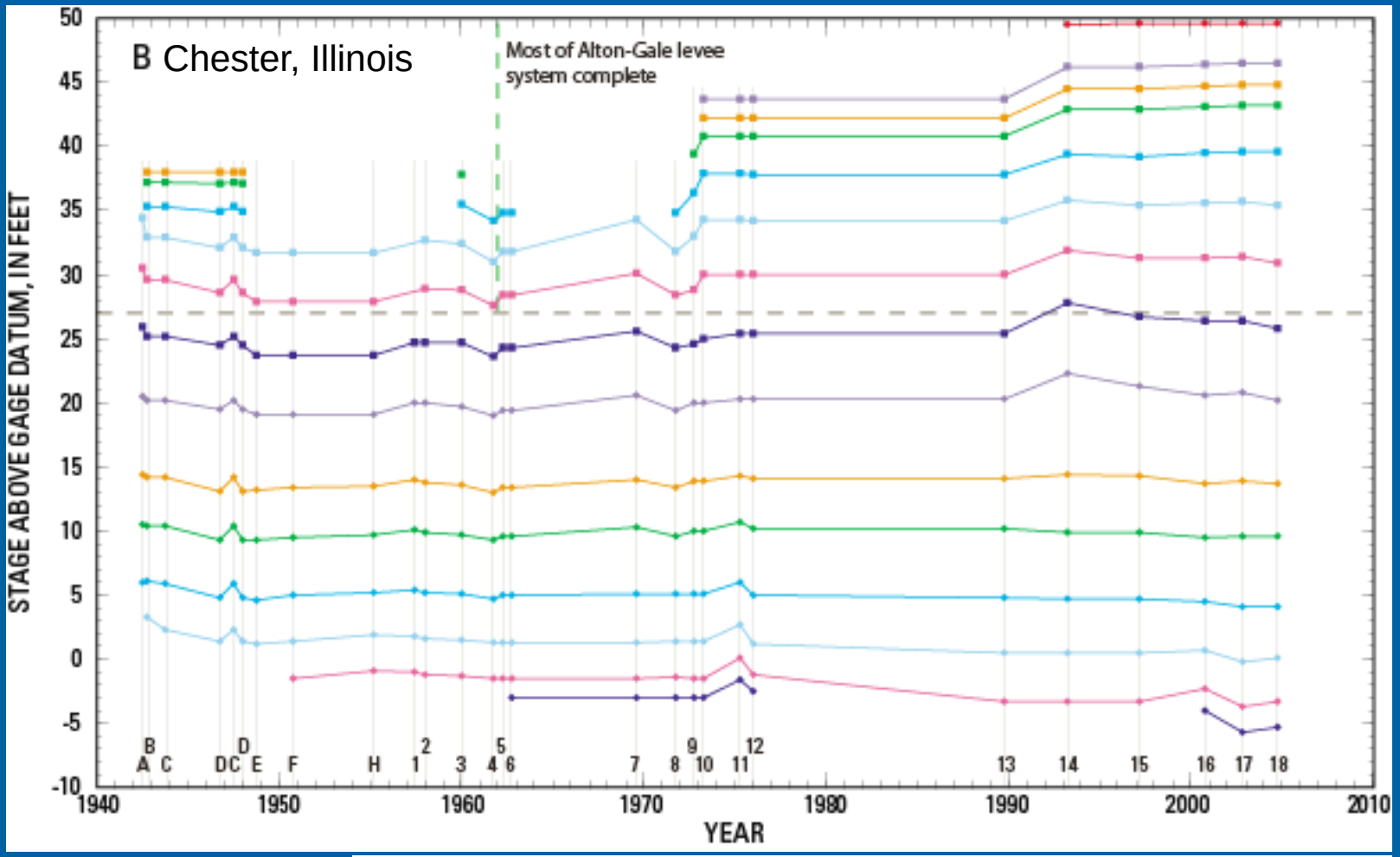

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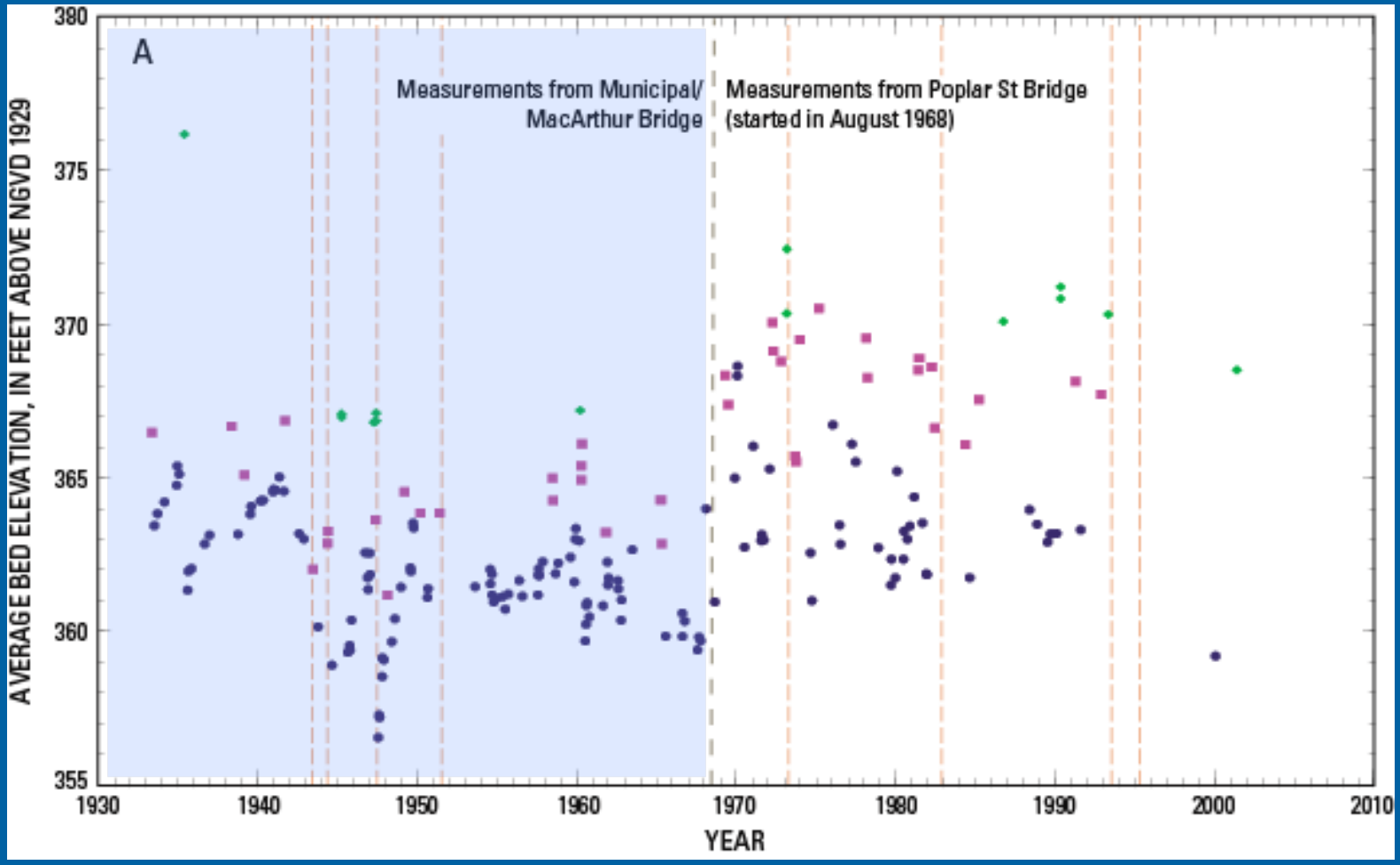
Stage from Measurements and Ratings

- St. Louis
  - Below flood stage, appears to be decreasing with time
  - Above flood stage, shows some increase with time
- Chester
  - Below 2/3 flood stage, appears to be decreasing with time
  - Above 2/3 flood stage, appears to be increasing with time
- Decreases below flood stage likely are caused by effects of wing dikes (as designed) and reduced sediment flux
- Increases above flood stage likely are caused by construction or raising of levees
- Large floods (such as in 70's and 90's) caused temporary fluctuations in rating
- Highest flows
  - STL—stages decreasing with time
  - Chester—stages increasing with time

USGS

Average Bed Elevation from Measurements



Flood with a peak discharge of 780,000 cubic feet per second or more at either streamgage

100,000 cubic feet per second +/- 5 percent

400,000 cubic feet per second +/- 2.5 percent

600,000 cubic feet per second +/- 2 percent

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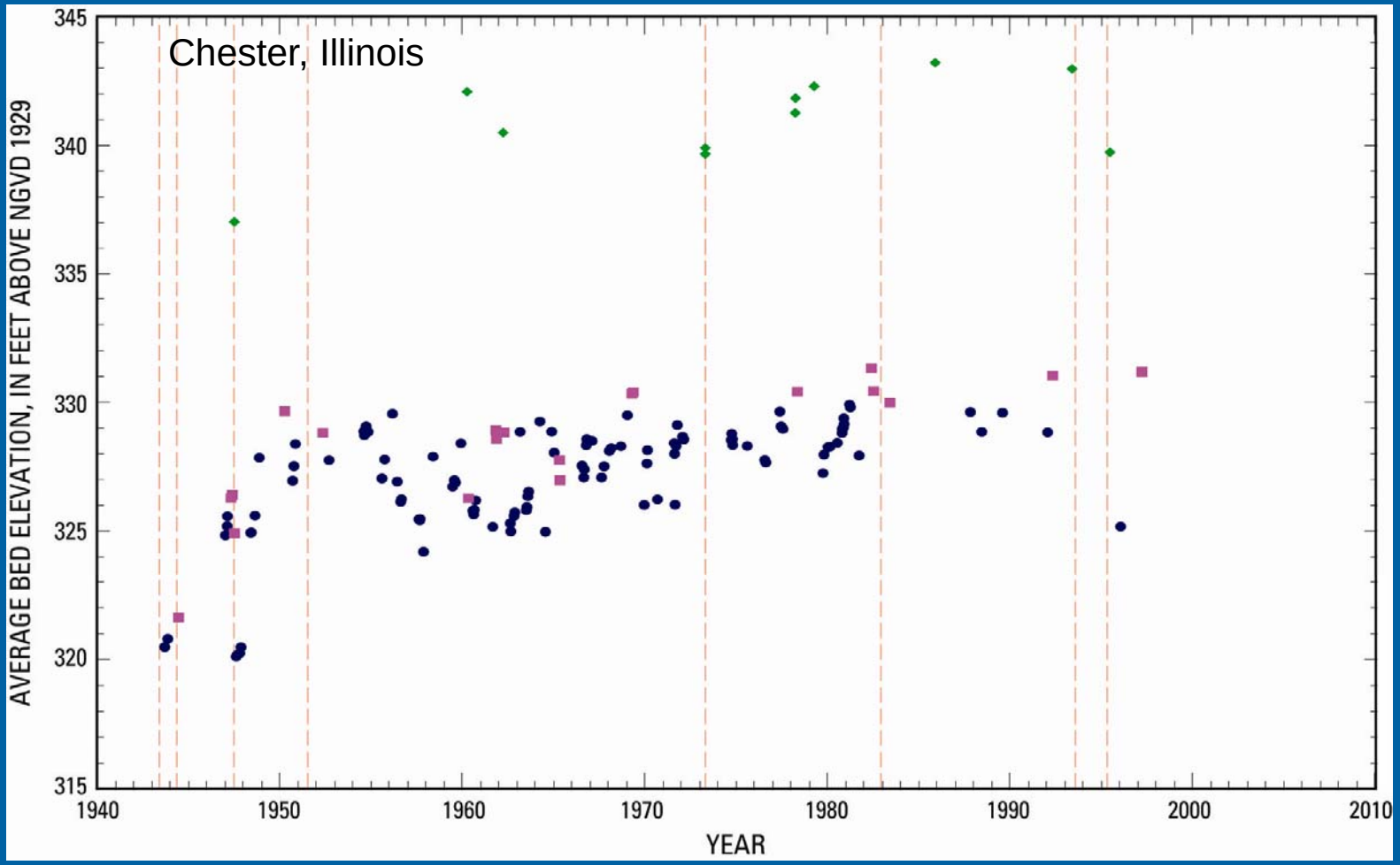

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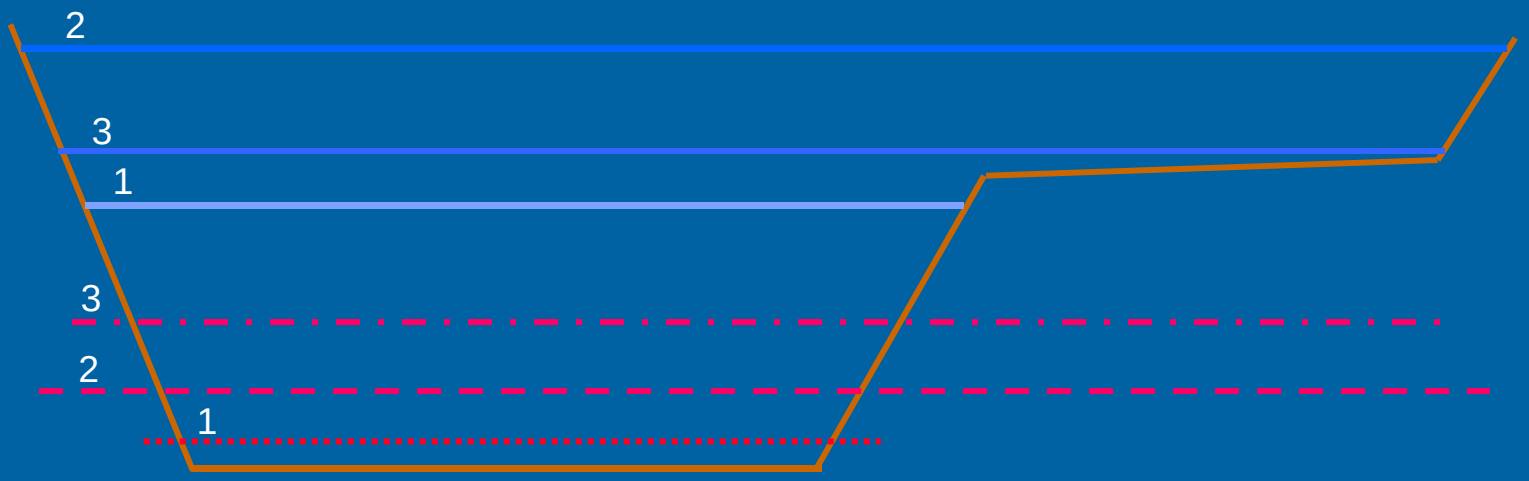
Average Bed Elevation from Measurements

- Value determined from Total Measured Area divided by Top Width, subtracted from gage height
- For flows higher than bank-full, average bed is strongly influenced by flood plain



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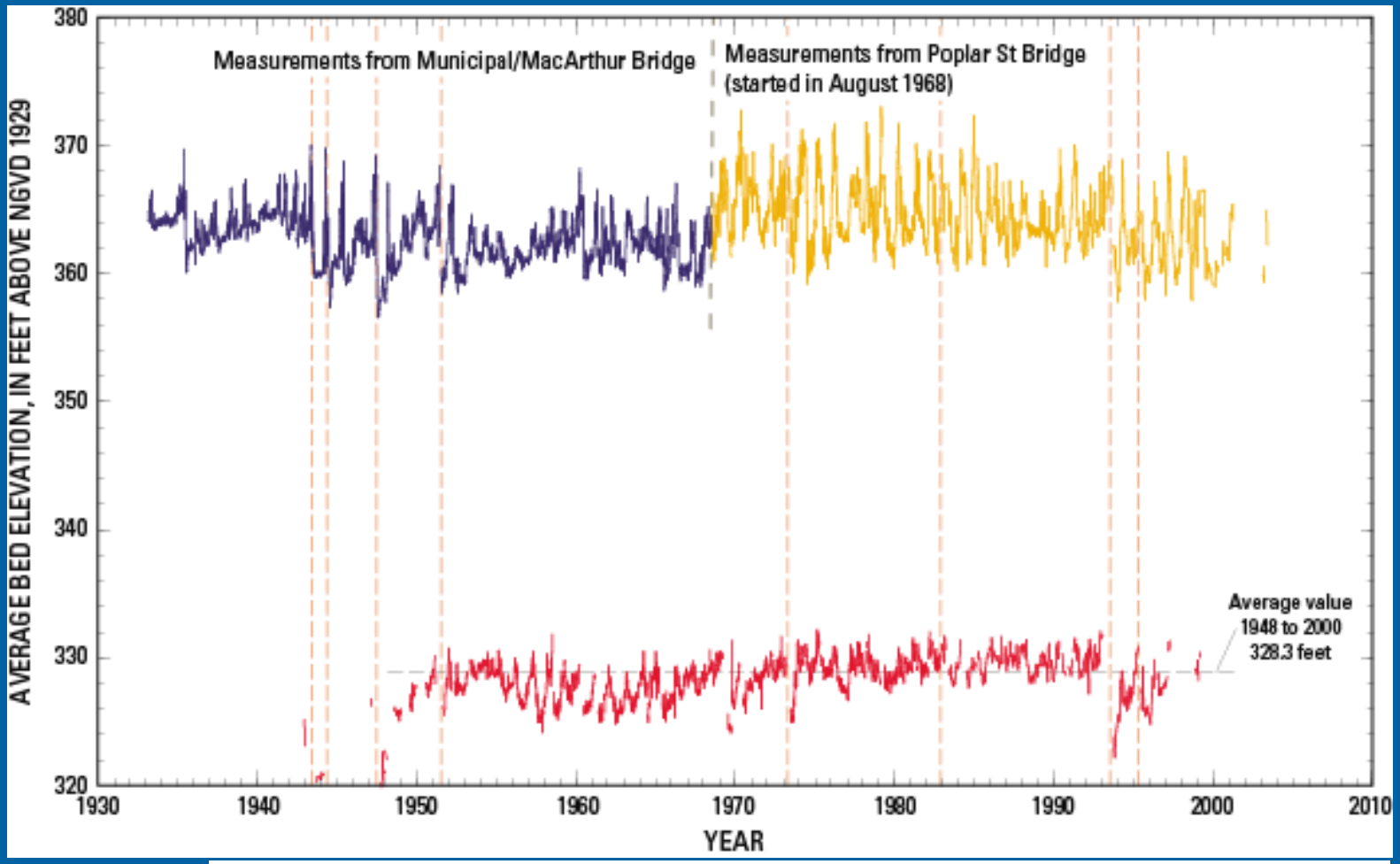

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Examination of Measurement Data

- Top widths
  - STL—Indicates change in measurement location
  - Chester—Indicates infilling of overflow channel
- Average Velocity
  - STL—No substantial changes with time
  - Chester—Slight increase with time
- Average Bed Elevation
  - STL—When measurement location change considered, indicates lowering of bed with time
  - Chester—Slight raising of bed with time
  - Profoundly affected by and responsive to floods

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Data Examined for Period of USGS Operation

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Data Examined for Historic Period of Record

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- **Daily Data at St. Louis, Missouri, since 1861**

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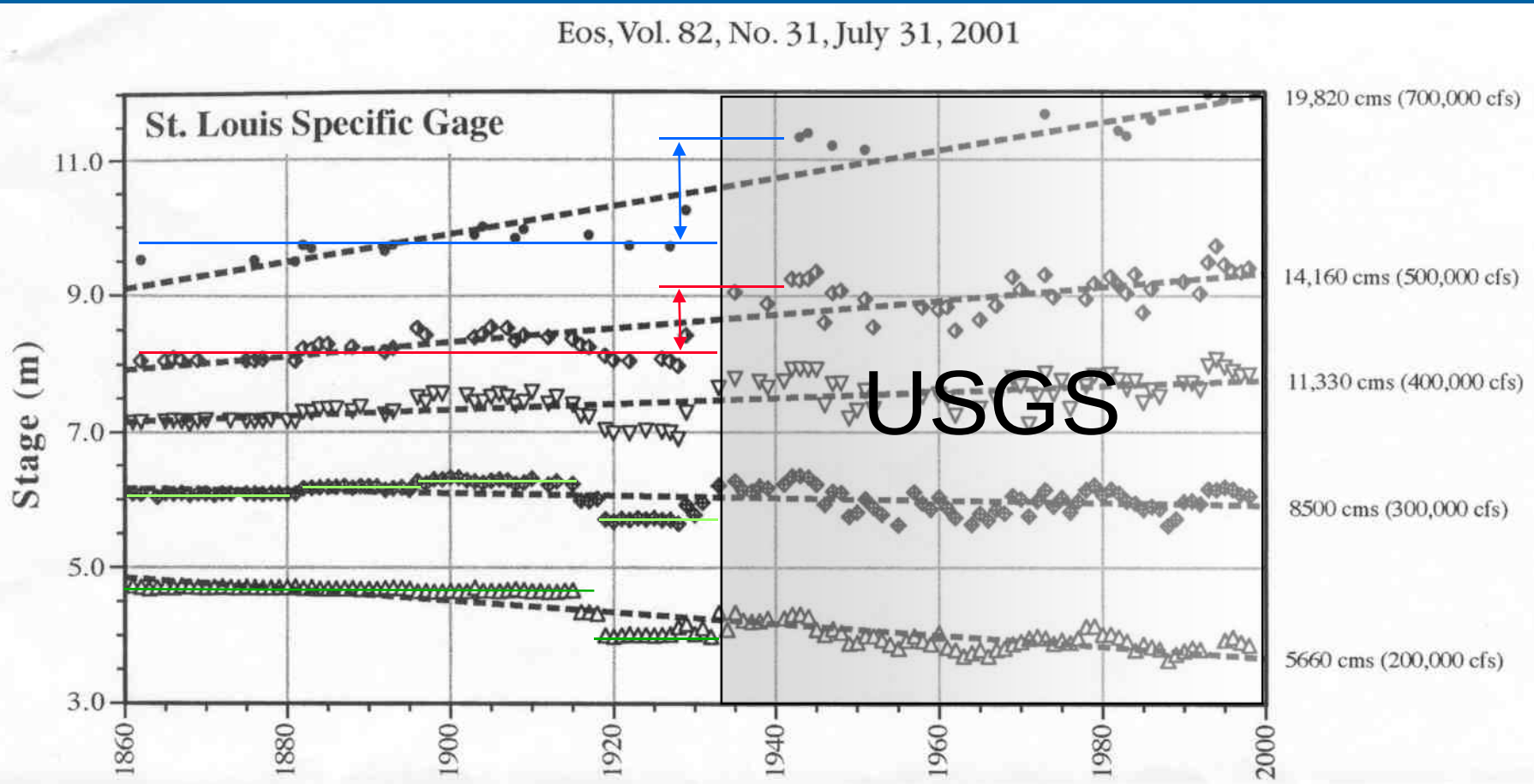

Fig. 2. Trends in stage over time are shown at the St. Louis gage of the Mississippi River using the specific-gage technique. Each line indicates stages associated with a fixed discharge, so that changes in stage over time indicate changes in the conveyance capacity of this section of the river.

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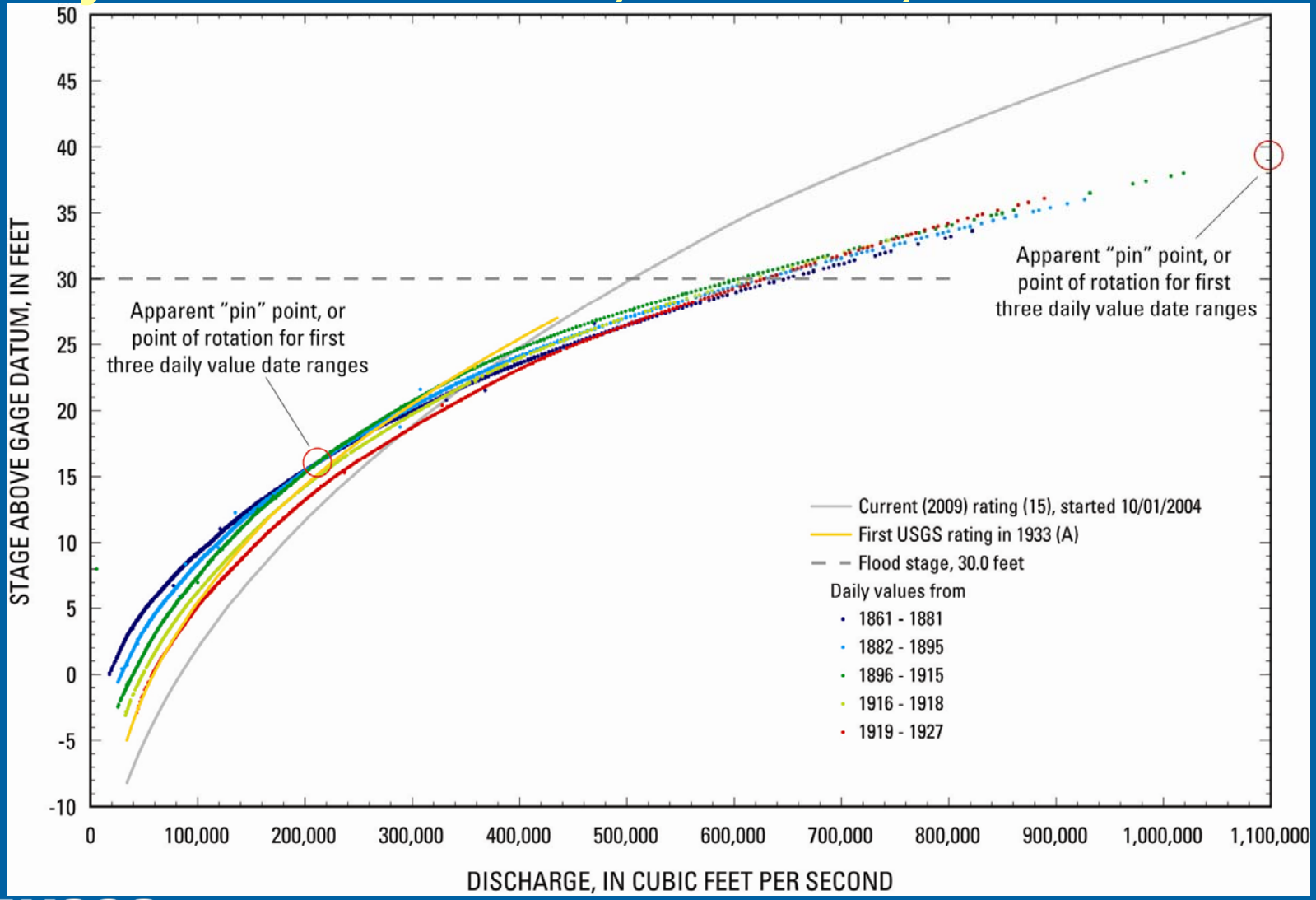

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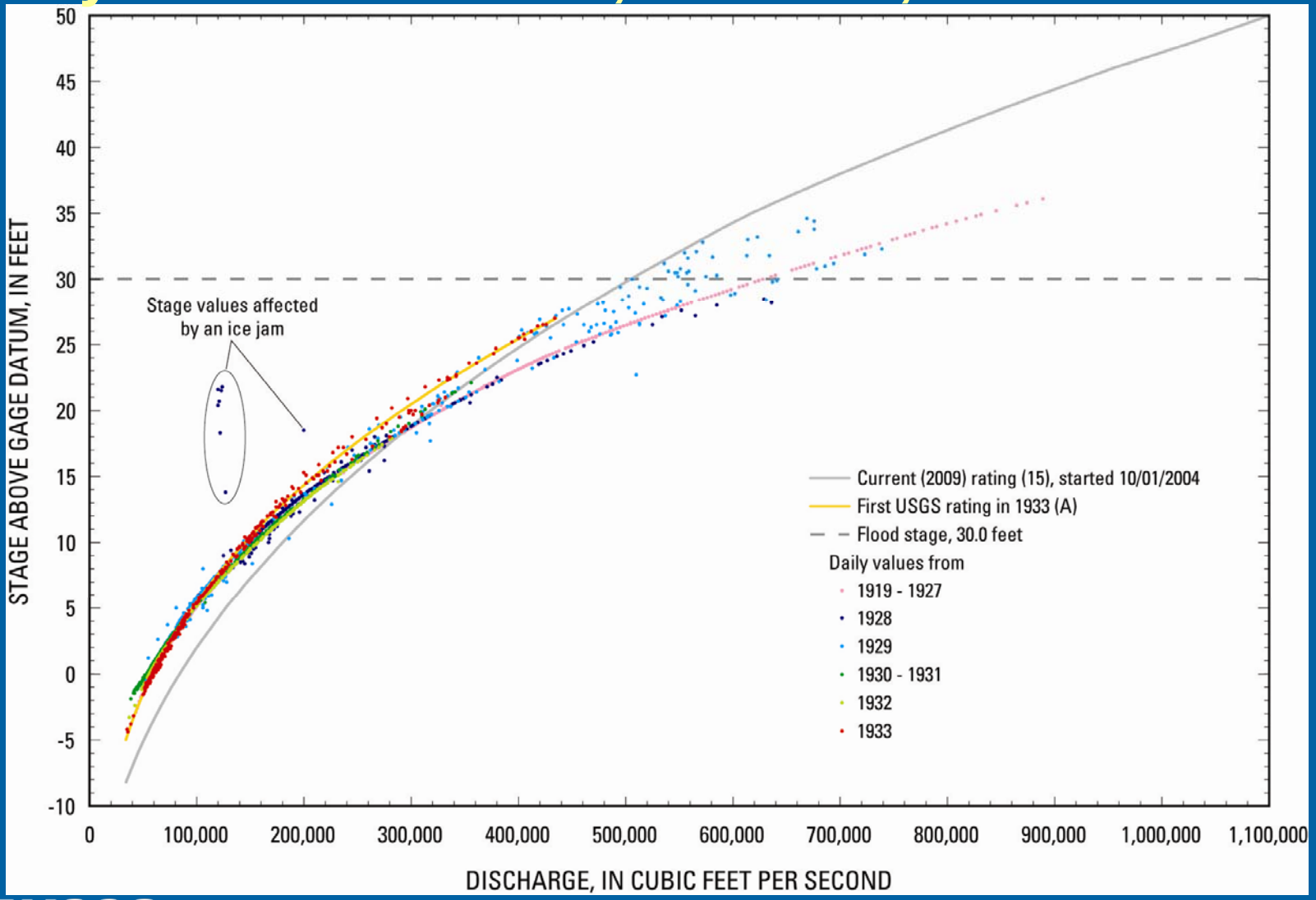

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Daily Data at St. Louis, Missouri, since 1861

- Before USGS began operation in 1933, USACE used:
  - Different measurement equipment (floats & rods, meters)
  - Different measurement techniques (boat measurements)
- Comparison studies in 1940s and 1970s showed the earlier equipment and methods used by USACE measured as much as 17 percent more than USGS Price AA current meter (higher Q for a given stage)
- Physical model tests of historic floods (using historic floodplain conditions) by USACE (Dyhouse, 1995)
  - Suggested nearly 33 percent reduction of 1844 peak to 870,000 cfs
  - Suggested reducing 1903 peak to 780,000 cfs (23% reduction)
  - However, offered no systematic adjustment of remainder of data record

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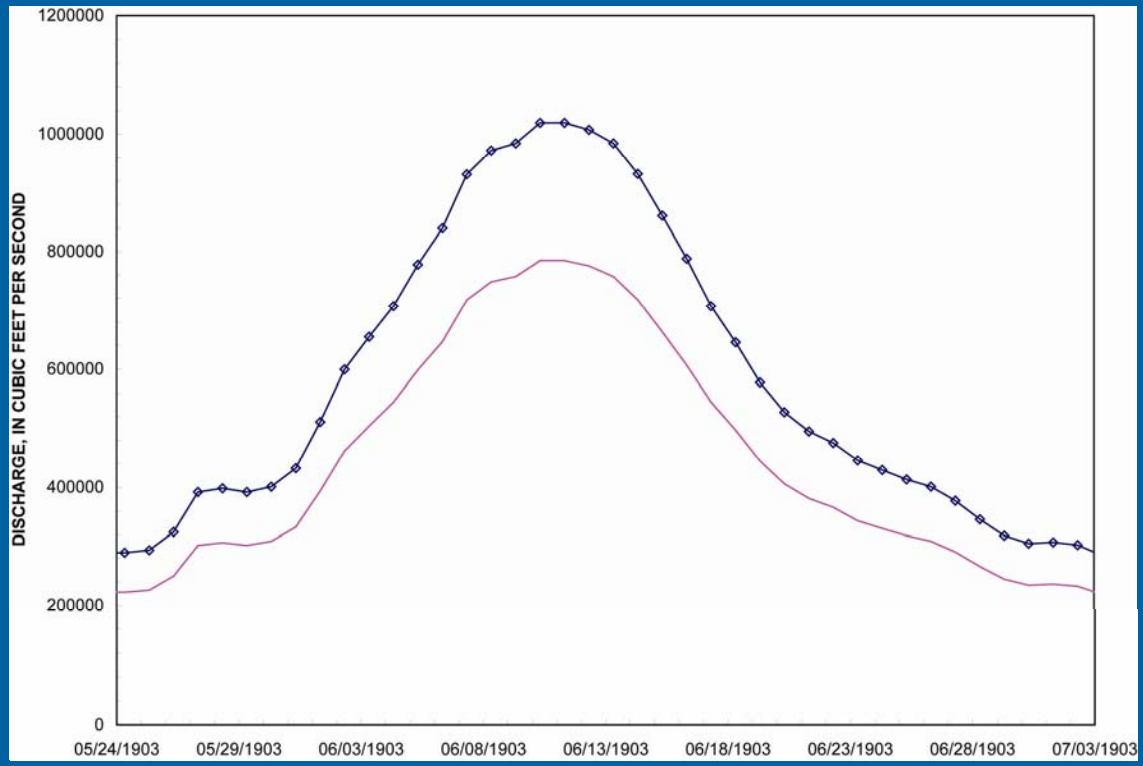
Daily Data at St. Louis, Missouri, since 1861

- Historic peak in 1844 was an isolated point
- Peak in 1903 was part of a systematic period of record
  - Cannot adjust peak without adjusting entire record
    - Neighboring daily values
    - Other flood peaks
- Ultimately
  - 1844 peak reduced to 1,000,000 cfs (23%)
  - No change made to 1903 peak of 1,020,000 cfs



- If a proportional reduction of entire historic record were to occur to bring 1844 and 1903 peaks to suggested levels…

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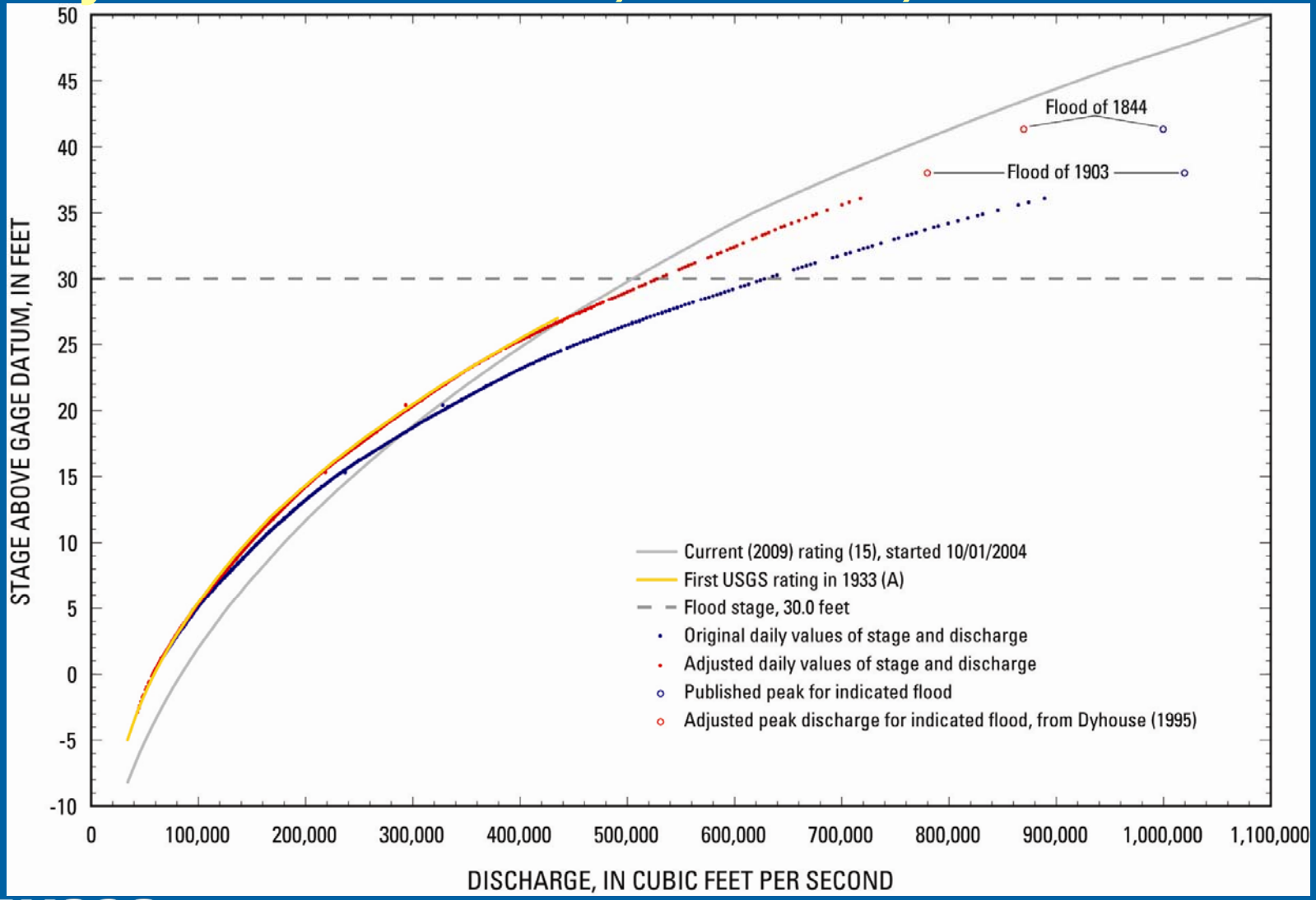

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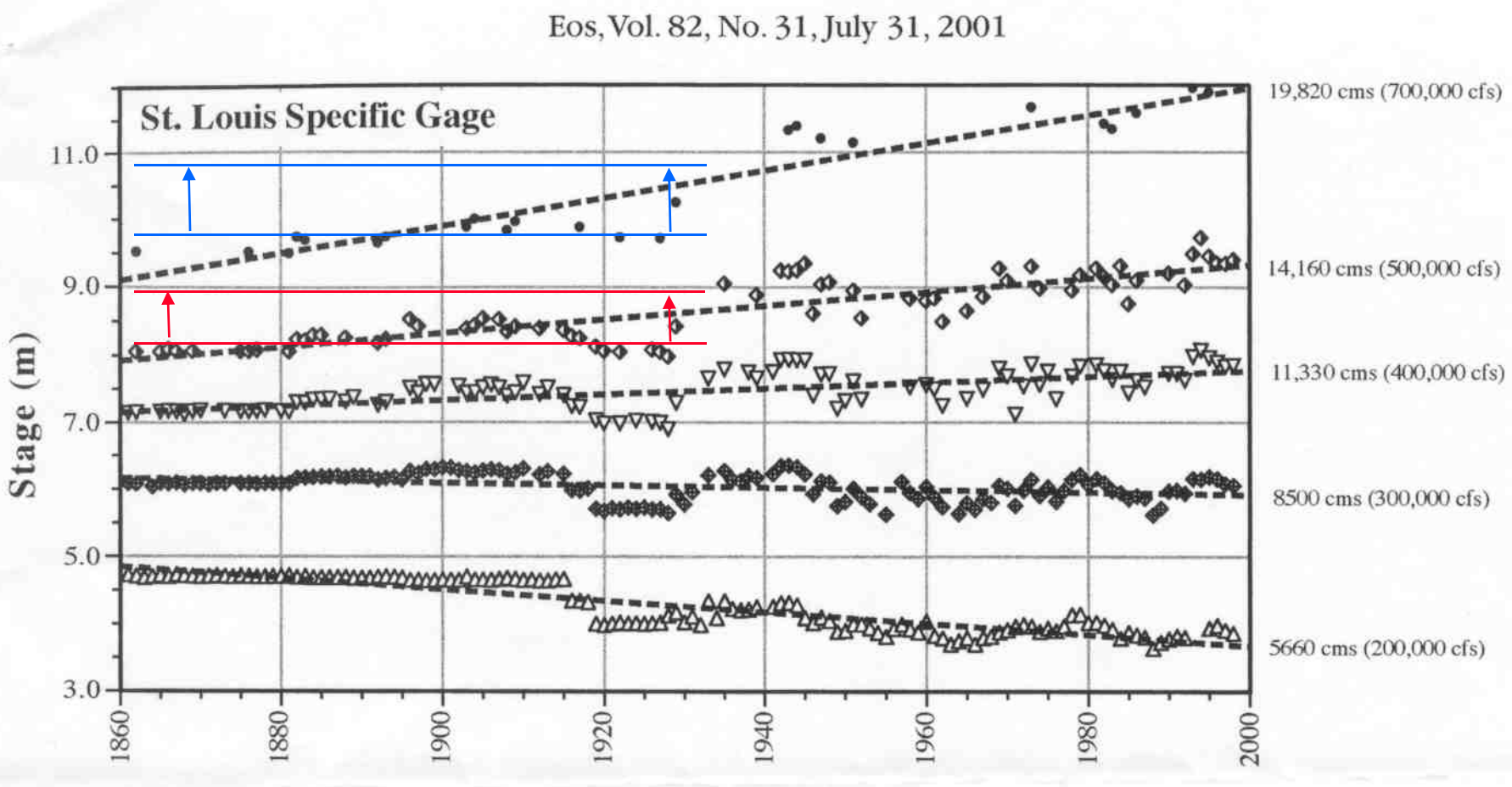

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USGS

Summary

- Since USGS began operation of gages:
  - Stage is decreasing for a given discharge at St. Louis for flows less than bank-full, due to wing dikes and reduced sediment flux
  - Stage is decreasing for a given discharge at Chester for flows less than 2/3 bank-full, due to combined action of wing dikes and reduced sediment flux, and in-filling of Horse Island Chute overflow
  - Stage has increased for a given discharge for flows greater than bank-full at both streamgages, primarily due to levees on flood plains
- Measurement methods, equipment, and location must be consistent for a valid comparison of data with time
- Floods have a substantial effect on trends in measurements and daily data
- There may be justification to adjust the historic systematic period of record prior to USGS operation

USGS

Future Research Needs

- Need to examine other stations with period of record extending through the transition from USACE to USGS operation to find similar “step” changes
  - MoWSC has archived USCOE Mississippi River Commission documents containing daily stage (back to 1887 at least) and daily discharge (back to 1928) for other stations on MMR (Chester, Thebes)—need to be digitized (paper copies only)
  - Other stations not on MMR
- Re-examine comparison measurements done in 40’s and 70’s
  - Not to “validate” measurements using different methods
  - Isolate and quantify the differences for potential corrections
- Use other archived USCOE MRC documents containing measurement information (back to 1866) to examine measurement techniques and how ratings were developed

USGS

Final Report

Examination of Direct Discharge Measurement Data and Historic Daily Data for Selected Gages on the Middle Mississippi River, 1861-2008

by Richard J. Huizinga

USGS Scientific Investigations Report 2009-5232

http://pubs.usgs.gov/sir/2009/5232/

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