Upper Yellowstone River Streamflow Trends

and some additional basin information

(Chuck Dalby, DNRC-WRD, Helena, MT 406-444-6644 cdalby@mt.gov)

- Additional information
  - Ten-years of U.S. Supreme Court litigation MT v WY
    - What did we win ?
  - 2011 peak flow large but not greater than 1997
    - How has the channel changed in Spring Creek reach since floods of 1996-1997 ?
  - Climate Change ? Is it real ? Do you need to be concerned ? What do local producers see on the ground ?

Ten-years of U.S. Supreme Court litigation

MT v WY What did we win ?

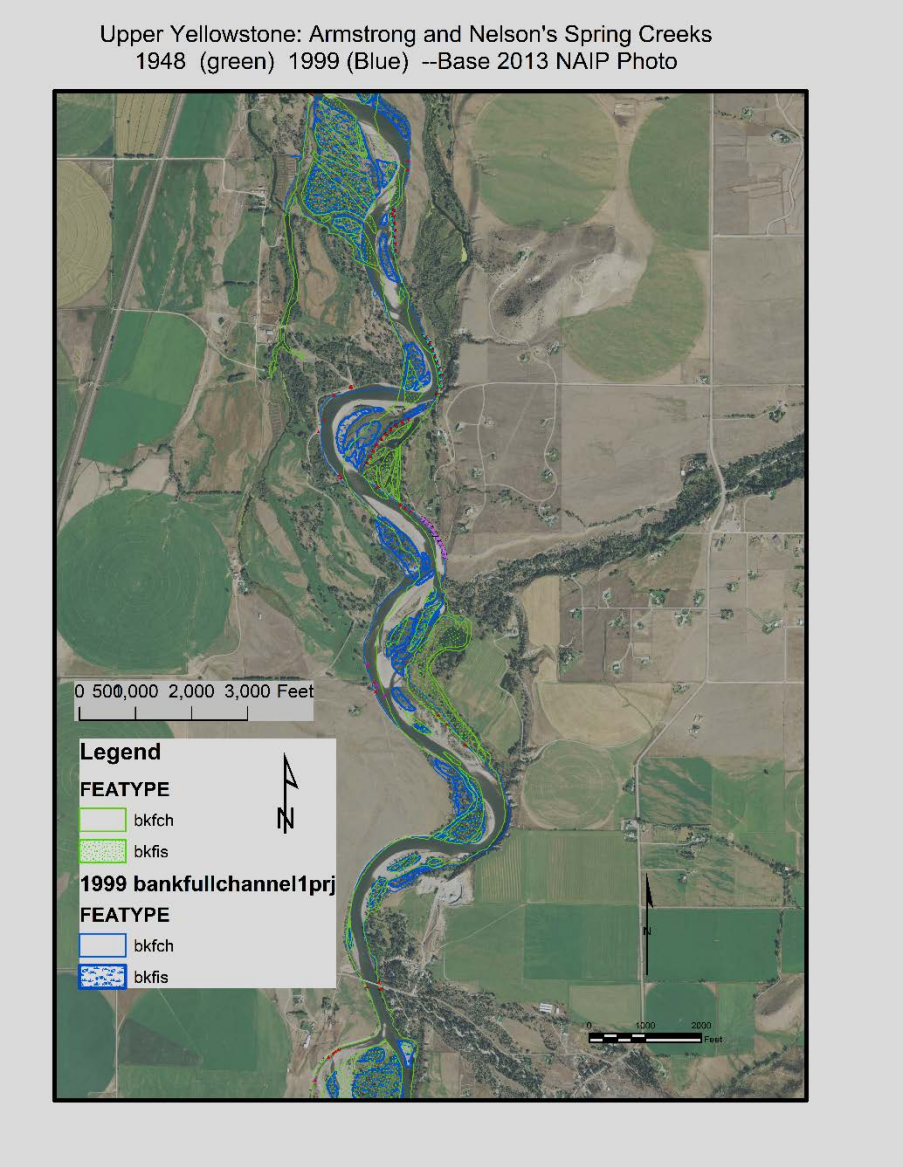
Recent news article: MT spent $5 million to get $100,000 damages !

--Harm/Damages required to get toe in door of US Supreme Court;
MT new we wouldn't get much money—wanted opportunity to set constraints on WY water use in water short years and limit future storage in Bighorns.

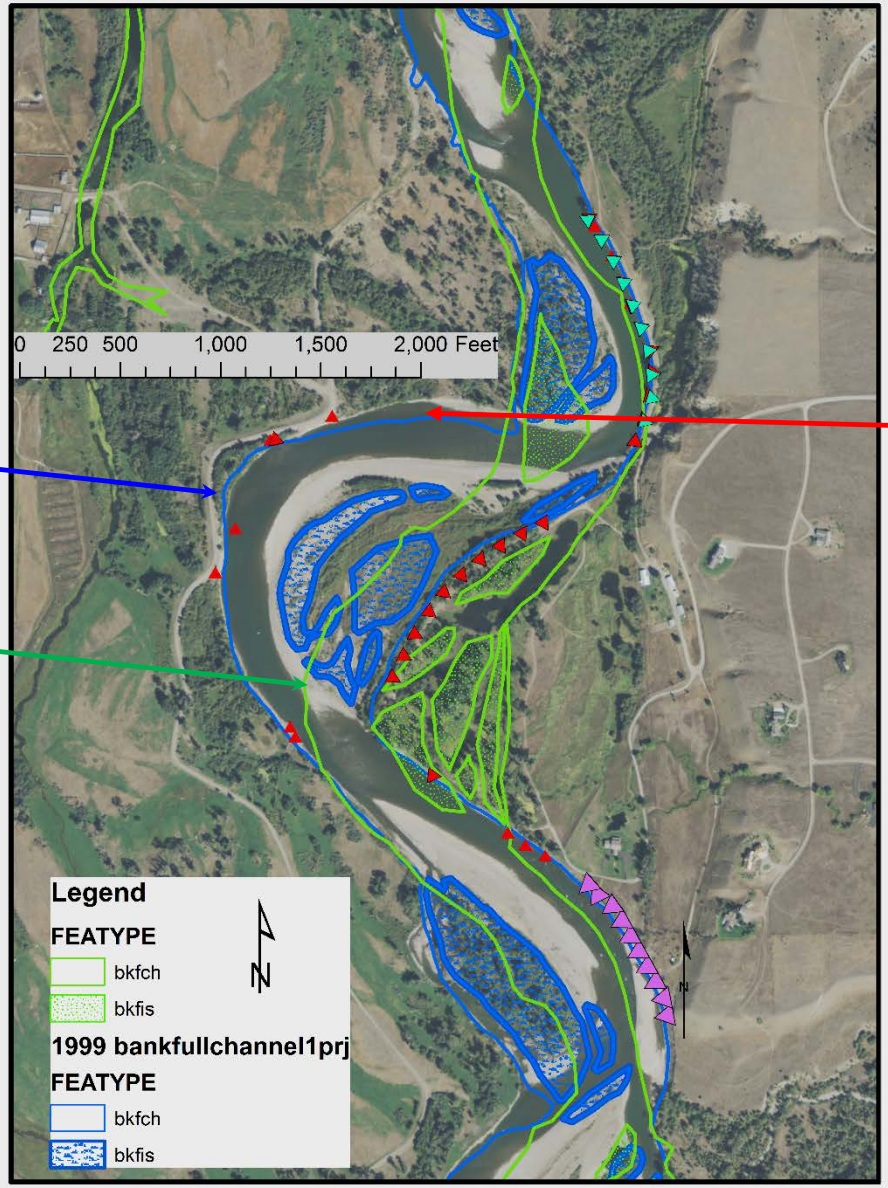
--We won right to "call" on WY to fill Tongue River Reservoir;
--WY can't build new storage in Bighorns using old 1940's permits and assign a priority date of the old permit.

2011 peak flow close to record flood of 1997?

How has the channel changed since floods of 1996-1997 ?



Upper Yellowstone: Armstrong and Nelson's Spring Creeks
1948 (green) 1999 (Blue) --Base 2013 NAIP Photo



1999 Channel

1948 Channel

Areas of new erosion

Global Warming / Climate Change

Is it real or a plot to make scientists rich, fool the public, and freeze us in the dark ?

Upper Yellowstone River Streamflow Trends

Streamflow records for 4 Upper Yellowstone USGS stream gaging stations examined for changes/trends in:

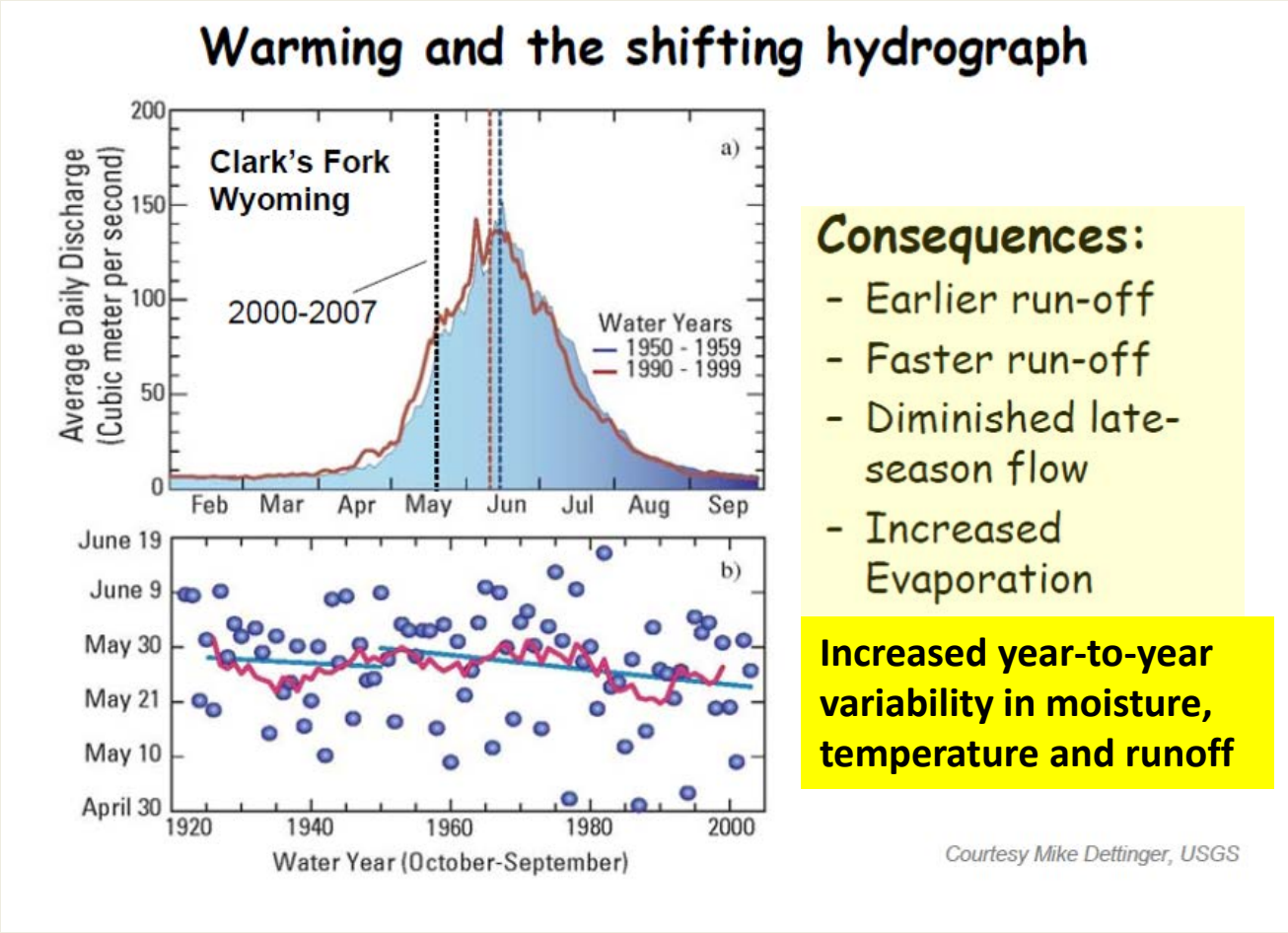
Annual discharge—total volume of flow moving past stream gage (sometimes expressed a constant daily rate (cubic-feet-second) that would produce the same volume in 365 days);

Peak discharge– the instantaneous discharge that is the largest in a year;

Snowpack—snowpack size controls runoff volumes—peak flows influenced by snowpack size and temperature (temp. controls rate of melt and if it arrives as rain or snow)

Upper Yellowstone River Streamflow Trends

How might we expect streamflow to change with global warming ?



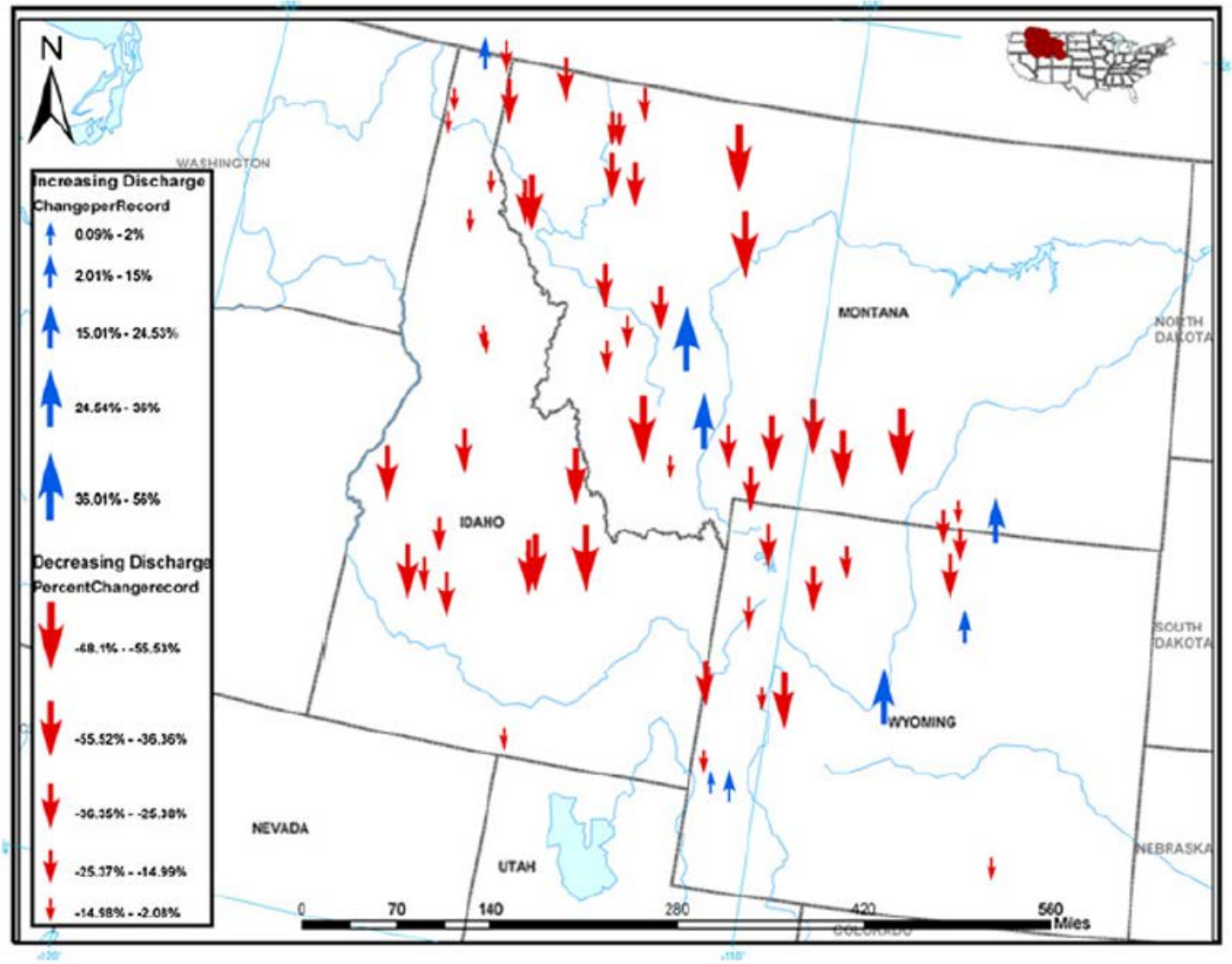
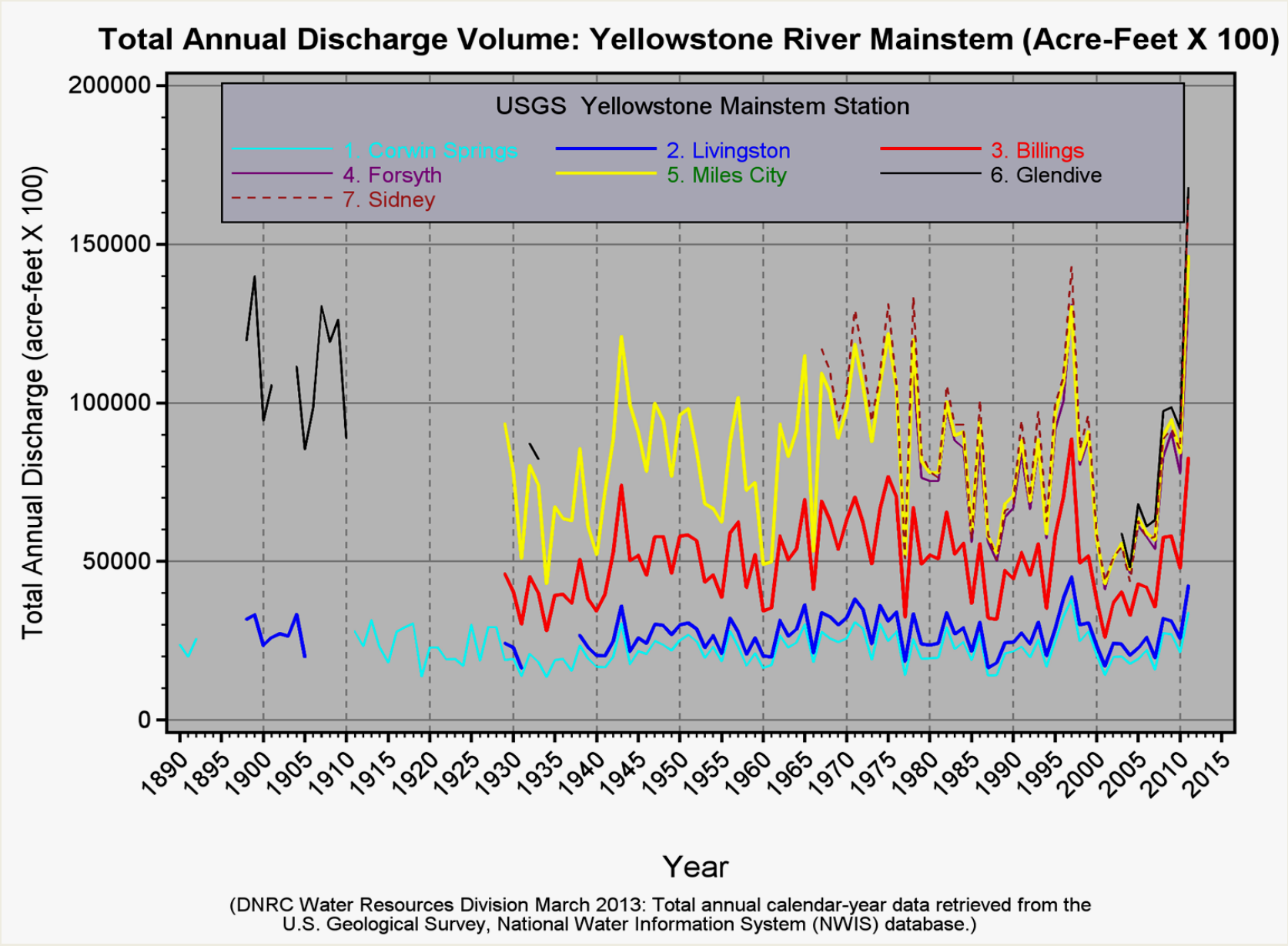


Fig. 5 Amount and type of normalized discharge change per record across the Central Rockies. The downward pointing red arrows signify a decreasing slope and the upward pointing blue arrows signify an increasing slope. The Larger the arrow the larger the discharge change at each gauging station. This figure shows a decreasing trend across the study area with very few positive slopes

YELLOWSTONE RIVER: Corwin Springs to Glendive



(DNRC Water Resources Division March 2013: Total annual calendar-year data retrieved from the U.S. Geological Survey, National Water Information System (NWIS) database.)

Location of Upper Yellowstone USGS Stream Gages

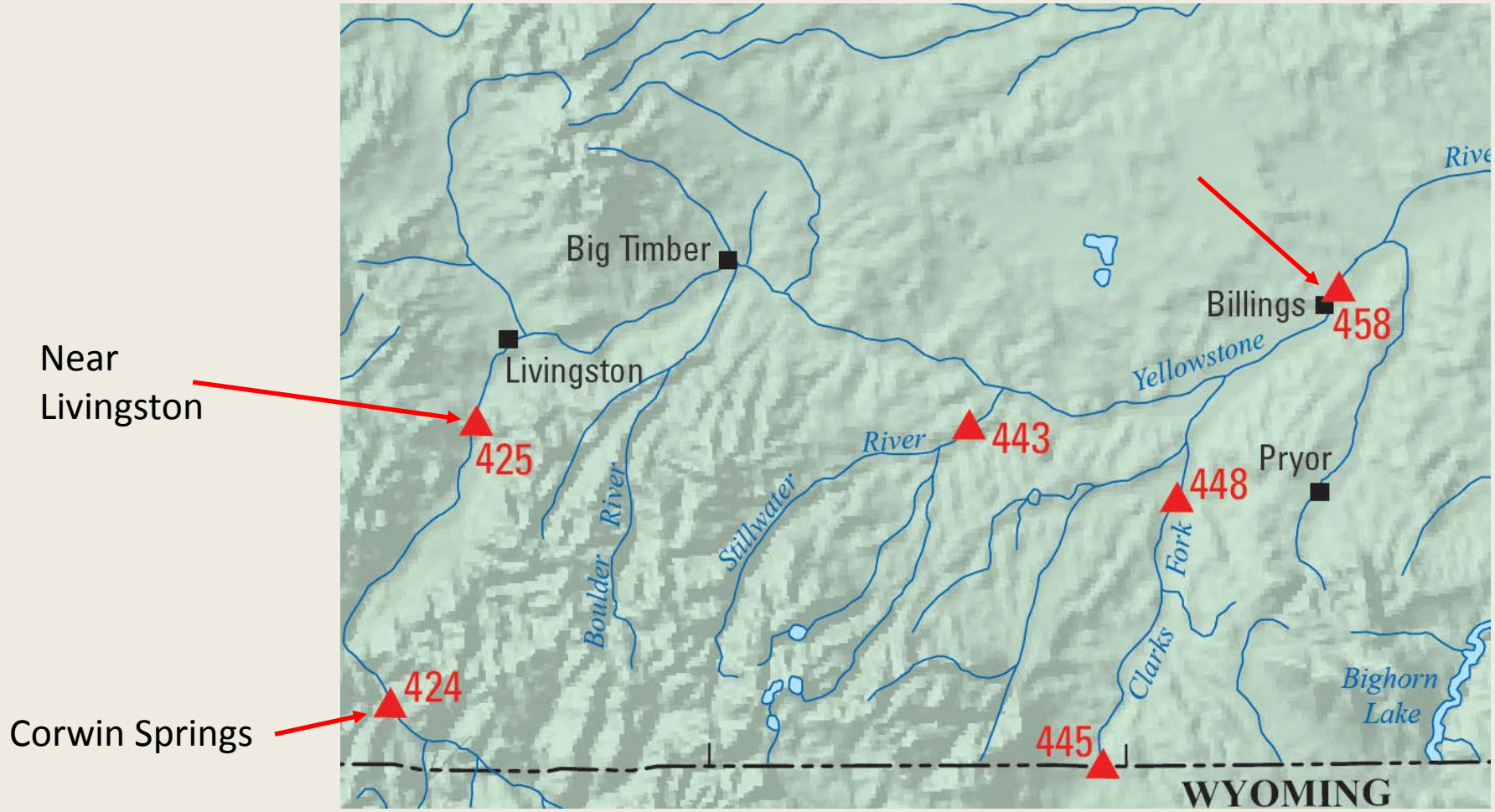
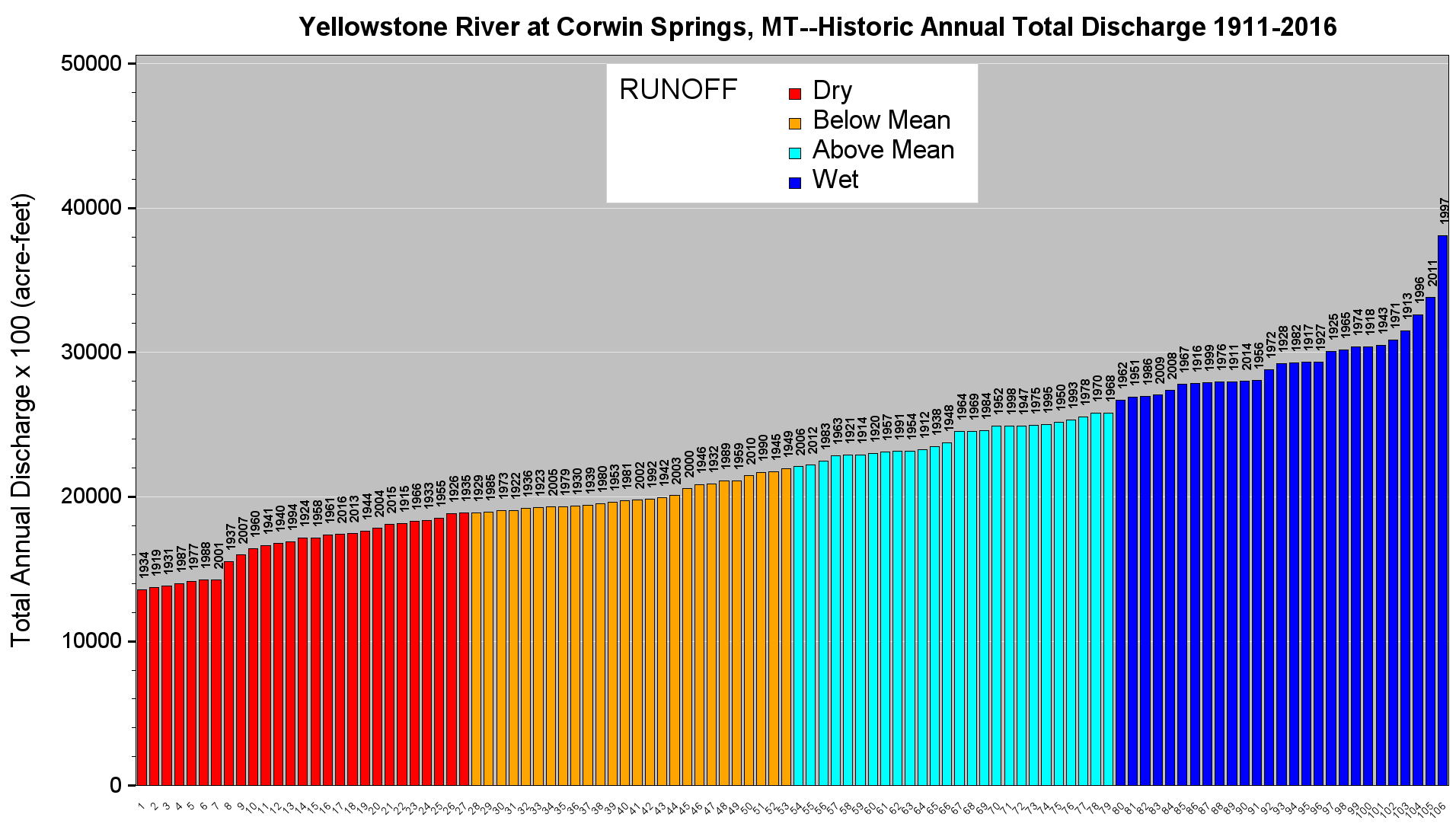


Table 1. Information for selected long-term gaging stations in or near Montana.—Continued

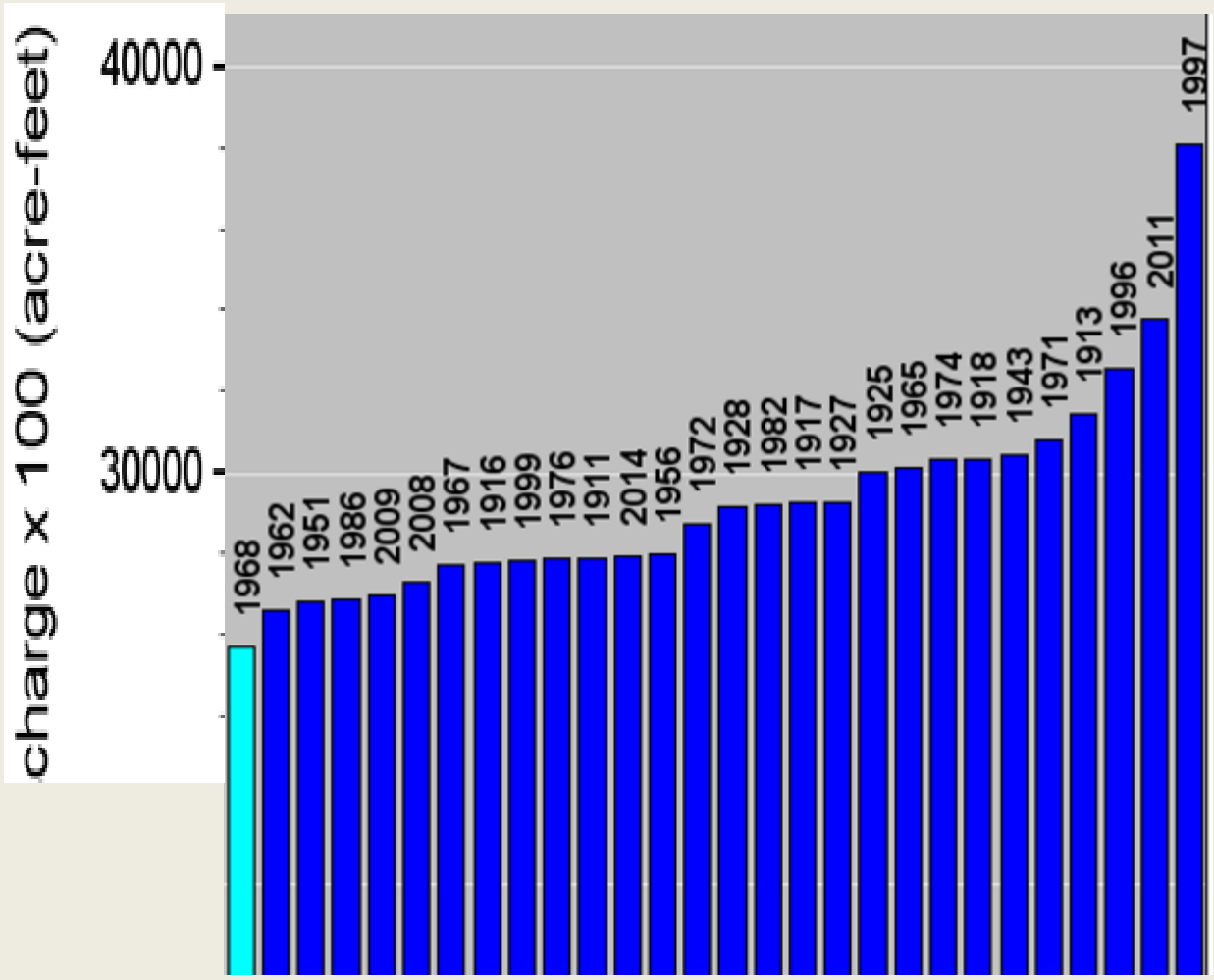
[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Contributing drainage area, in square miles	Percent of drainage basin affected by dams	Mean basin elevation, in feet above NAVD 88	Number o years of an nual peak-fl records
Streamflow-gaging stations in the Missouri River Basin—Continued								
Yellowstone River Basin								
424	06191500	Yellowstone River at Corwin Springs, Montana	45.1121	-110.7937	2,616	0.0	8,343	105
425	06192500	Yellowstone River near Livingston, Montana	45.5972	-110.5665	3,551	0.3	8,012	87
458	06214500	Yellowstone River at Billings, Montana	45.8001	-108.4680	11,414	1.8	6,544	86

Corwin Springs—Annual volume of runoff ranked from lowest year to highest year

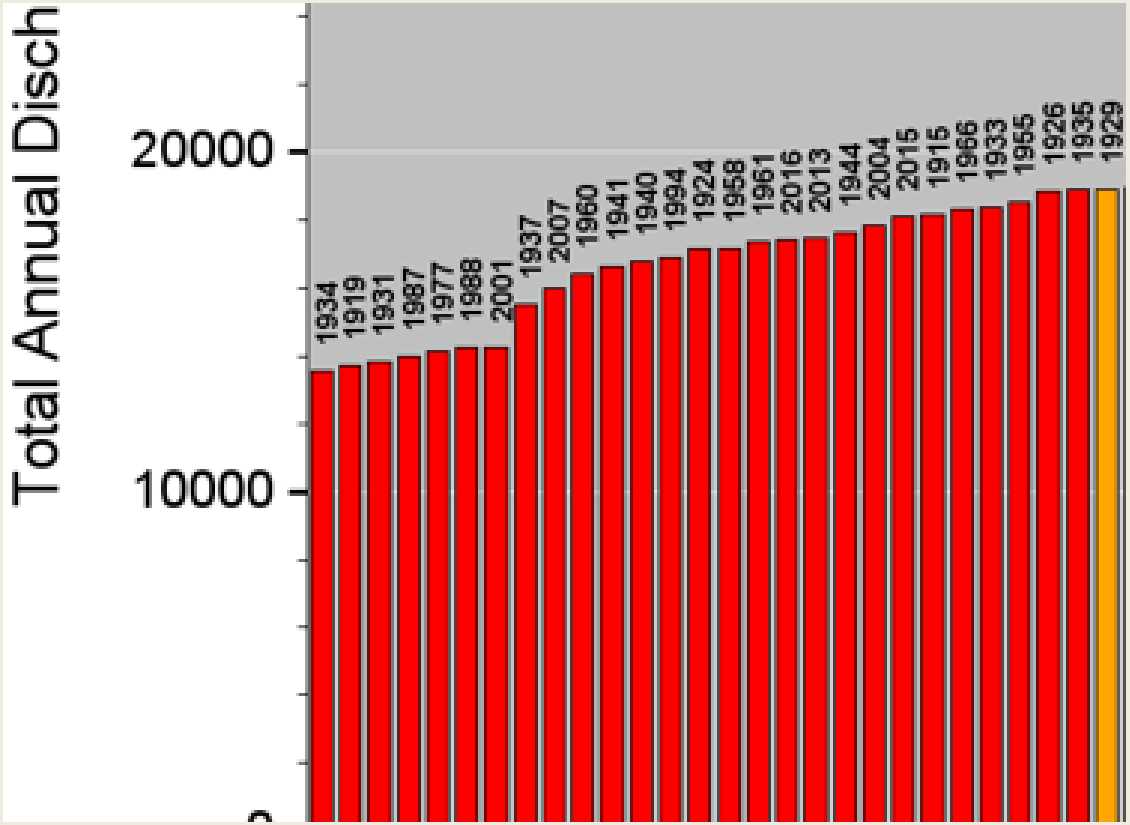


Yellowstone River at Corwin Springs—HIGHEST Annual Discharge (greater than 75% of average annual discharge 1911 to 2016)



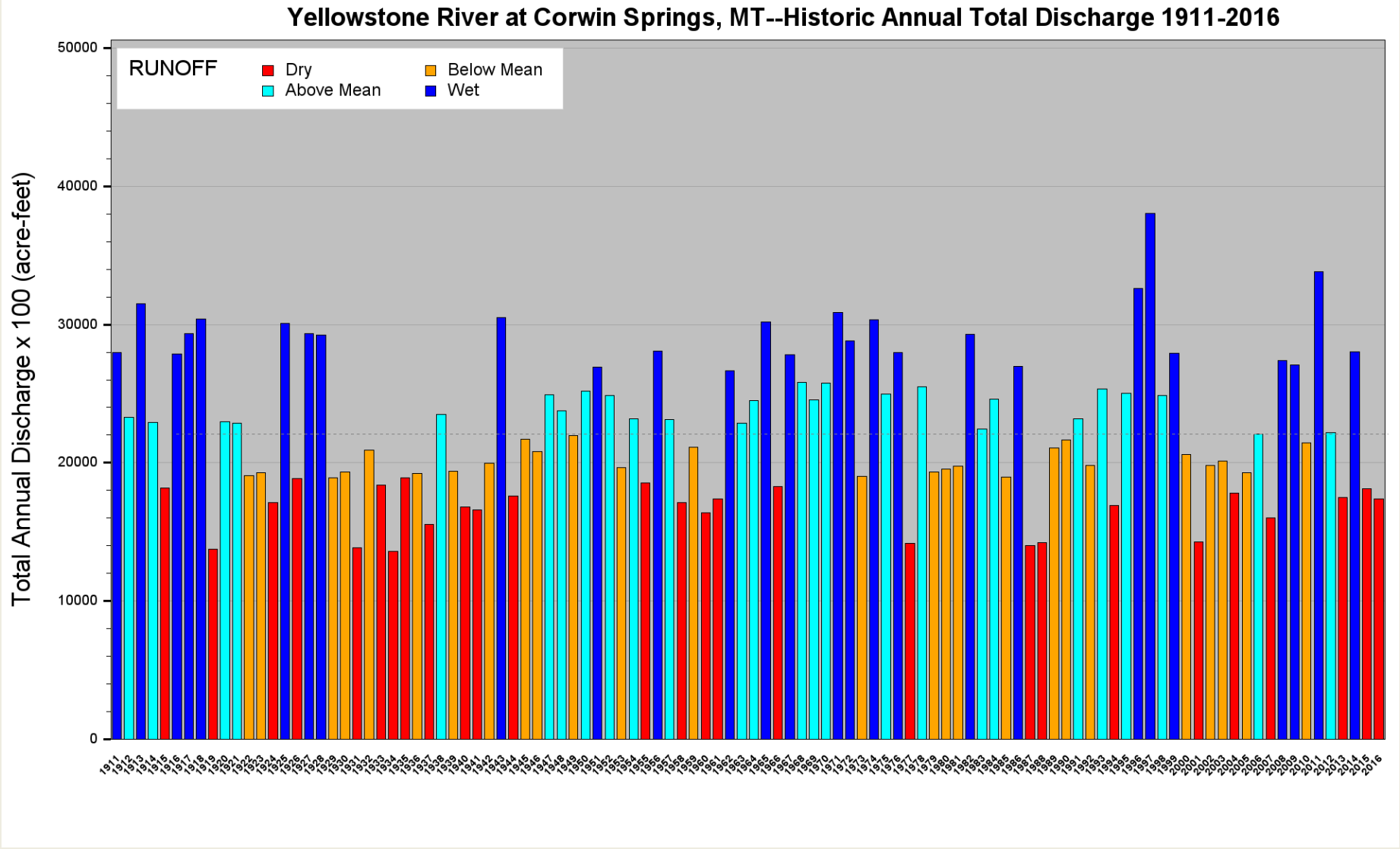
Highest 5 years:
1997
2011
1996
1913
1971

Yellowstone River at Corwin Springs—LOWEST Annual Discharge (less than 25% of average annual discharge 1911 to 2016)

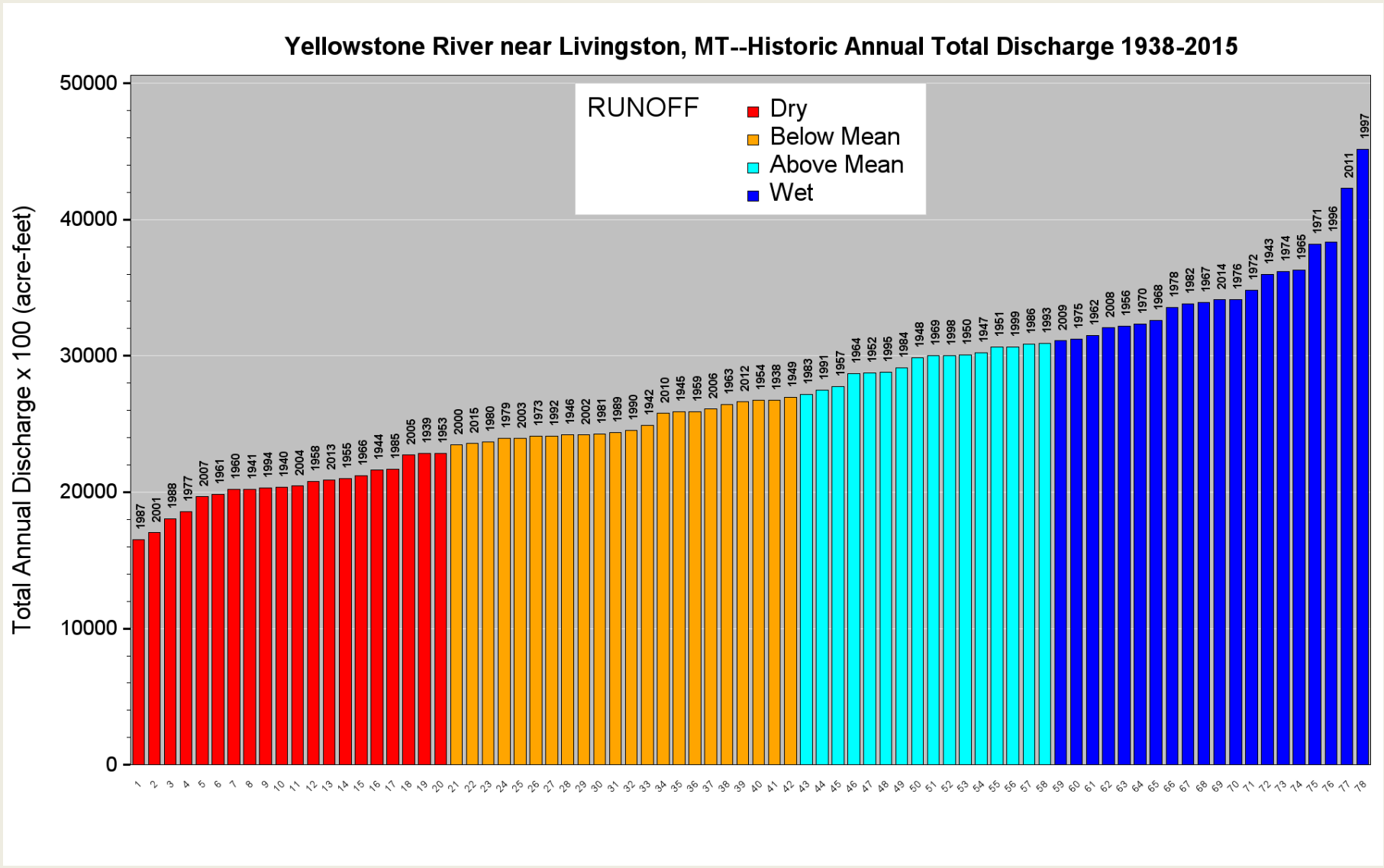


Lowest 5 years:
1934
1919
1931
1987
1997

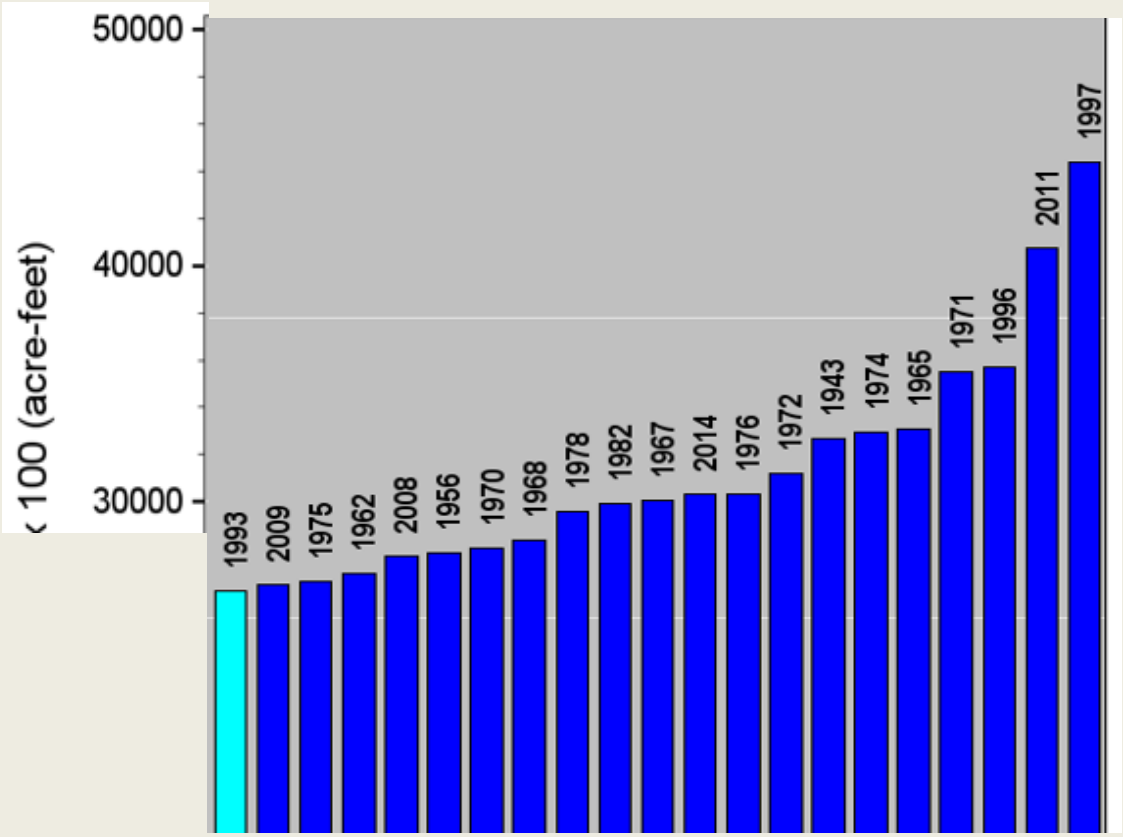
Corwin Springs—Annual volume of runoff in sequence 1911 to 2016



Livingston—Annual volume of runoff ranked from lowest year to highest year

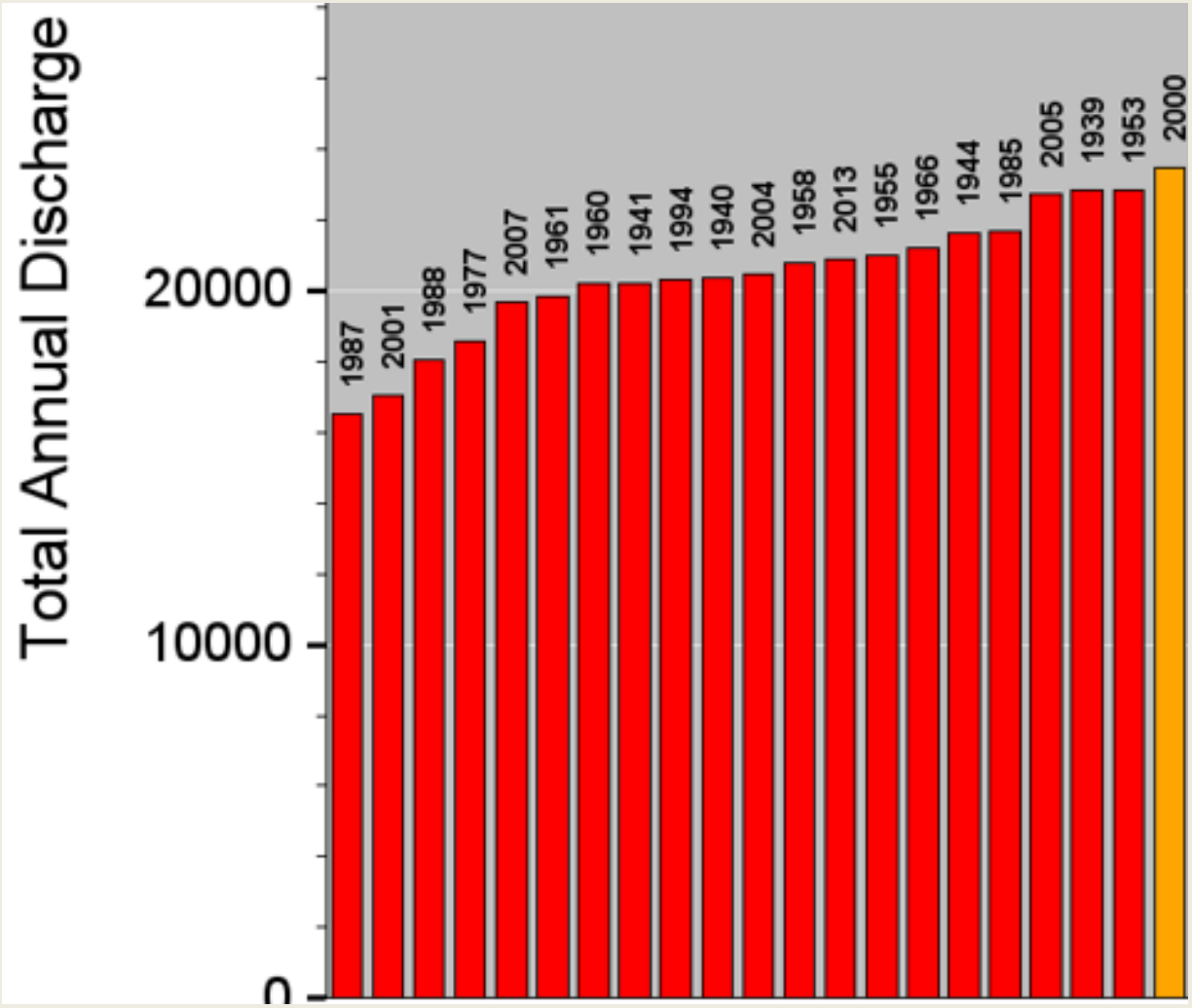


Yellowstone River near Livingston—HIGHEST Annual Discharge (greater than 75% of average annual discharge 1911 to 2016)



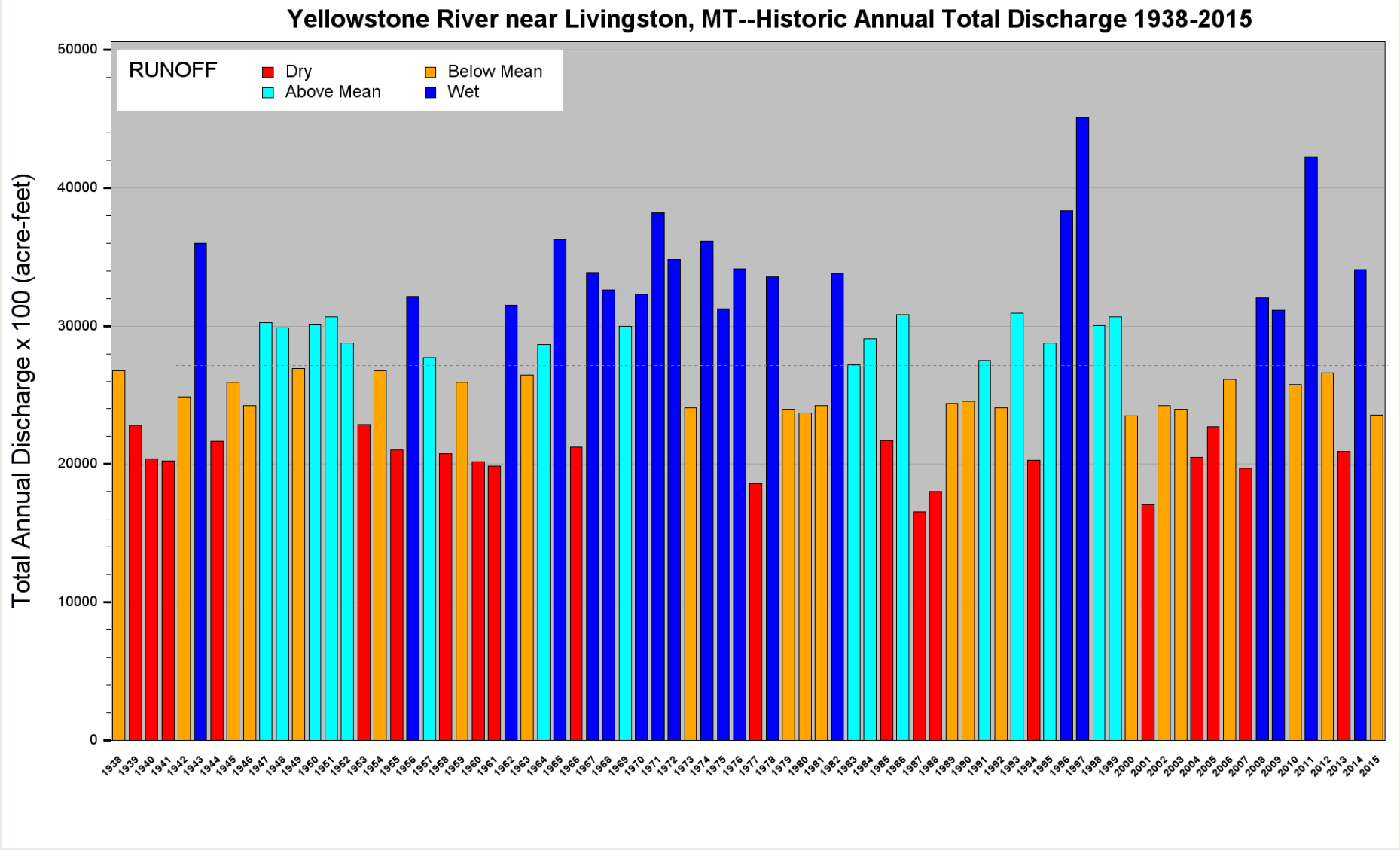
Highest 5 years:
1997
2011
1996
1971
1965

Yellowstone River near Livingston—LOWEST Annual Discharge (less than 25% of average annual discharge 1911 to 2016)

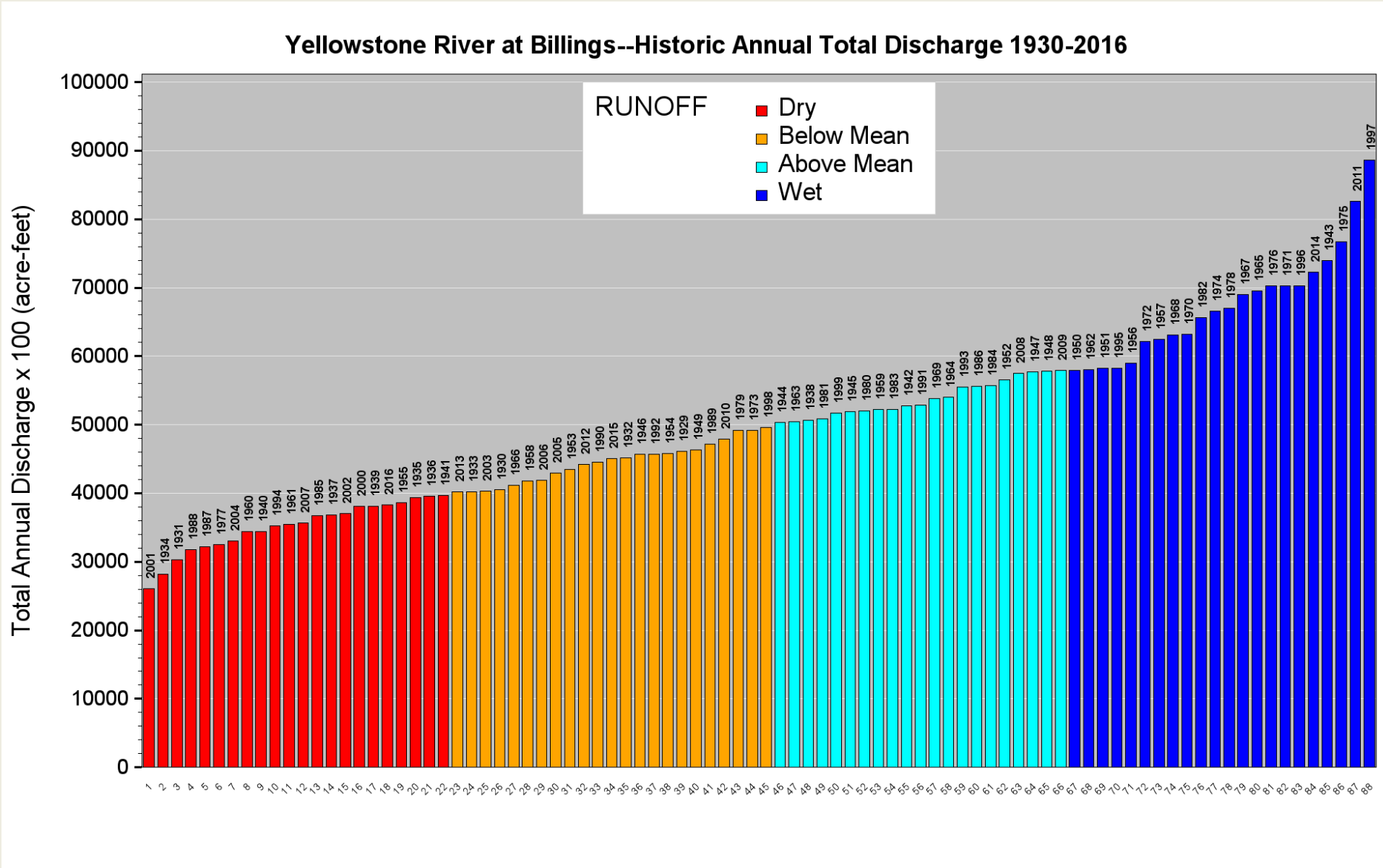


Lowest 5 years:
1987
2001
1988
1977
2007

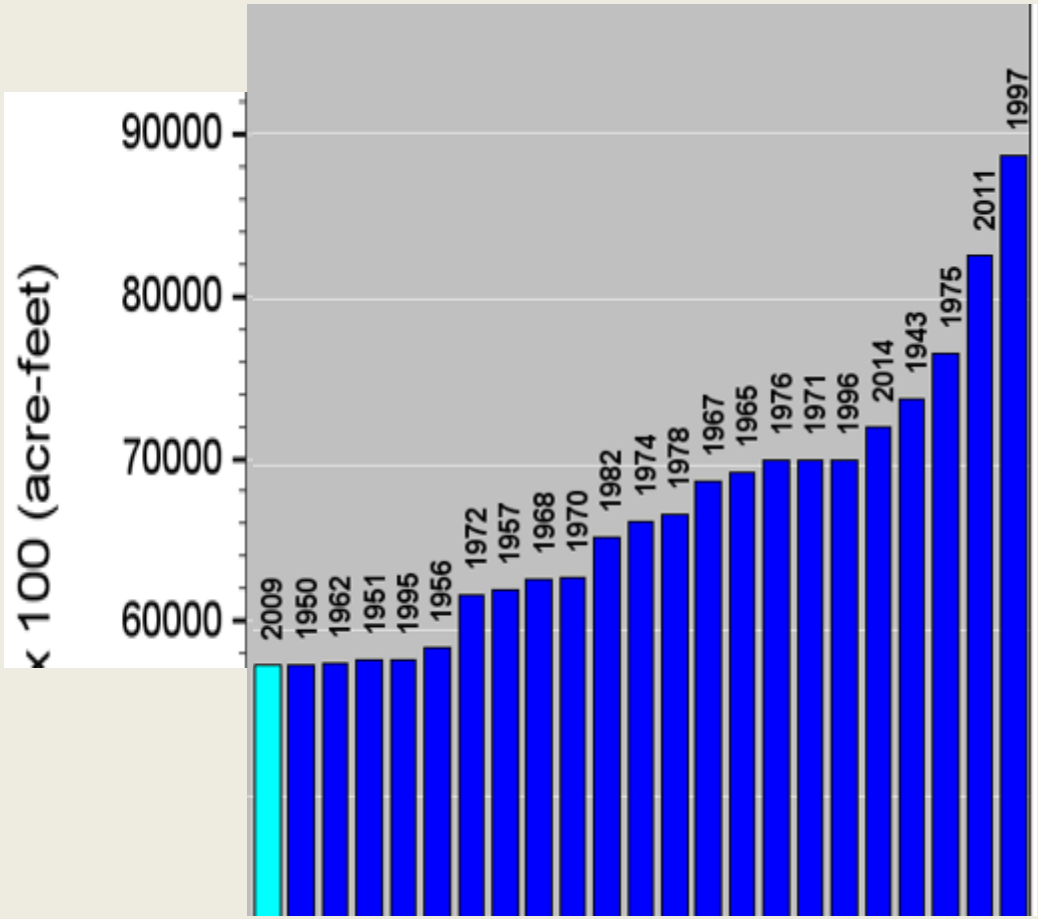
Livingston—Annual volume of runoff in sequence 1938 to 2015



Billings—Annual volume of runoff ranked from lowest year to highest year

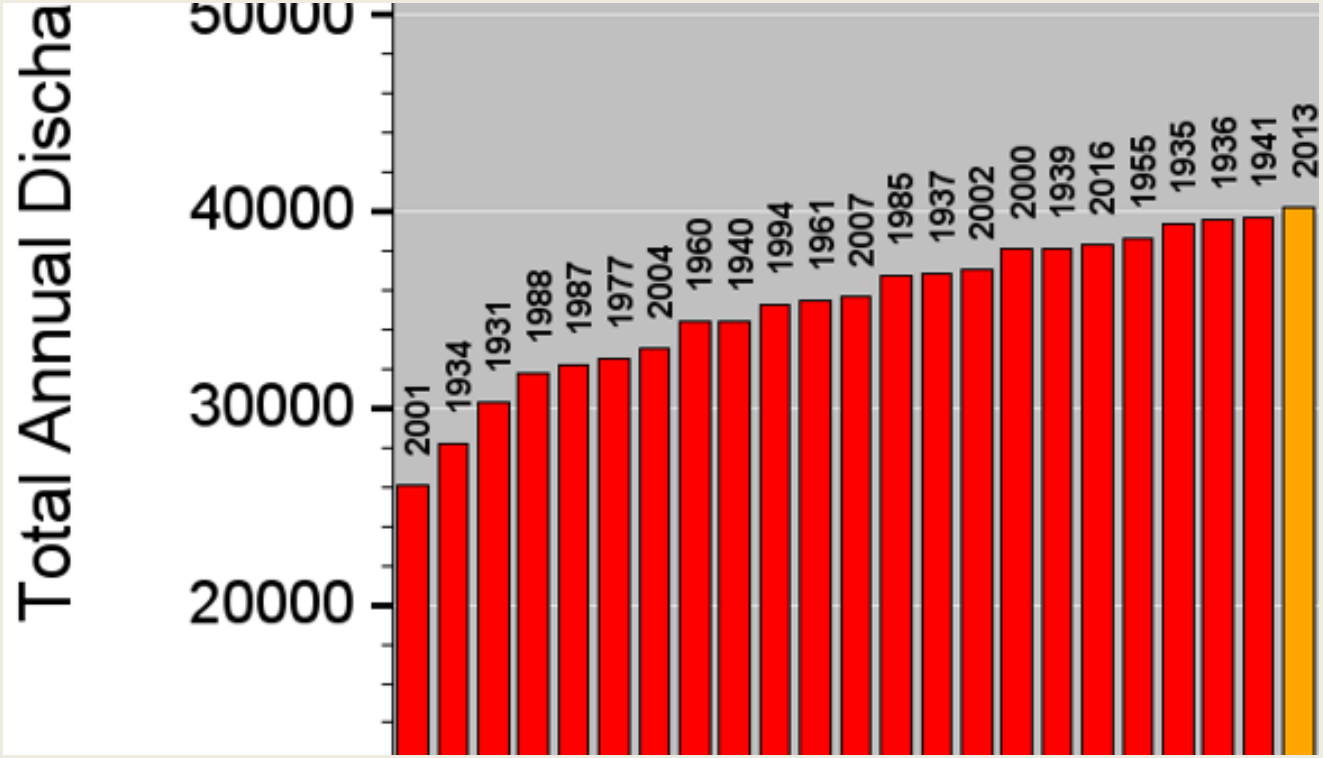


Yellowstone River at Billings—HIGHEST Annual Discharge
(greater than 75% of average annual discharge 1930 to 2016)



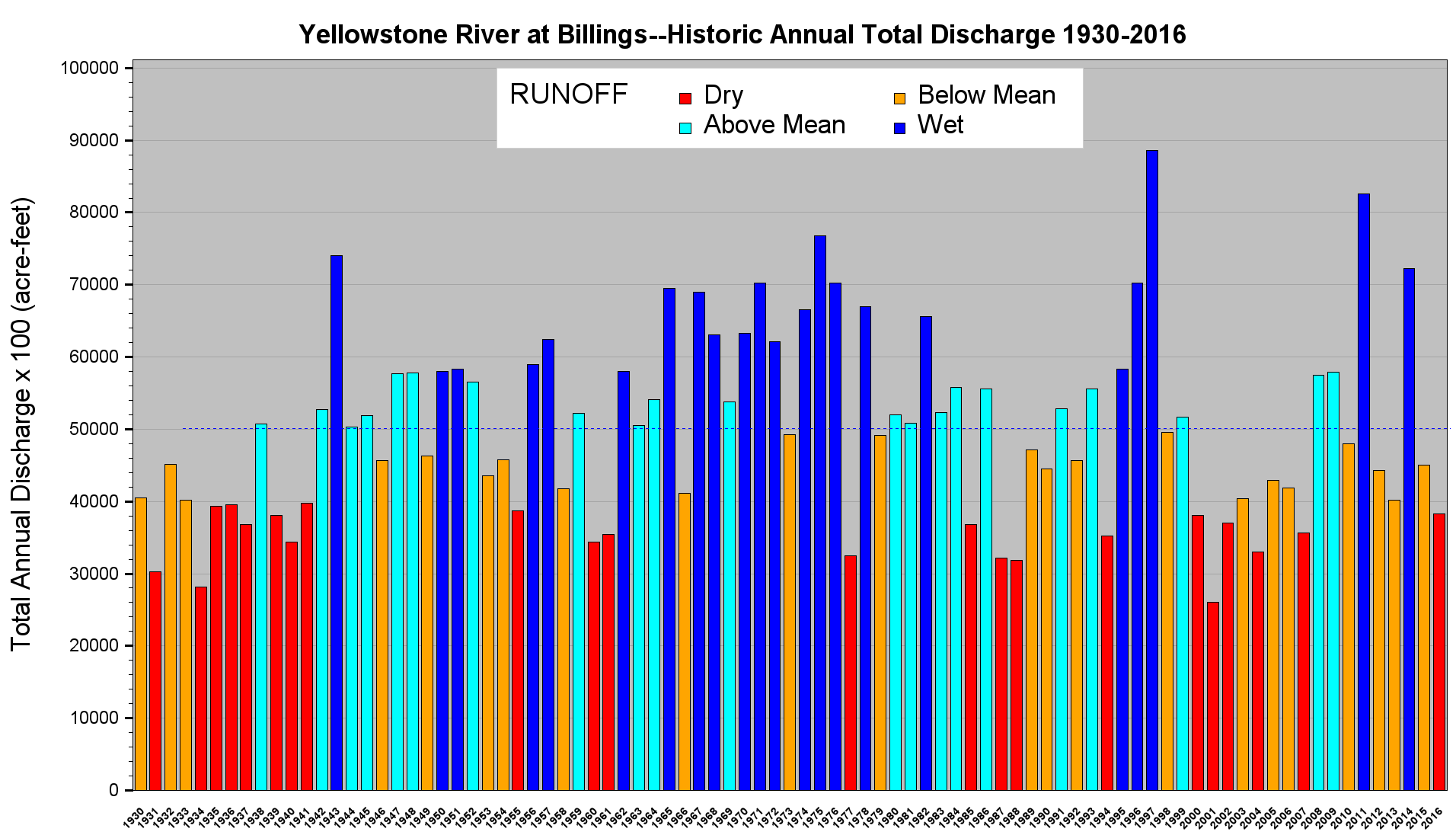
Highest 5 years:
1997
2011
1975
1943
2014

Yellowstone River at Billings--LOWEST Annual Discharge
(less than 25% of average annual discharge 1930 to 2016)



Lowest 5 years:
2001
1934
1931
1988
1987

Billings—Annual volume of runoff in sequence 1930 to 2016



Annual runoff volume:
Summary of Top 5 Highest Years and Low 5 Lowest Years

Corwin

Highest 5 years:
1997
2011
1996
1913
1971

Lowest 5 years:
1934
1919
1931
1987
1997

Livingston

Highest 5 years:
1997
2011
1996
1971
1965

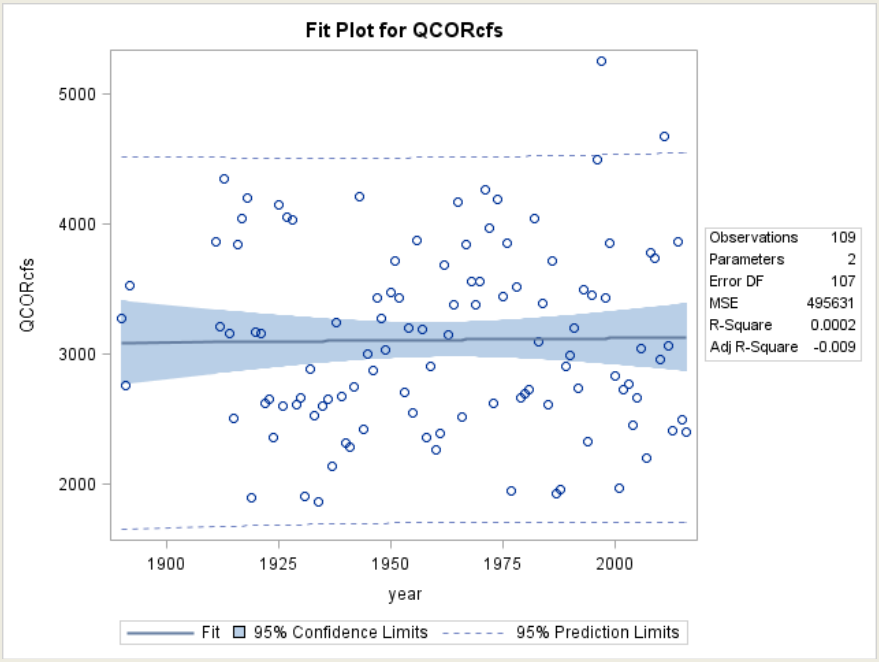
Lowest 5 years:
1987
2001
1988
1977
2007

Billings

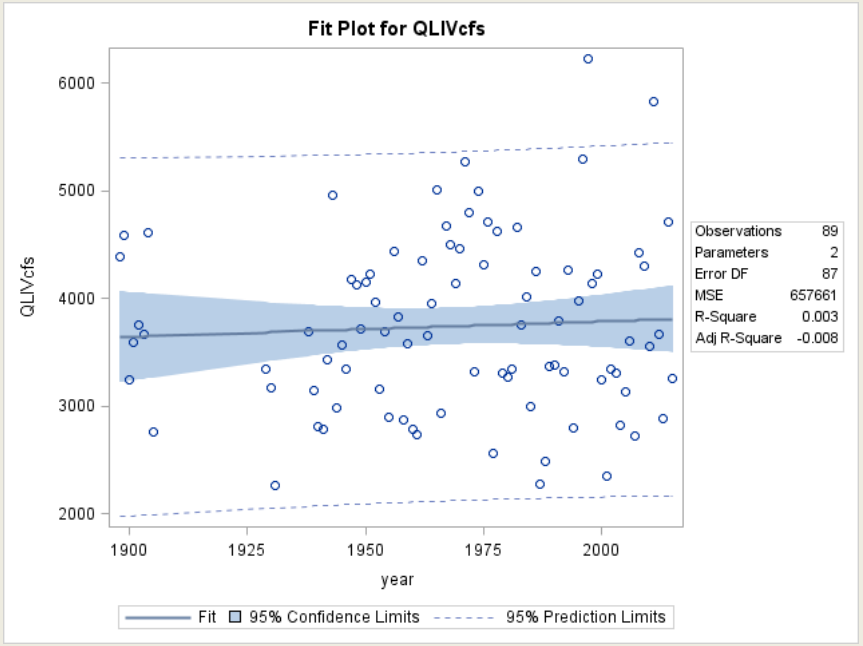
Highest 5 years:
1997
2011
1975
1943
2014

Lowest 5 years:
2001
1934
1931
1988
1987

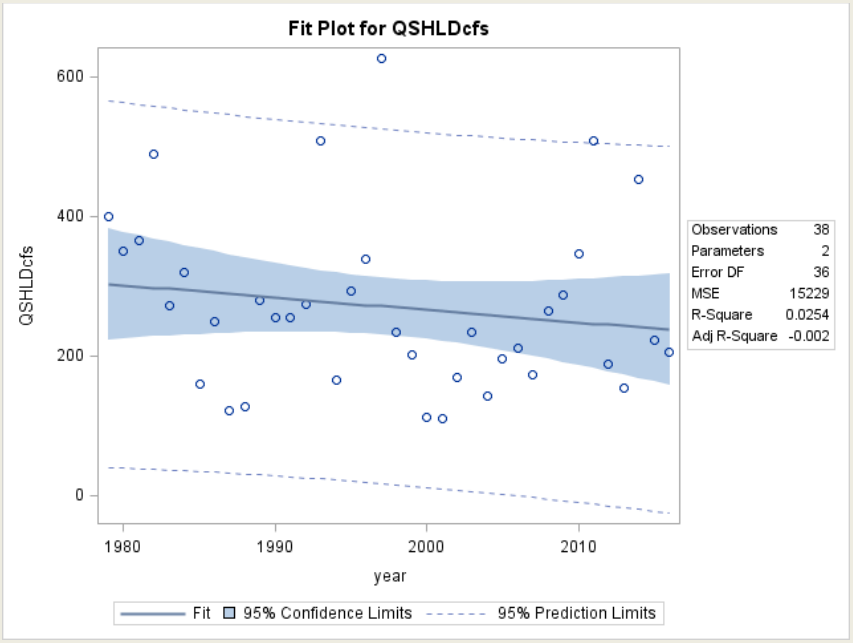
Corwin Springs Annual Discharge (cfs x10)



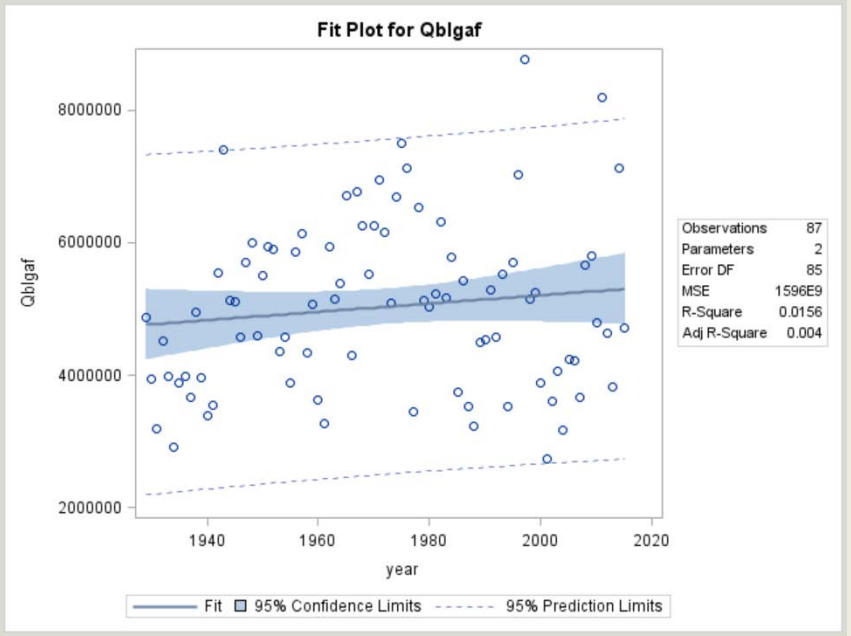
Livingston Annual Discharge (cfs x10)



Shields R. Annual Discharge (cfs x10)



Billings Annual Discharge (acre-feet)



Have Peak Flows Changed Over Time ?

Annual volume of runoff is important for water-supply;
Annual Peak Flow is important for Channel Maintenance
(erosion and deposition)

Corwin: No trend in size of peak flows
Peak flows occur about 2-3 weeks earlier

Livingston: Small increase in peak flows
Peak flows occur about 2 weeks earlier

Billings: Small increase in peak flows
Peak flows occur about 1 week earlier

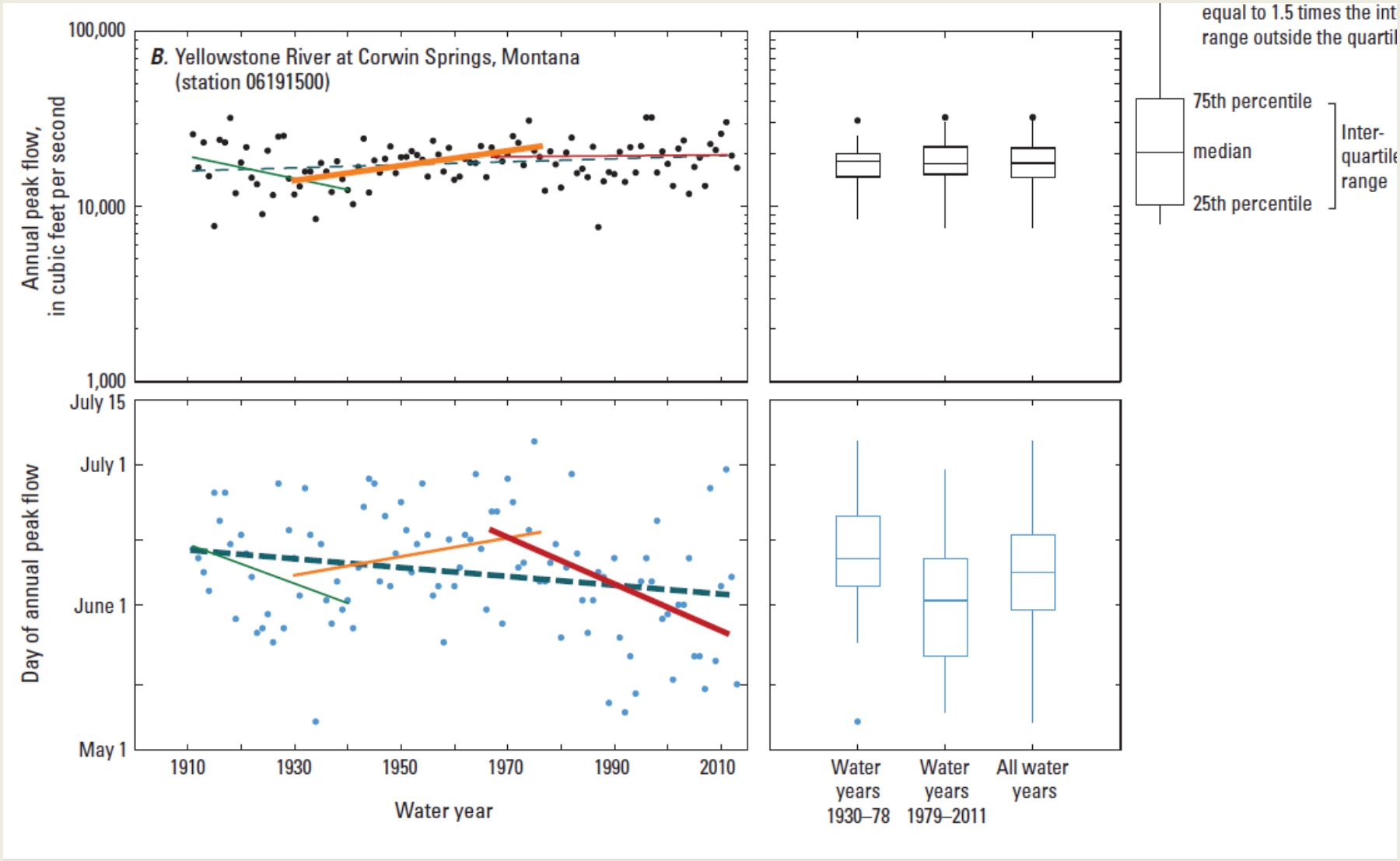
Temporal trends and stationarity in annual peak flow and peak-flow timing for selected long-term streamflow-gaging stations in or near Montana through water year 2011: Chapter B in *Montana StreamStats*

Scientific Investigations Report 2015-5019-B

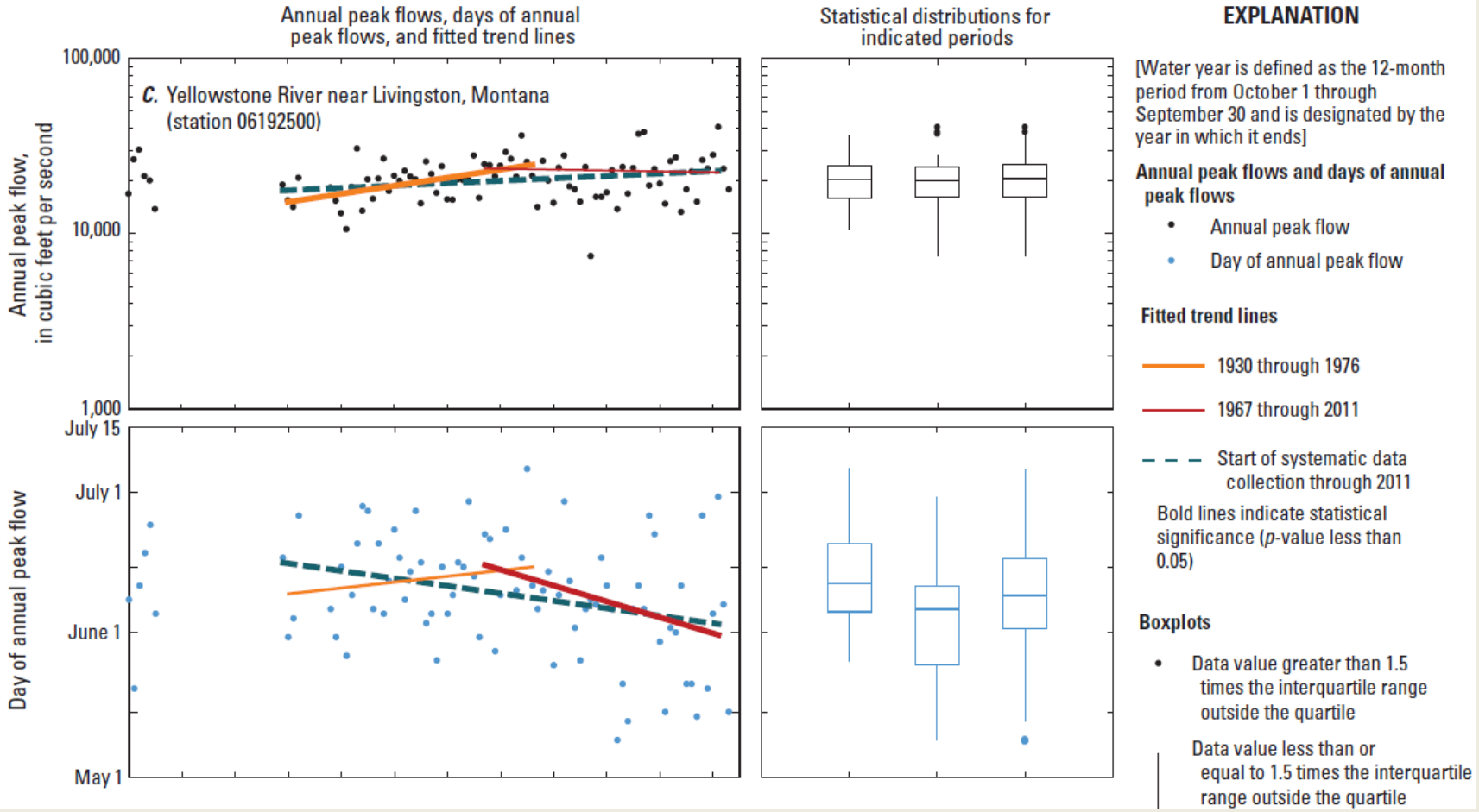
Prepared in cooperation with the Montana Department of Transportation and Montana Department of Natural Resources and Conservation

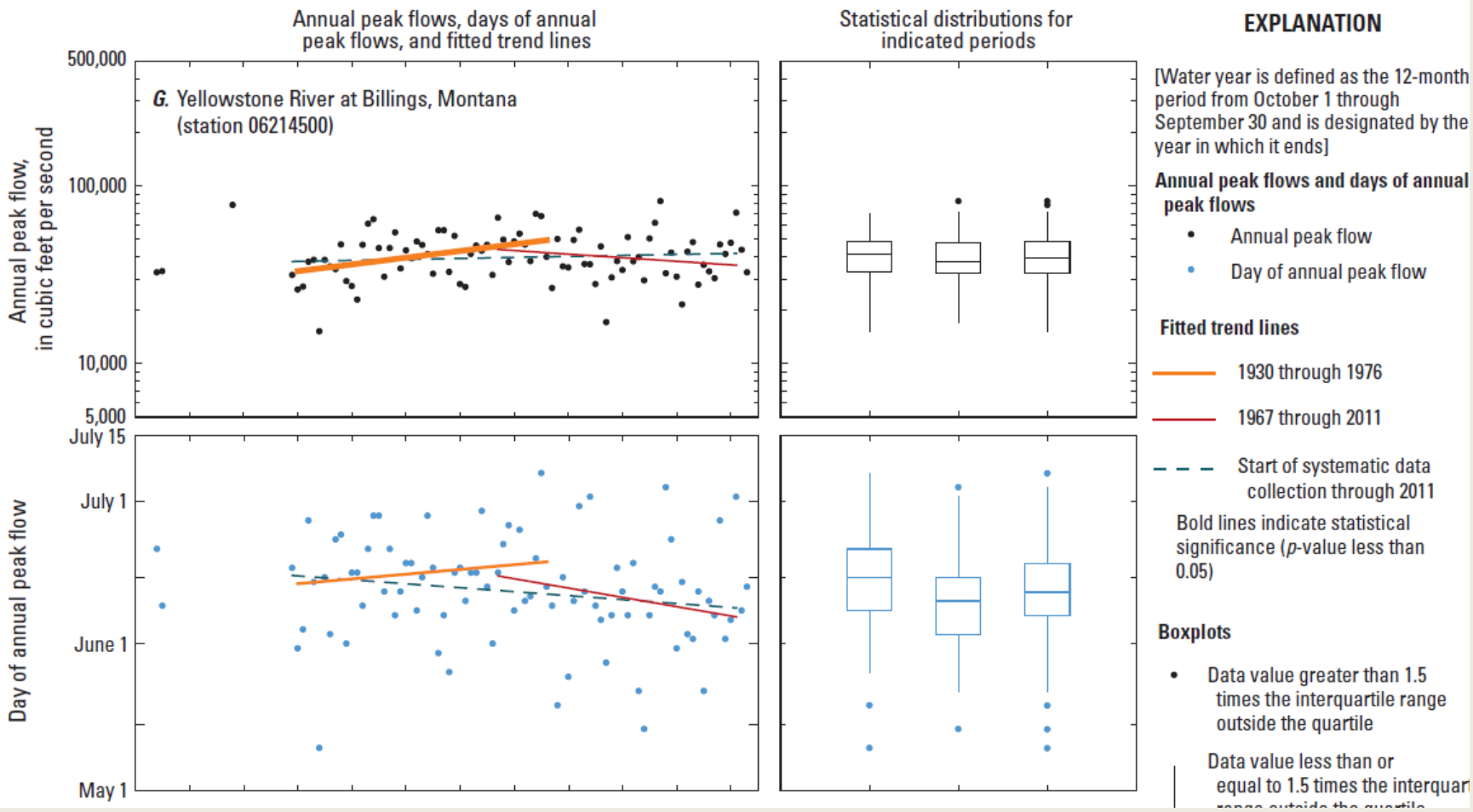
By: Steven K. Sando , Peter M. McCarthy , Roy Sando , and DeAnn M. Dutton

Temporal Trends and Stationarity for Selected Long-Term Streamflow-Gaging Stations, Montana



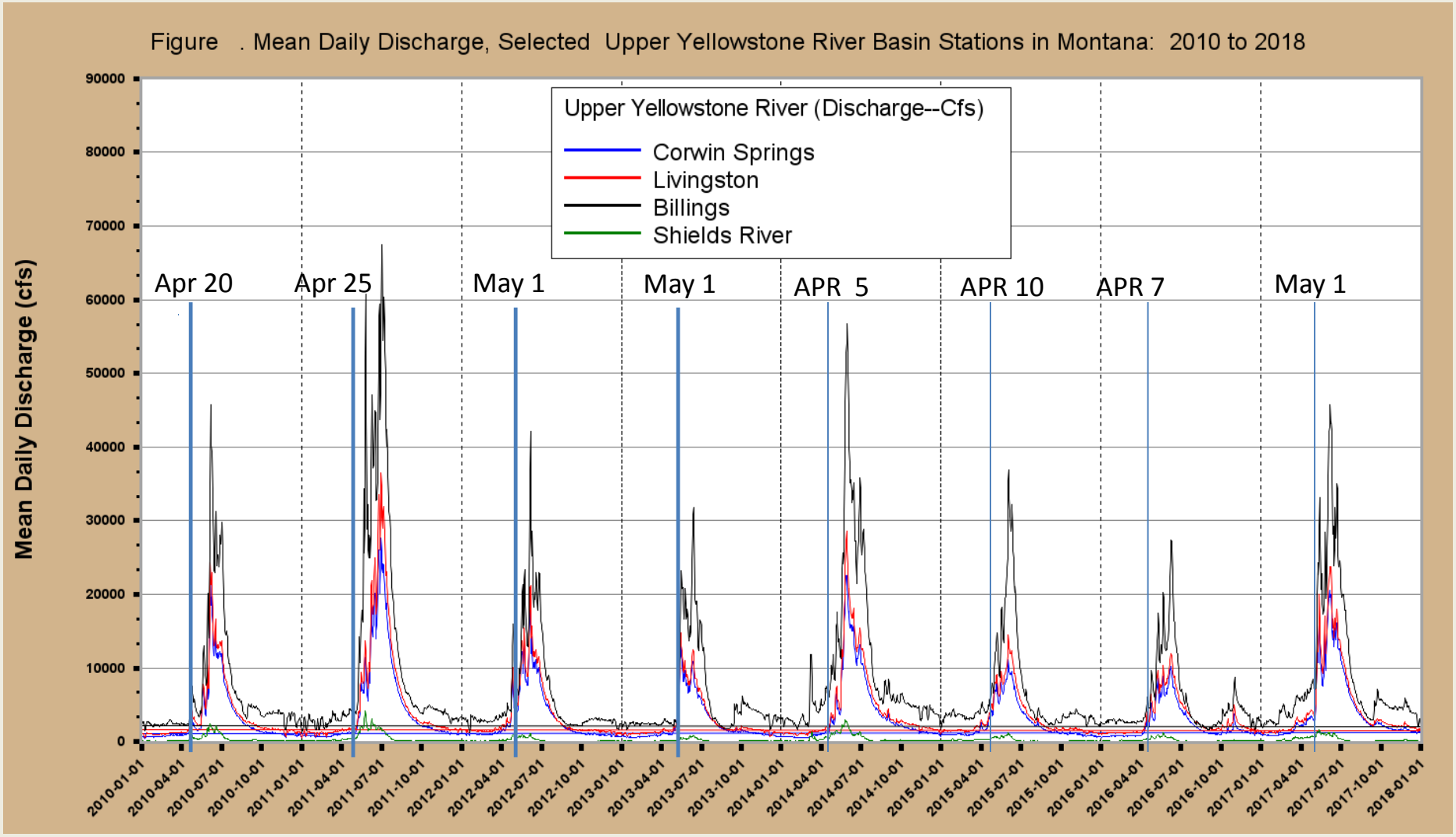
Temporal Trends and Stationarity for Selected Long-Term Streamflow-Gaging Stations, Montana




Annual peak flows, days of annual peak flows, and fitted trend lines
Statistical distributions for indicated periods
G. Yellowstone River at Billings, Montana (station 06214500)
Annual peak flow, in cubic feet per second
500,000
100,000
10,000
5,000
Day of annual peak flow
July 15
July 1
June 1
May 1
EXPLANATION
[Water year is defined as the 12-month period from October 1 through September 30 and is designated by the year in which it ends]
Annual peak flows and days of annual peak flows
Annual peak flow
Day of annual peak flow
Fitted trend lines
1930 through 1976
1967 through 2011
Start of systematic data collection through 2011
Bold lines indicate statistical significance (p-value less than 0.05)
Boxplots
Data value greater than 1.5 times the interquartile range outside the quartile
Data value less than or equal to 1.5 times the interquart

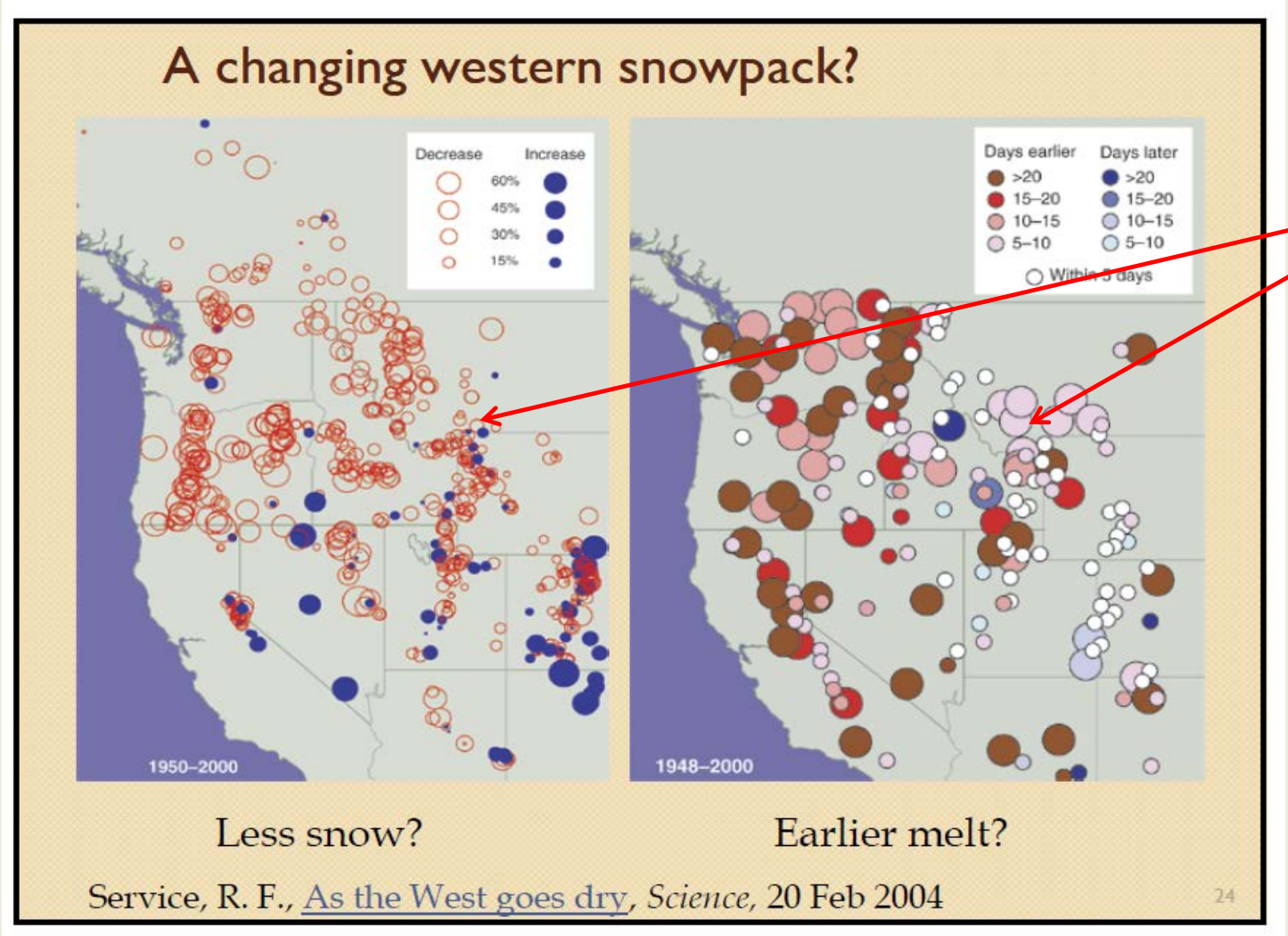
Is runoff starting earlier ?

(not clear without better analysis of entire record— 1900's to present)



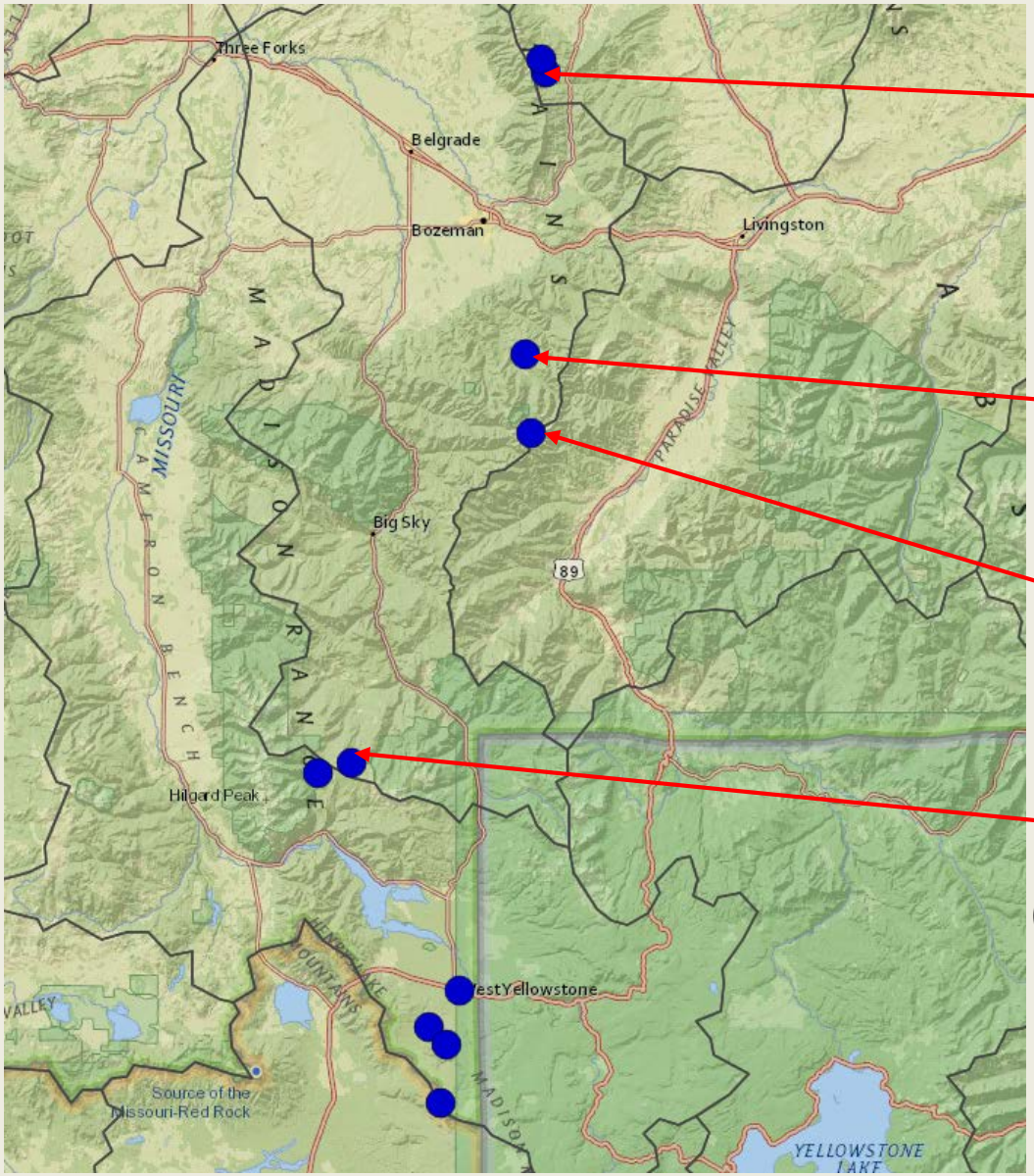
Has snowpack changed over time in the Upper Yellowstone Watershed ?

Previous studies indicate less snow and earlier melt



Upper Yellowstone

SNOTEL Stations in Upper Yellowstone Watershed (improve analysis with long-term snowcourse data



Sacajawea-6,650 ft

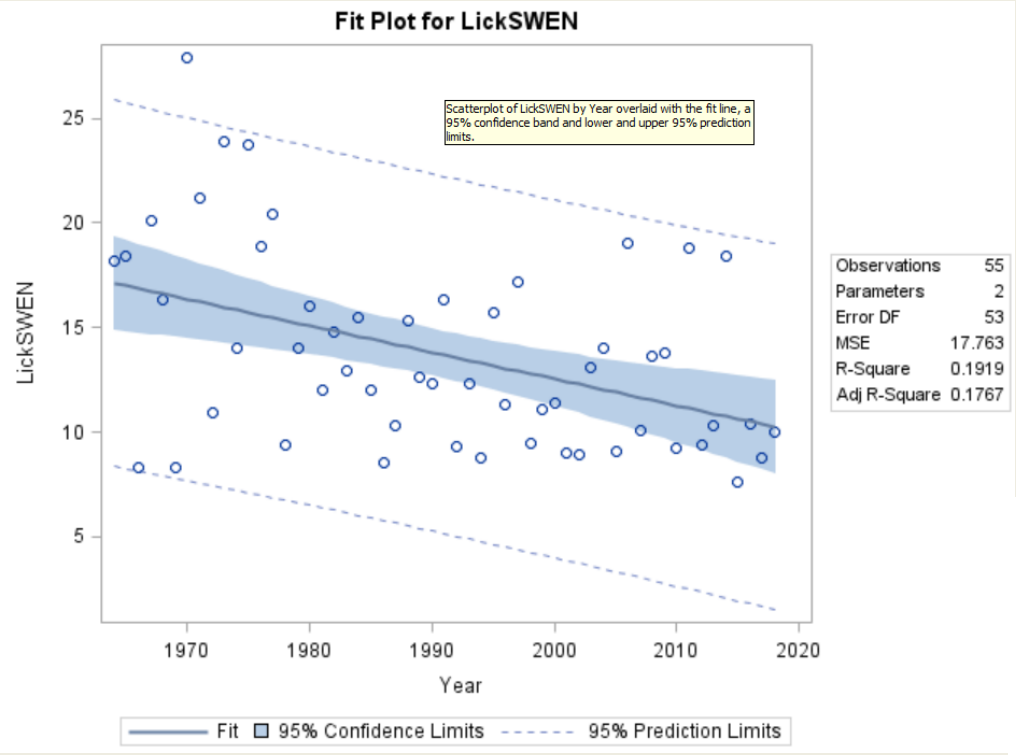
Lick Creek—6,860 (selected for long record)

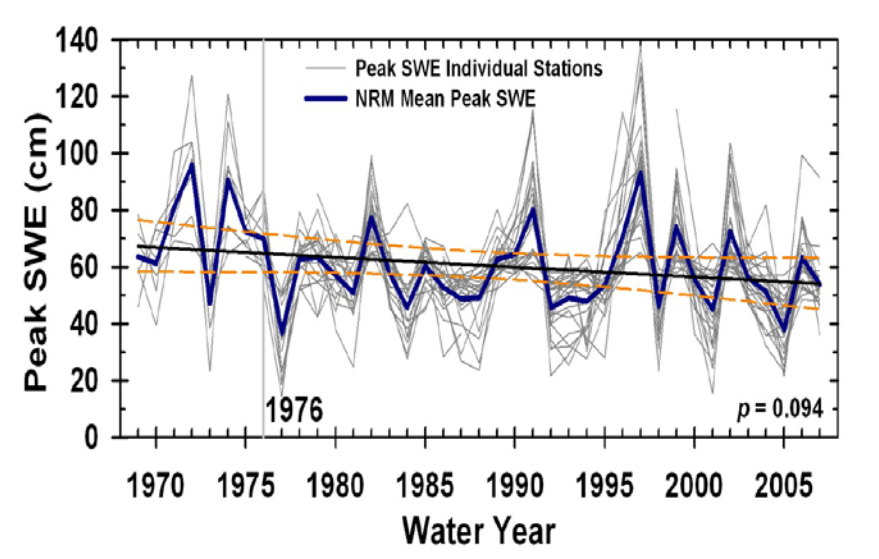
Shower Falls-8,100

Carrot Basin---9,000 ft

(improve analysis with long-term snowcourse data, and more stations)

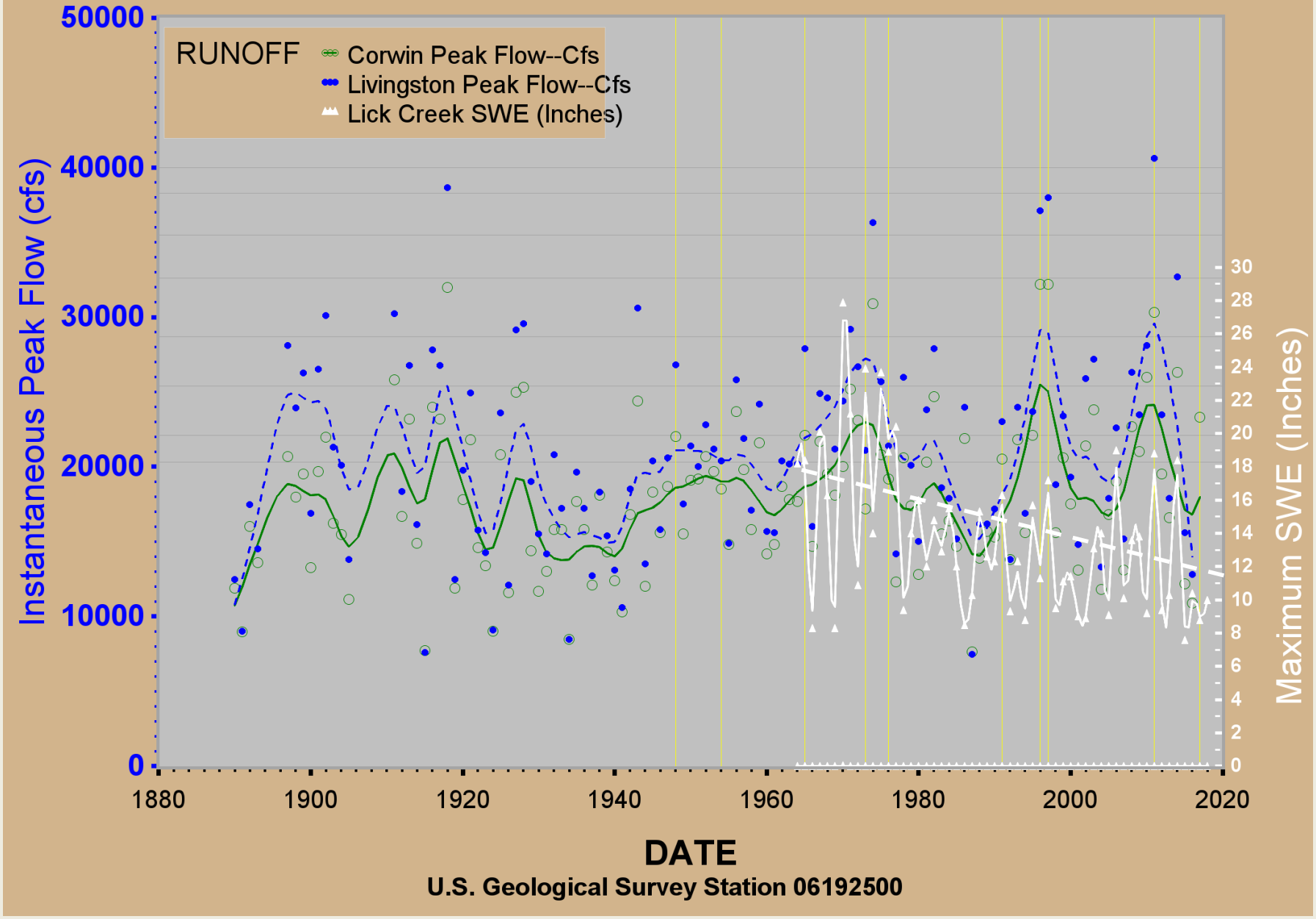
Plot of Lick Creek maximum snow water equivalent (SWE) over 1964 to 2017 indicates **decline peak amount of accumulated snow**





Greg Pederson, USGS Bozeman

Figure . Historic Annual Peak Flows and Maximum Snow Water Equivalent(SWE)
Yellowstone River near Livingston, MT: 1964-2017



U.S. Geological Survey Station 06192500

TRENDS in STREAMFLOW and SNOWPACK CONCLUSIONS

--Annual volume and pattern of runoff for the Yellowstone River at Corwin Springs, near Livingston, and Billings shows no long-term trend;

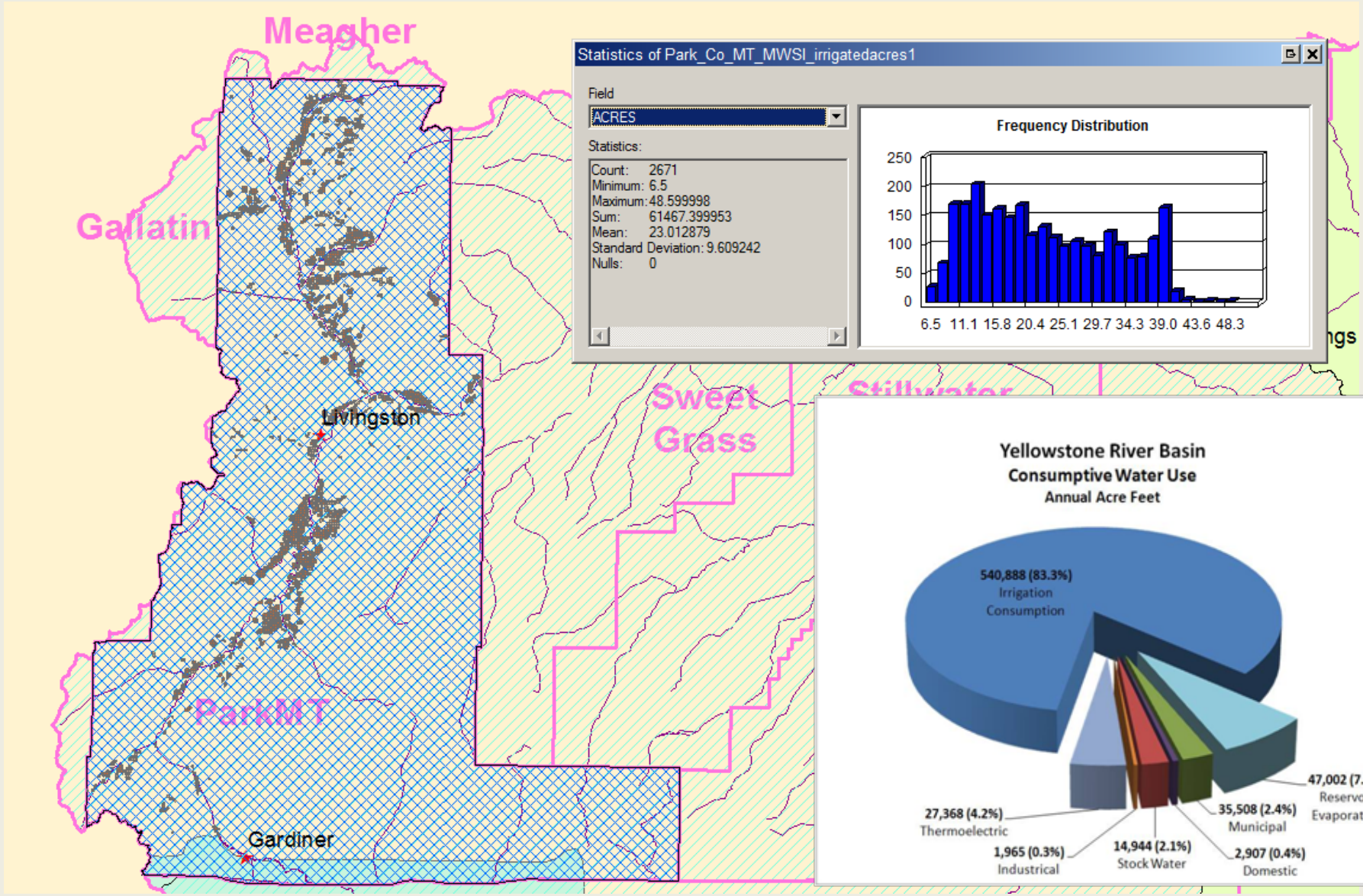
--No trend in size of peak flows at Corwin Springs; slight Increasing trend at Livingston and Billings;

--Peak flows about 2 weeks earlier at Corwin Springs and Livingston; 1 week at Billings

--Lick Creek maximum annual SWE declined significantly

More work needed on timing of runoff and SWE declines (esp. upper elevation stations)

THE END


Meagher
Gallatin
Livingston
Sweet Grass
ParkMT
Gardiner
Statistics of Park_Co_MT_MWSI_irrigatedacres1
Field
ACRES
Statistics:
Count: 2671
Minimum: 6.5
Maximum: 48.599998
Sum: 61467.399953
Mean: 23.012879
Standard Deviation: 9.609242
Nulls: 0
Frequency Distribution
250
200
150
100
50
0
6.5 11.1 15.8 20.4 25.1 29.7 34.3 39.0 43.6 48.3
Yellowstone River Basin
Consumptive Water Use
Annual Acre Feet
540,888 (83.3%)
Irrigation
Consumption
47,002 (7.2%)
Reservoir
Evaporation
35,508 (2.4%)
Municipal
2,907 (0.4%)
Domestic
14,944 (2.1%)
Stock Water
1,965 (0.3%)
Industrical
27,368 (4.2%)
Thermoelectric

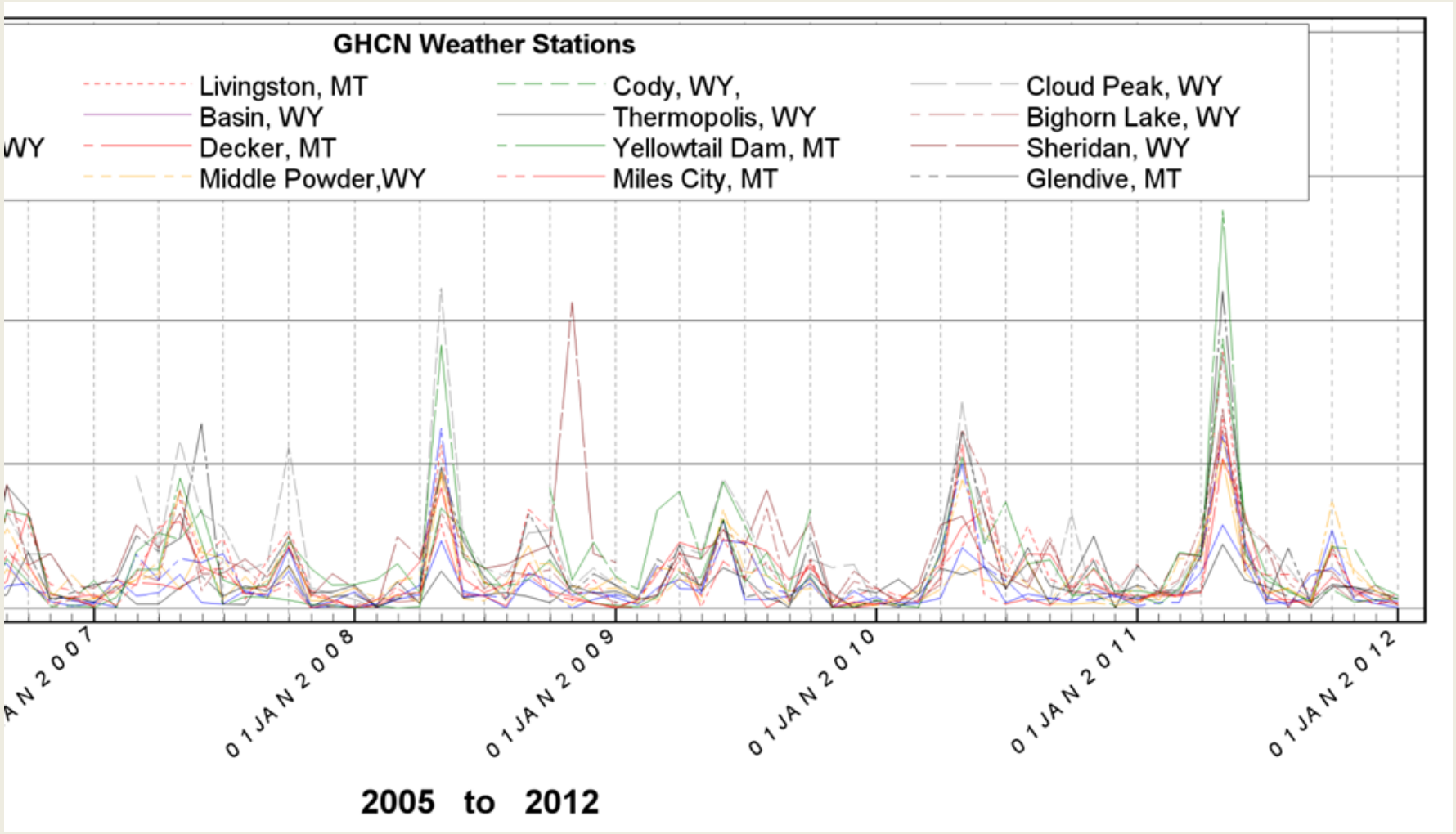

GHCN Weather Stations
Livingston, MT
Basin, WY
Decker, MT
Middle Powder,WY
Cody, WY,
Thermopolis, WY
Yellowtail Dam, MT
Miles City, MT
Cloud Peak, WY
Bighorn Lake, WY
Sheridan, WY
Glendive, MT
WY
AN 2007
01JAN2008
01JAN2009
01JAN2010
01JAN2011
01JAN2012
2005 to 2012

Figure Total Monthly Precipitation for Selected Stations in Yellowstone River Basin of Montana and Wyoming

Global Historical Climatology Network Stations. Version 3--National Climate Data Center

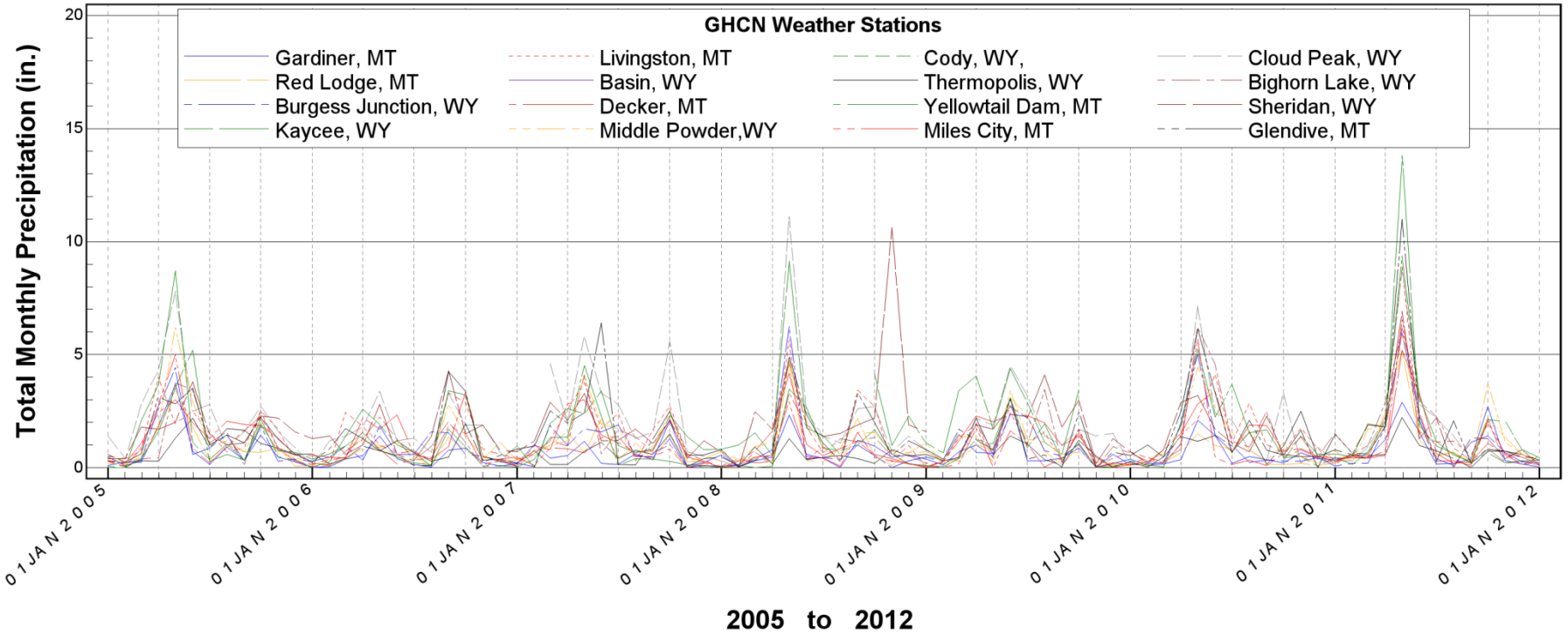


Figure IV-27 - Annual departure from mean annual streamflow at Billings and Sidney Montana, showing the drought of the 1930's and early 2000's.

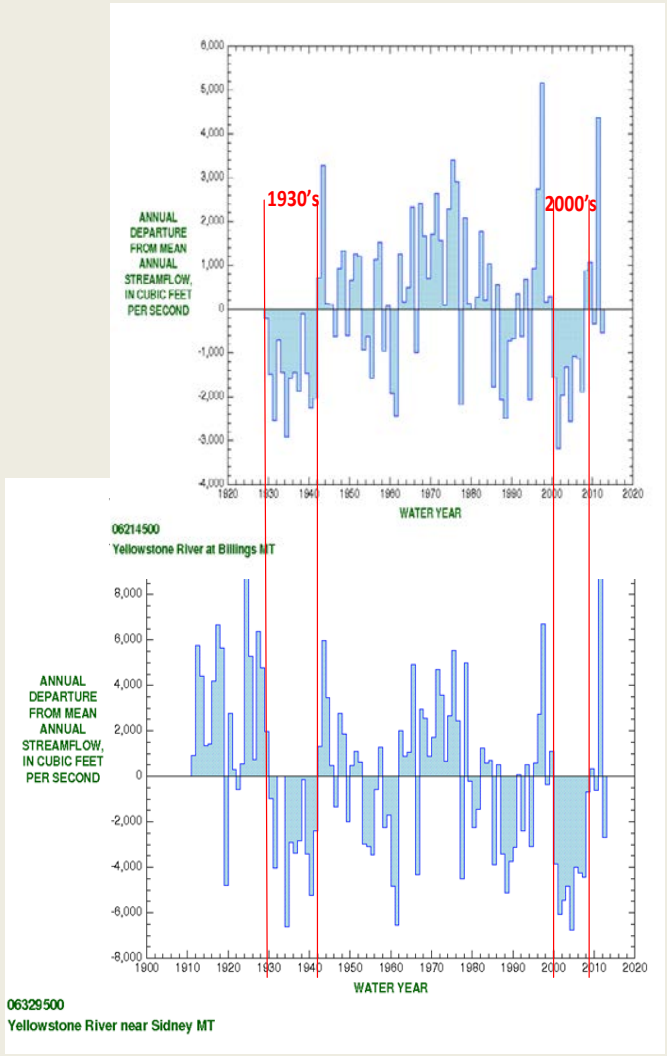
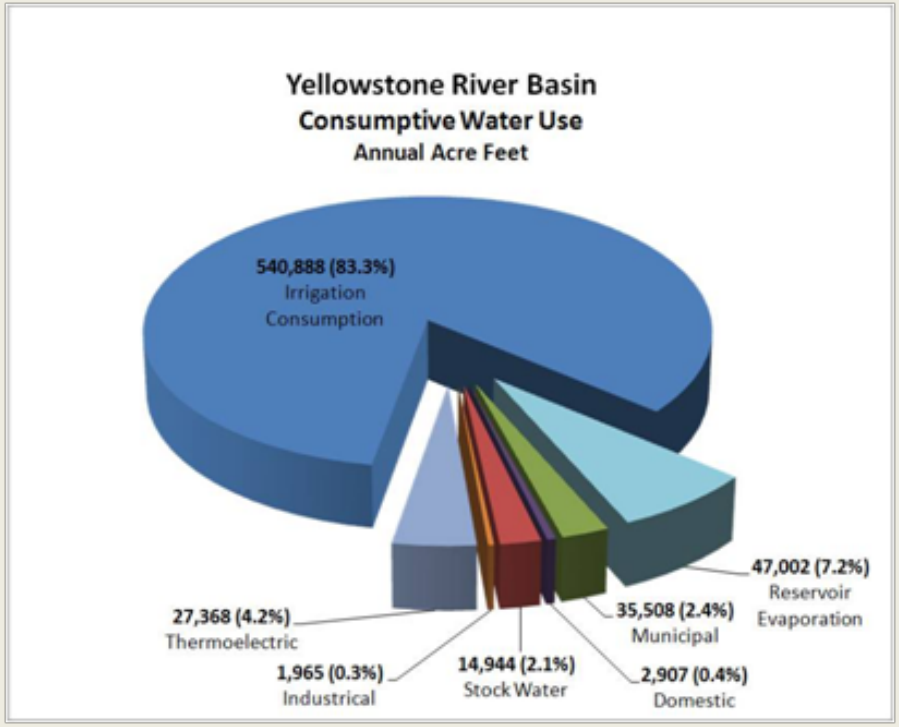
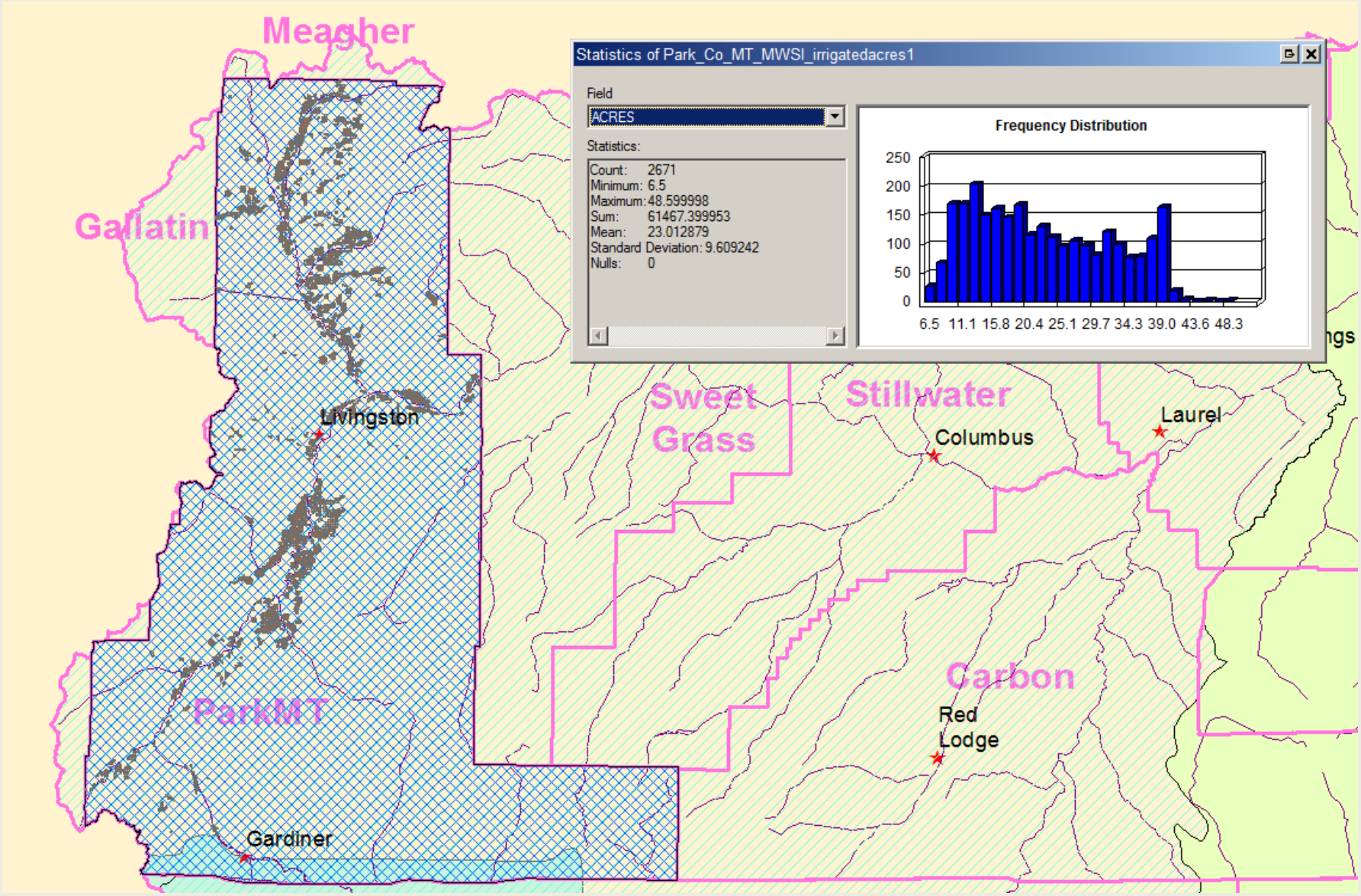


Figure V-16 - Estimated Total Annual Water Consumption in the Montana Portion of the Yellowstone River Basin




Meagher
Gallatin
Livingston
Sweet Grass
Stillwater
Columbus
Laurel
Park MT
Carbon
Red Lodge
Gardiner
Statistics of Park_Co_MT_MWSI_irrigatedacres1
Field
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Statistics:
Count: 2671
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Standard Deviation: 9.609242
Nulls: 0
Frequency Distribution
250
200
150
100
50
0
6.5 11.1 15.8 20.4 25.1 29.7 34.3 39.0 43.6 48.3

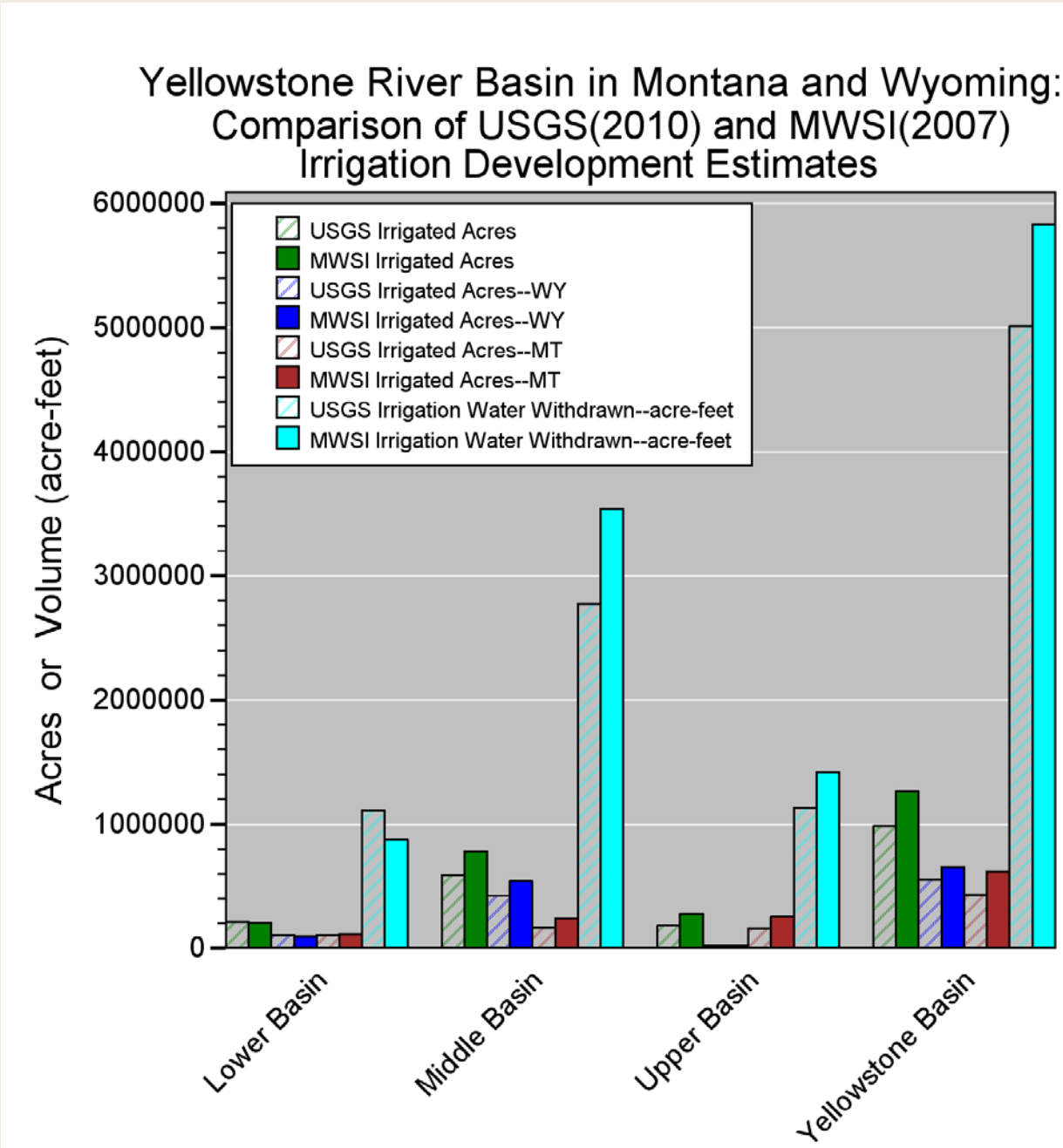
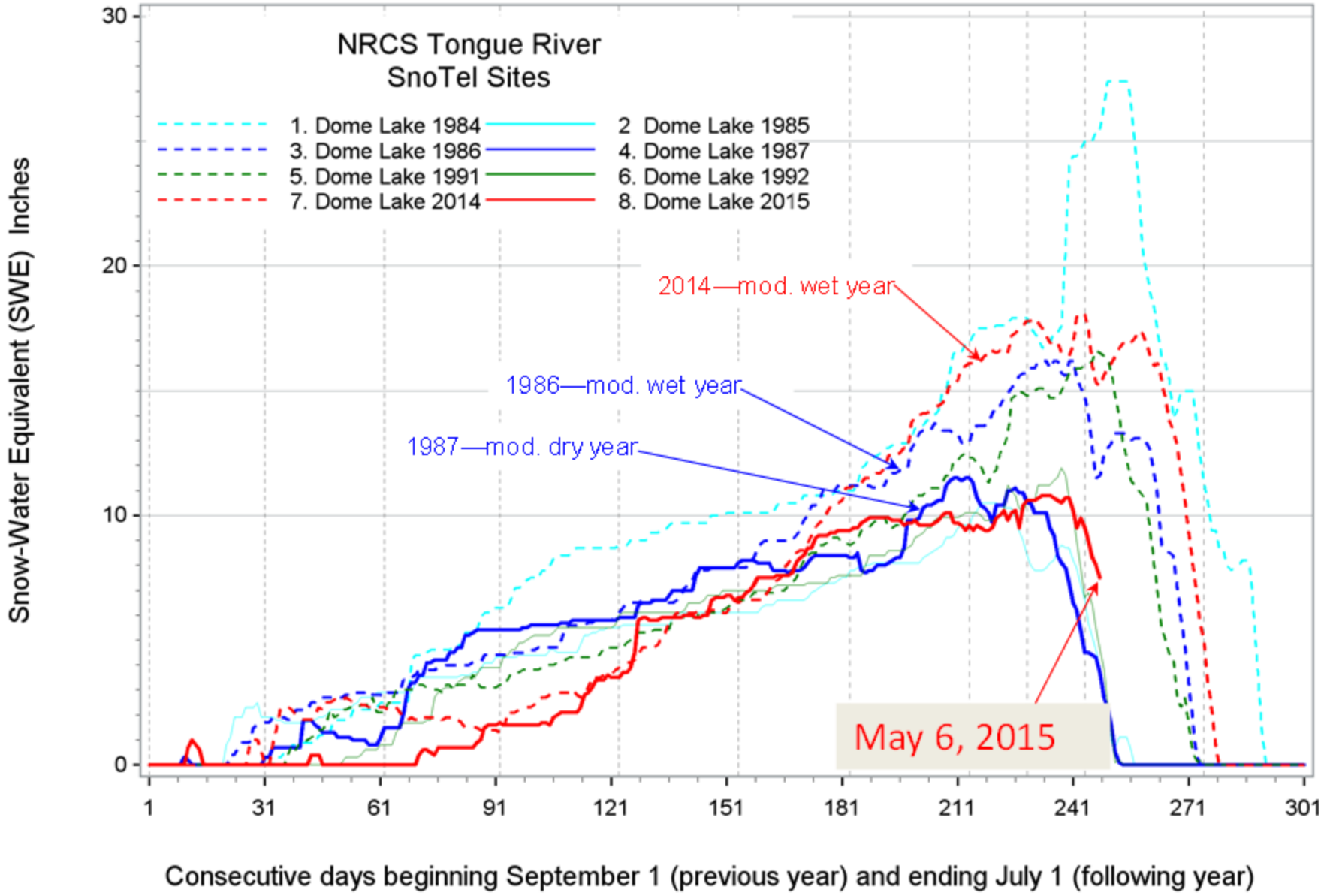
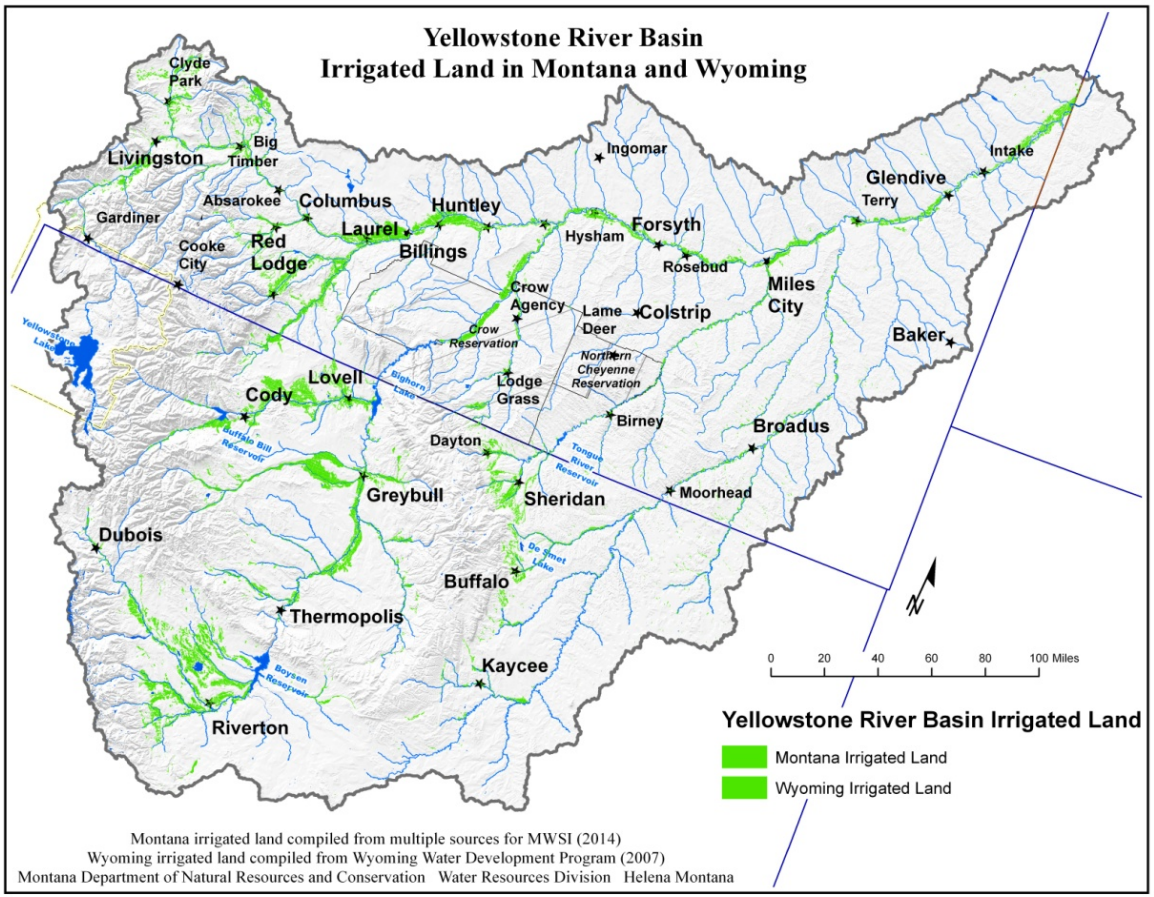
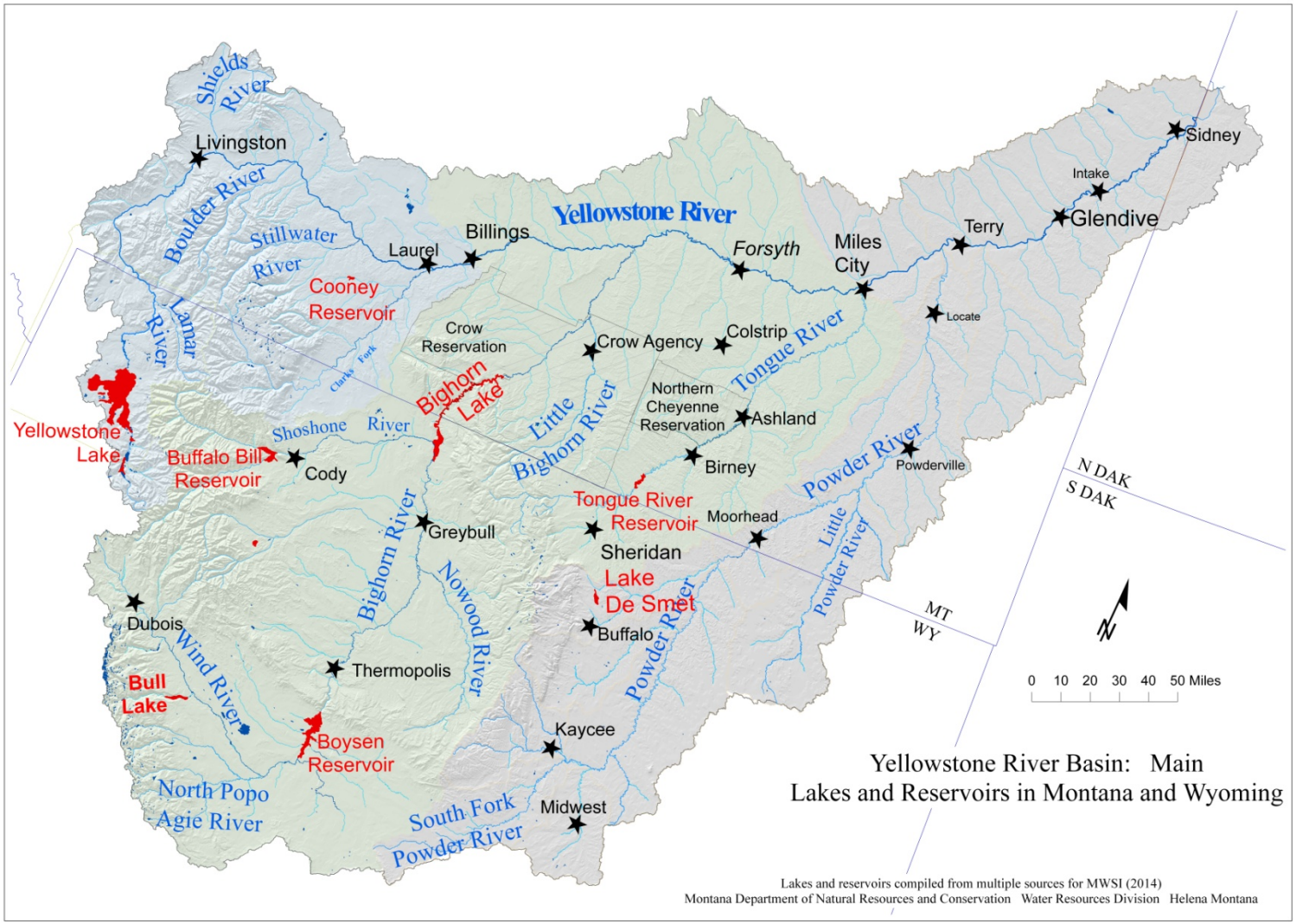

Yellowstone River Basin in Montana and Wyoming:
Comparison of USGS(2010) and MWSI(2007)
Irrigation Development Estimates
Acres or Volume (acre-feet)
6000000
5000000
4000000
3000000
2000000
1000000
0
USGS Irrigated Acres
MWSI Irrigated Acres
USGS Irrigated Acres--WY
MWSI Irrigated Acres--WY
USGS Irrigated Acres--MT
MWSI Irrigated Acres--MT
USGS Irrigation Water Withdrawn--acre-feet
MWSI Irrigation Water Withdrawn--acre-feet
Lower Basin
Middle Basin
Upper Basin
Yellowstone Basin

Figure . Tongue River Basin SNOTEL Measurements --Dome Lake Paired Wet_Dry Years

(Data retrieved from Wyoming NRCS SNOTEL database. DNRC Water Management Bureau May 2015)




Yellowstone River Basin
Irrigated Land in Montana and Wyoming
Clyde Park
Livingston
Big Timber
Absarokee
Columbus
Huntley
Gardiner
Laurel
Billings
Cooke City
Red Lodge
Ingomar
Intake
Glendive
Terry
Hysham
Forsyth
Rosebud
Miles City
Crow Agency
Lame Deer
Colstrip
Crow Reservation
Northern Cheyenne Reservation
Baker
Yellowstone Lake
Lovell
Cody
Bighorn Lake
Lodge Grass
Birney
Broadus
Buffalo Bill Reservoir
Dayton
Tongue River Reservoir
Greybull
Sheridan
Moorhead
Dubois
Big Smoke Lake
Buffalo
Thermopolis
Kaycee
Boysen Reservoir
Riverton
0 20 40 60 80 100 Miles
Yellowstone River Basin Irrigated Land
Montana Irrigated Land
Wyoming Irrigated Land
Montana irrigated land compiled from multiple sources for MWSI (2014)
Wyoming irrigated land compiled from Wyoming Water Development Program (2007)
Montana Department of Natural Resources and Conservation Water Resources Division Helena Montana


Shields River
Livingston
Boulder River
Stillwater River
Laurel
Billings
Yellowstone River
Forsyth
Miles City
Terry
Intake
Glendive
Sidney
Cooney Reservoir
Lamar River
Crow Reservation
Crow Agency
Colstrip
Locate
Tongue River
Clarks Fork
Bighorn Lake
Northern Cheyenne Reservation
Ashland
Little Bighorn River
Yellowstone Lake
Shoshone River
Buffalo Bill Reservoir
Cody
Birney
Powderville
Powder River
N DAK
S DAK
Tongue River Reservoir
Moorhead
Greybull
Bighorn River
Sheridan
Lake De Smet
Nowood River
Little Powder River
MT
WY
Dubois
Wind River
Buffalo
Powder River
Thermopolis
Bull Lake
0 10 20 30 40 50 Miles
Kaycee
Boysen Reservoir
North Popo Agie River
South Fork Powder River
Midwest
Yellowstone River Basin: Main Lakes and Reservoirs in Montana and Wyoming
Lakes and reservoirs compiled from multiple sources for MWSI (2014)
Montana Department of Natural Resources and Conservation Water Resources Division Helena Montana