Prepared in cooperation with the Yellowstone River Conservation District Council and the U.S. Army Corps of Engineers

Streamflow Statistics for Unregulated and Regulated Conditions for Selected Locations on the Upper Yellowstone and Bighorn Rivers, Montana and Wyoming, 1928–2002

Scientific Investigations Report 2014–5115

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Yellowstone River downstream from Highway 89 Bridge, Montana. Photograph by Katherine Chase, U.S. Geological Survey (USGS) , May 14, 2014.

Back cover. Looking west at the Yellowstone River and Crazy Mountains, near Big Timber, Montana. Photograph by Katherine Chase, USGS, May 14, 2014.

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

CES	cumulative effects study
NAVD 88	North American Vertical Datum of 1988
Reclamation	Bureau of Reclamation
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
YRCDC	Yellowstone River Conservation District Council

Streamflow Statistics for Unregulated and Regulated Streamflow Conditions for Selected Locations on the Upper Yellowstone and Bighorn Rivers, Montana and Wyoming, 1928–2002

By Katherine J. Chase

Abstract

Major floods in 1996 and 1997 intensified public debate about the effects of human activities on the Yellowstone River. In 1999, the Yellowstone River Conservation District Council was formed to address conservation issues on the river. The Yellowstone River Conservation District Council partnered with the U.S. Army Corps of Engineers to carry out a cumulative effects study on the main stem of the Yellowstone River. The cumulative effects study is intended to provide a basis for future management decisions within the watershed. Streamflow statistics, such as flow-frequency data calculated for unregulated and regulated streamflow conditions, are a necessary component of the cumulative effects study.

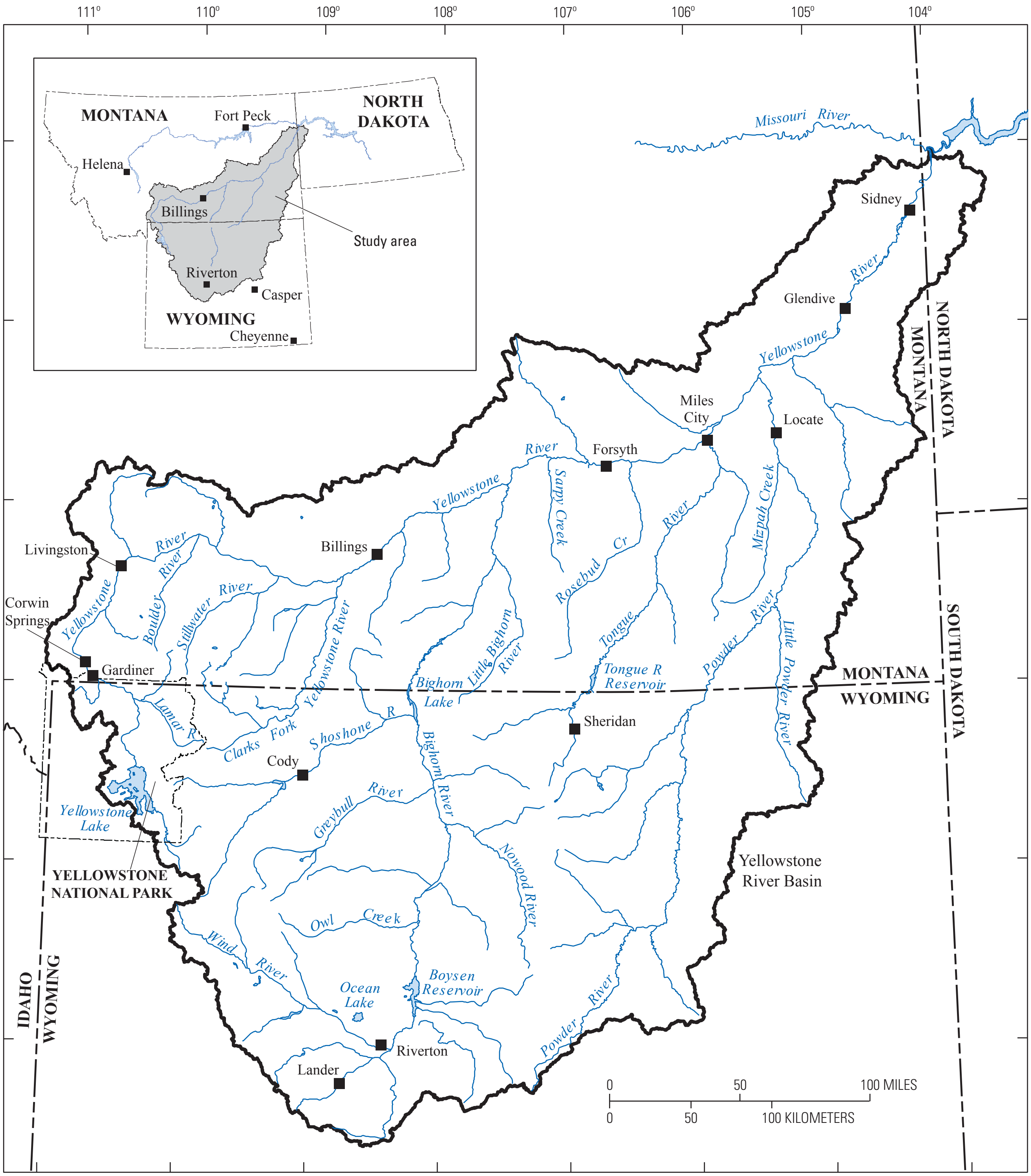
The U.S. Geological Survey, in cooperation with the Yellowstone River Conservation District Council and the U.S. Army Corps of Engineers, calculated low-flow frequency data and general monthly and annual statistics for unregulated and regulated streamflow conditions for the Upper Yellowstone and Bighorn Rivers for the 1928–2002 study period; these data are presented in this report. Unregulated streamflow represents flow conditions during the 1928–2002 study period if there had been no water-resources development in the Yellowstone River Basin. Regulated streamflow represents estimates of flow conditions during the 1928–2002 study period if the level of water-resources development existing in 2002 was in place during the entire study period.

Introduction

The Yellowstone River is one of the longest free-flowing rivers in the lower 48 states, draining about 70,000 square miles (mi^2) as it flows more than 600 miles (mi) from its origin east of Yellowstone National Park, Wyoming (Wyo.), through Montana (Mont.) to the confluence with the Missouri River in North Dakota (Jean and Crispin, 2001; U.S. Geological Survey, 2010; fig. 1). The Yellowstone River supports a wide variety of agricultural, domestic, industrial, and recreational uses.

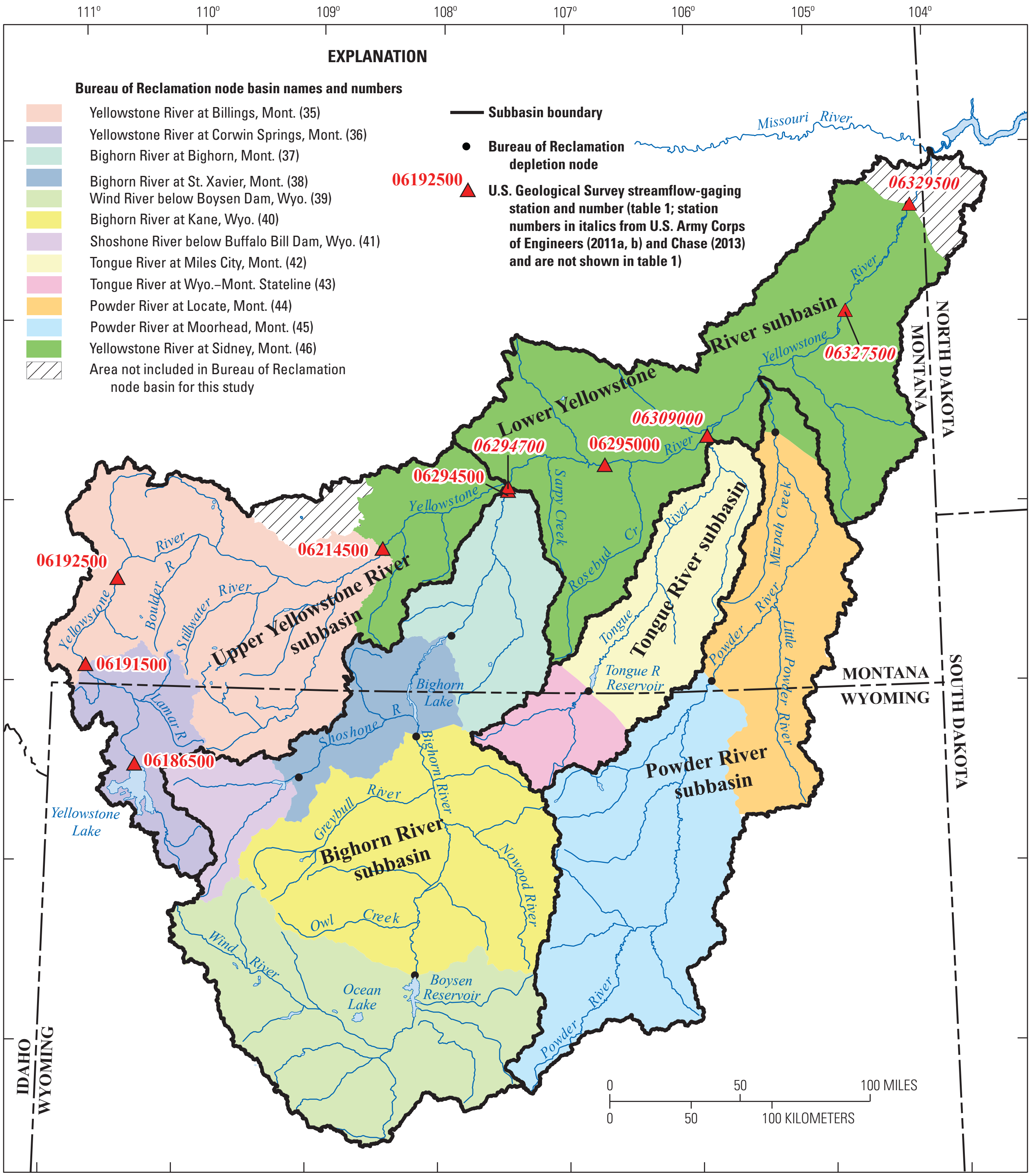
Major floods in 1996 and 1997 intensified public debate about the effects of human activities on the Yellowstone River, and led to multidisciplinary efforts to understand the river's response to flood control, channel stabilization, and other construction along the Yellowstone River corridor. In 1999, the Yellowstone River Conservation District Council (YRCDC) was formed to address conservation issues on the river. The YRCDC partnered with the U.S. Army Corps of Engineers (USACE) to carry out a cumulative effects study (CES) on the Yellowstone River main stem. The CES is intended to provide a scientific basis for future management decisions on the Yellowstone. Streamflow statistics for unregulated and regulated streamflow conditions along the Yellowstone River main stem are a necessary component of the CES. To facilitate the data analyses for this study, the Yellowstone River Basin was divided into five subbasins (fig. 2): (1) Upper Yellowstone River subbasin, (2) Bighorn River subbasin, (3) Lower Yellowstone River subbasin, (4) Tongue River subbasin, and (5) Powder River subbasin. For the purposes of this report, the Upper Yellowstone River is defined as the main stem Yellowstone River within the Upper Yellowstone River subbasin, and the Lower Yellowstone River is defined as the main stem Yellowstone River in the Lower Yellowstone River subbasin.

Some streamflow statistics for unregulated and regulated conditions for selected locations in the Yellowstone River Basin have been calculated by the USACE and by the U.S. Geological Survey (USGS). The USACE calculated peak-flow data, high-flow frequency data, and flow-duration data for unregulated and regulated streamflow conditions for the Yellowstone River main stem in the Upper Yellowstone River subbasin and for the Bighorn River (fig. 2; U.S. Army Corps of Engineers, 2011a, b). The USGS calculated peak-flow data, high-flow frequency data, low-flow frequency data, and flow-duration data for unregulated and regulated streamflow conditions for the Yellowstone River main stem in the Lower Yellowstone River subbasin and for the Tongue and Powder Rivers (Chase, 2013).



Base modified from U.S. Geological Survey Digital Line Graph (DLG), 1973, 1:2,000,000
Lambert Conformal Conic projection
Standard parallels 45°00' and 49°00'
Central meridian –109°30'
North American Datum of 1983 (NAD 83)

Figure 1. Location of the Yellowstone River Basin in Montana, Wyoming, and North Dakota.



Base modified from U.S. Geological Survey Digital Line Graph (DLG), 1973, 1:2,000,000
Lambert Conformal Conic projection
Standard parallels 45°00' and 49°00'
Central meridian –109°30'
North American Datum of 1983 (NAD 83)

Figure 2. Location of study subbasins in Montana, Wyoming, and North Dakota, and Bureau of Reclamation depletion node basins and streamflow-gaging stations in Montana and Wyoming. Depletion node basins from U.S. Department of the Interior, Bureau of Reclamation (2005).

The U.S. Geological Survey, in cooperation with the Yellowstone River Conservation District Council and the U.S. Army Corps of Engineers, calculated low-flow frequency data and general monthly and annual statistics for unregulated and regulated streamflow conditions for the Upper Yellowstone and Bighorn Rivers for the 1928–2002 study period. These data and statistics supplement the previous work by USACE and USGS.

Purpose and Scope

The primary purpose of this report is to supplement the previous streamflow statistical summaries (U.S. Army Corps of Engineers, 2011a, b; Chase, 2013) by presenting low-flow frequency data and monthly and annual streamflow characteristics for four streamflow-gaging stations on the Upper Yellowstone River and for one streamflow-gaging station on the Bighorn River for the 1928–2002 (calendar year) study period. These low-flow frequency data also were interpolated for 48 ungaged locations on the Upper Yellowstone River between streamflow-gaging stations. For two of the four streamflow-gaging stations on the Upper Yellowstone River, and for the streamflow-gaging station on the Bighorn River, data were calculated for two streamflow conditions: unregulated, where effects of streamflow regulation and water use have been removed, and regulated, where streamflows are adjusted to represent near-present-day (based on 2002 data) levels of development. For two of the four streamflow-gaging stations on the Upper Yellowstone River, data were calculated only for unregulated conditions.

Additionally, low-flow frequency data and monthly and annual streamflow characteristics are presented for nine ungaged locations on the Lower Yellowstone River, between the Bighorn River confluence and streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Mont.) for unregulated and regulated conditions. Low-flow frequency data and monthly and annual streamflow characteristics for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Mont.) were presented in Chase (2013) and also are presented in this report.

Information for selected streamflow-gaging stations on the Yellowstone and Bighorn Rivers is summarized in table 1; locations of selected streamflow-gaging stations in the Yellowstone River Basin are shown in figure 2. Selected streamflow-gaging stations outside of the Upper Yellowstone River subbasin also are included in figure 2 to facilitate association of this report with U.S. Army Corps of Engineers (2011a, b) and Chase (2013).

Description of Study Area

The headwaters of the Yellowstone River are in northern Wyoming, east of Yellowstone National Park. The river enters Montana near the town of Gardiner and flows north and east across 500 mi of Montana to its confluence with the Missouri River in North Dakota (fig. 1). Elevations in the drainage basin range from about 13,780 feet (ft) above the North American Vertical Datum of 1988 (NAVD 88) in the mountains south of Yellowstone National Park, to about 2,700 ft at the Yellowstone and Bighorn River confluence, to 1,850 ft at the Missouri River confluence (Zelt and others, 1999; U.S. Geological Survey, 2010). Major tributaries to the Yellowstone River include the Bighorn, Tongue, and Powder Rivers (fig. 1).

Generally, the climate is semiarid with cold winters and warm summers. Based on climatic data for 1971–2000, monthly mean temperatures at Yellowstone Lake, Wyo. (fig. 1; elevation 7,870 ft above NAVD 88) ranged from -3.1 degrees Fahrenheit (°F) in January to 70.4 °F in July. Monthly mean temperatures at Billings, Mont. (elevation 3,097 ft) ranged from 13.3 °F in January to 88.4 °F in July. The mean annual precipitation of 20.40 inches (in.) at Yellowstone Lake, Wyo., was distributed fairly evenly throughout the year, whereas about 46 percent of the mean annual precipitation (13.96 in.) at Billings, Mont., fell from May to August (National Oceanic and Atmospheric Administration, 2002).

The typical annual flow pattern for the Yellowstone River upstream from Livingston, Mont., consists of a peak during the late spring/early summer mountain snowmelt (Zelt and others, 1999). For the Yellowstone River downstream from Billings, Mont., the typical annual flow pattern consists of a lowland snowmelt peak during the late winter/early spring followed by a peak from the mountain snowmelt during the late spring/early summer (Zelt and others, 1999). Several short- to moderate-duration rainstorm peaks typically augment the spring/summer snowmelt peaks and the summer base flows.

Methods for Calculating Streamflow Statistics for Unregulated and Regulated Conditions

Observed daily streamflow records from USGS streamflow-gaging stations served as the basis for calculating the streamflow statistics. Daily mean streamflows (referred to herein as “daily streamflows”) for the Upper Yellowstone River and the Bighorn River were retrieved and analyzed using methods developed by the USACE and the USGS. The USACE retrieved daily streamflows for selected USGS streamflow-gaging stations (U.S. Geological Survey, 2010) and organized the data into a USACE Hydrologic Engineering Center Data Storage System database using the computer program HEC-DSSvue (U.S. Army Corps of Engineers, 2009a; Douglas J. Clemetson, U.S. Army Corps of Engineers, written commun., 2011). The USACE also synthesized missing daily streamflows to develop a complete set of daily streamflows for the Upper Yellowstone River and Bighorn River streamflow-gaging stations for the 1928–2002 study period (U.S. Army Corps of Engineers, 2011a, b). The 1928–2002 study period was chosen for this investigation because the USACE desired

Table 1. Information for selected streamflow-gaging stations in the Yellowstone River Basin, Montana and Wyoming (U.S. Geological Survey, 2010).

[--, no data]

Station number	Station name	Drainage area (square miles)	Contributing drainage area (square miles)[1]	Period of record (through 2010)	Streamflow condition(s) analyzed	
06186500	Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyo.	991	--	1922–82, 1983–86, 1988–2010	Unregulated[2]	--
06191500	Yellowstone River at Corwin Springs, Mont.	2,619	--	1889–93, 1910–2010	Unregulated	--
06192500	Yellowstone River near Livingston, Mont.	3,551	--	1897–1905, 1928–32, 1937–2010	Unregulated	Regulated[3]
06214500	Yellowstone River at Billings, Mont.	11,805	11,408	1904–05, 1928–2010	Unregulated	Regulated
06294500	Bighorn River above Tullock Creek near Bighorn, Mont.	22,414	--	1945–55, 1956–2010	Unregulated	Regulated
06295000	Yellowstone River at Forsyth, Mont.	40,146	39,455	1921–23, 1977–2010	Unregulated	Regulated

[1]Contributing area only specified for selected streamflow-gaging stations in U.S. Geological Survey (2010).

[2]Unregulated streamflow represents flow conditions that might have occurred during the 1928–2002 study period if there had been no water-resources development in the Yellowstone River Basin.

[3]Regulated streamflow represents estimates of flow conditions during the 1928–2002 study period if the level of water-resources development existing in 2002 was in place during the entire study period.

a 75-year study period, and Bureau of Reclamation (Reclamation) depletions data (necessary to estimate unregulated and regulated streamflows) only were available until 2002. Finally, the USACE modified the daily streamflows to represent unregulated and regulated streamflow conditions (U.S. Army Corps of Engineers, 2011a, b).

The USGS then used the USACE datasets to calculate low-flow frequency statistics for unregulated and regulated daily streamflows for 1928–2002 for this report. Low-flow frequency statistics included annual *n*-day low-flow frequency data, seasonal *n*-day low-flow frequency data, and monthly 7-day low-flow frequency data, as discussed in the “Low-Flow Frequency Analysis” section.

Streamflow Conditions Analyzed

For three Yellowstone River streamflow-gaging stations; 06192500 (Yellowstone River near Livingston, Mont.), 06214500 (Yellowstone River at Billings, Mont.), and 06295000 (Yellowstone River at Forsyth, Mont.), and for the Bighorn River streamflow gaging station 06294500 (Bighorn River above Tullock Creek near Bighorn, Mont.), streamflow datasets were synthesized for two hypothetical streamflow conditions: unregulated and regulated (table 1, figs.1 and 2). These datasets are more homogenous than the observed streamflow datasets at sites affected by water-use development, because effects of changing water-use practices were removed (for the unregulated dataset) or modified to be uniform through the study period (for the regulated dataset). Data homogeneity is an important criterion for the procedures used in the statistical analyses (U.S. Interagency Advisory Council on Water Data, 1982).

Unregulated conditions represent estimates of streamflows during the 1928–2002 study period assuming there was no water-resources development in the basin. Water-resources development includes irrigation operations, reservoir operations, and other human-caused changes to the amount and timing of streamflow. Historic depletions estimated by Reclamation (U.S. Department of the Interior Bureau of Reclamation, 1999, 2005) and described in the section “Depletion Estimates,” account for changes to streamflow caused by water-resources development throughout the Yellowstone River Basin. Unregulated streamflows were estimated by adding the historic depletions estimated by Reclamation to the observed streamflows.

Regulated streamflows represent estimates of streamflows during the 1928–2002 study period assuming a uniform level of water-resources development existing in 2002 and applied throughout the entire study period. Regulated streamflows were estimated by subtracting the “2002-level depletions” (described in the section “Depletion Estimates”) from the unregulated streamflows.

Because of minimal effects from regulation and depletion, only unregulated streamflows were analyzed for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyo.) and streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Mont.), which are the two most upstream sites on the Yellowstone River (table 1 and fig. 2). For both streamflow-gaging stations, the maximum difference between unregulated and regulated flows was less than 2 cubic feet per second (ft^3/s), which is less than 1 percent of the lowest unregulated flow during the study period (380 ft^3/s).

Depletion Estimates

The U.S. Department of the Interior, Bureau of Reclamation (2005) developed estimates of historic and 2002-level depletions for the entire Missouri River Basin for water years 1929–2002. Depletion estimates were developed for 118 node basins in the Missouri River Basin, which included 12 node basins (fig. 2) in the Yellowstone River Basin. The node basin boundaries do not necessarily correspond with the subbasin boundaries (fig. 2). For example, the Yellowstone River at Sidney node basin includes the Lower Yellowstone River subbasin and a part of the Upper Yellowstone River subbasin. Also, a small part of the Upper Yellowstone River subbasin northwest of streamflow-gaging station 06214500 (Yellowstone River at Billings, Mont.) was not included in any node basins within the Yellowstone River Basin; this area corresponds with the noncontributing drainage area of 691 mi^2 at streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Mont.) (table 1; difference between drainage area and noncontributing drainage area).

The term "depletion" refers to changes to natural streamflows that result from water-resources development. In almost all cases, water-resources development results in net decreases in streamflow during periods of 1 or more years; however, some water-resources development (for example, reservoir and irrigation operations) can result in decreases in streamflow (relative to natural conditions) during specific times of the year and increases in streamflow during other times of the year. Thus, the term "depletion" as used in this report and by Reclamation (U.S. Department of the Interior, Bureau of Reclamation, 2005) does not imply a decrease in streamflow, especially on a seasonal basis. Positive depletions indicate decreases in streamflow relative to natural conditions, and conversely, negative depletions indicate increases in streamflow relative to natural conditions.

The historic depletions determined by Reclamation (U.S. Department of the Interior, Bureau of Reclamation, 2005) included monthly estimates of irrigation operations, reservoir operations, and other water uses that existed each year during 1929–2002. Those estimates were based on climatological records, the irrigation methods in use and number of irrigated acres, and municipal and industrial water uses for each year. The 2002-level depletions determined by Reclamation were based on estimates of irrigation operations, reservoir operations, and municipal and industrial water uses that existed in 2002, which then were applied to each year during 1929–2002. Applying the 2002-level depletions to each year accounts for effects of interannual climatic variability on water demand and consumptive use. Because Reclamation did not develop depletion estimates for 1928, monthly depletions for 1928 (this study) were estimated from the monthly averages for the years 1929–1933 for the historic and 2002-level depletions. The Reclamation 1929–2002 depletion data and 1928 estimates are presented in appendix 1 in Chase (2013). As reported in Chase (2013), the U.S. Army Corps of Engineers (2011b) modified the monthly depletions calculated by Reclamation for the Bighorn River subbasin. These modified depletions were used to calculate streamflows for unregulated and regulated streamflow conditions for this report.

Low-Flow Frequency Analysis

Annual *n*-day low-flow frequency data were developed from an annual series of the lowest daily streamflows for *n*-day consecutive periods within each climatic year, from April 1 to March 31 (Riggs, 1972). For example, an annual series of 7-day low flows consists of the lowest mean flow that occurred during any 7-day consecutive period during each year of record. In addition, seasonal low-flow frequency data were developed from the annual series of the lowest daily streamflows for 7- and 30-day consecutive periods for the winter (January–March), spring (April–June), summer (July–September) and fall (October–December) seasons. Monthly low-flow frequency data also were developed from the annual series of the lowest daily streamflows for 7-day consecutive periods for each month.

The computer program HEC-SSP (U.S. Army Corps of Engineers, 2010) was used to calculate the low-flow frequency relations for *n*-day datasets for unregulated and regulated streamflow conditions. The log-Pearson III distribution (U.S. Interagency Advisory Council on Water Data, 1982) was used to estimate low-flow frequency data for consecutive periods of 7 and 30 days for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. The 200- and 500-year low-flow frequency data were not estimated because the study period only includes 75 years of data, and USGS guidelines recommend limiting analyses to twice the period of record (Parrett, 1997; Walter Hofmann, U.S. Geological Survey, written commun., 1973). Nonexceedance probabilities were calculated using only nonzero flows, then a conditional adjustment probability was used to adjust the non-exceedance probability for the zero flows in the record. If the log-Pearson III distribution did not fit the data, then a Pearson III distribution (U.S. Interagency Advisory Council on Water Data, 1982) was applied. If neither the log-Pearson III nor the Pearson III distribution fit the data, a graphical curve was fit through the data. Where applicable, a graphical curve was determined by visually examining the pattern of plotted points and estimating streamflow magnitudes at intersections of perceived uniform-fit lines and reported probability levels. Straight-line fits were applied between reported probability levels.

Monthly and Annual Streamflow Characteristics

Maxima, minima, and mean monthly and annual streamflows were calculated for unregulated and regulated conditions using HEC-DSSvue (U.S. Army Corps of Engineers, 2009a). The standard deviations of the mean monthly streamflows and the mean annual streamflows also were calculated.

Interpolation of Low-Flow Statistics for Locations Between Streamflow-Gaging Stations

The Yellowstone River was divided into study reaches for the CES (fig. 3). For study reaches PC2, PC12, B2 and C10, the statistics calculated at the streamflow-gaging station that is located within or at the end of each reach represent the study-reach statistics. For the ungaged reaches on the Upper Yellowstone River main stem (48 reaches), low-flow frequency statistics were linearly interpolated between streamflow-gaging stations. Low-flow frequency statistics interpolation was extended downstream, from streamflow-gaging station 06214500 (Yellowstone River at Billings, Mont.) to streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Mont.) to supplement the results of Chase (2013). The Yellowstone River between Billings and Forsyth extends into the Lower Yellowstone River subbasin (fig. 2) and includes nine ungaged reaches in the Lower Yellowstone River subbasin. Monthly and annual streamflow characteristics are reported for the streamflow-gaging stations but are not reported for the ungaged reaches because some of these statistics (including maximum and minimum values with associated months of occurrence) cannot be accurately determined by interpolation.

To be consistent with Chase (2013), streamflow statistics for ungaged reaches were linearly interpolated on the basis of approximate drainage area at the downstream end of each ungaged reach relative to the drainage areas of the bracketing streamflow-gaging stations. In many cases, such as downstream from a relatively large tributary, changes in streamflow statistics between different locations on a river channel do not vary linearly with proportional changes in drainage area. Therefore, the interpolated statistics for reaches A18 and B1, [Clarks Fork Yellowstone River confluence to streamflow-gaging station 06214500 (Yellowstone River at Billings, Mont.)] and C1 through C9 [Bighorn River confluence to streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Mont.)], might not be as representative of actual conditions as for the rest of the reaches. In fact, at some locations a given streamflow statistic decreased between one streamflow-gaging station and the next downstream streamflow-gaging station. In those locations, interpolation on the basis of drainage areas resulted in unrealistically large decreases in the streamflow statistic in reaches containing a large tributary (such as the Bighorn River). Because this study was largely focused on calculation of streamflow statistics at gaging stations, and because streamflow data to improve interpolation are unavailable, the interpolated data are presented with those unrealistic decreases.

Drainage areas for locations at the downstream end of each study reach were estimated using digital elevation models (cell size 689 square meters) provided by the USACE (Douglas J. Clemetson, U.S. Army Corps of Engineers, written commun., 2009). For study reach A12, which includes the Stillwater River confluence, and for reach A17, which includes the Clarks Fork Yellowstone confluence, the drainage areas were estimated for a location just upstream from each confluence. In some instances, the drainage areas estimated for the streamflow-gaging stations using the digital elevation models were different (by as much as 1 percent of total contributing drainage area) than the drainage areas reported by the U.S. Geological Survey (2010), probably because of differences in the resolution of the elevation data and methods used to delineate the drainage area boundaries.

Streamflow Statistics for Unregulated and Regulated Conditions for Selected Locations on the Upper Yellowstone and Bighorn Rivers

Streamflow statistics for 1928–2002 were calculated only for unregulated conditions for two streamflow-gaging stations on the Upper Yellowstone River main stem; 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyo.) and 06191500 (Yellowstone River at Corwin Springs, Mont.). Streamflow statistics were calculated for unregulated and regulated conditions for the two other streamflow-gaging stations on the Upper Yellowstone River main stem; 06192500 (Yellowstone River near Livingston, Mont.), and 06214500 (Yellowstone River at Billings, Mont.), and for the Bighorn River streamflow gaging station 06294500 (Bighorn River above Tullock Creek near Bighorn, Mont.) in the Upper Yellowstone River subbasin. Additionally, to provide information relating to calculation of interpolated estimates at ungaged locations and supplement the results of Chase (2013), streamflow statistics were calculated for one streamflow-gaging station on the Lower Yellowstone River main stem; 06295000 (Yellowstone River at Forsyth, Mont.). Streamflow statistics for the six streamflow-gaging stations are presented in tables and figures contained in appendix 1. The tables and graphs summarize annual, seasonal, and monthly *n*-day low-flow frequency data; and maxima, minima, and mean monthly and annual streamflow data.

In addition, low-flow frequency data were interpolated for 48 ungaged locations between streamflow-gaging stations on the Upper Yellowstone River main stem, and for nine ungaged locations on the Lower Yellowstone River to supplement the results of Chase (2013). Interpolated annual *n*-day

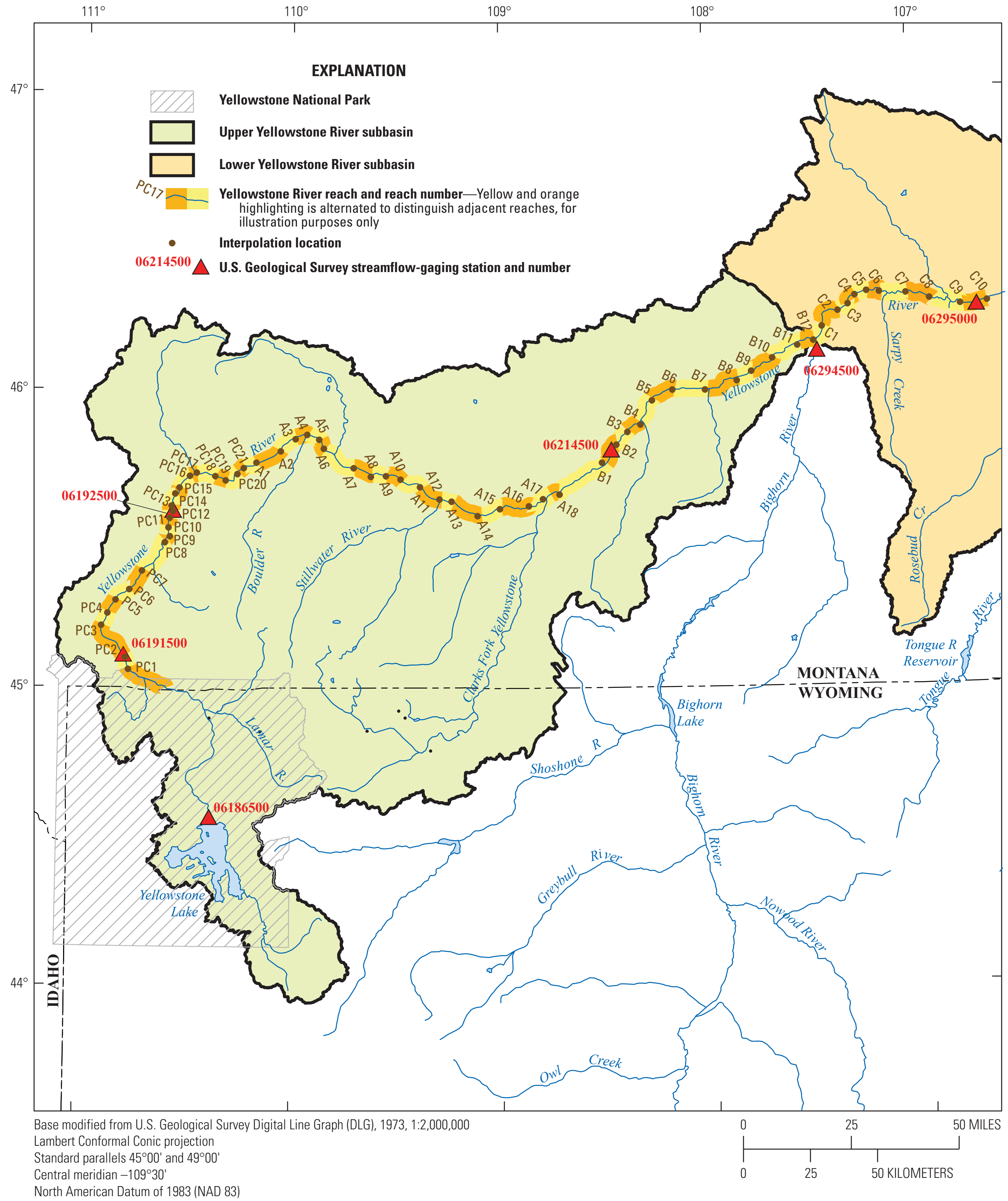


Figure 3. Location of selected reaches along the Yellowstone River, Montana (modified from Bryan Swindell, DTM Consulting, Inc., written commun., 2011).

low-flow frequency data for the 57 ungaged locations between streamflow-gaging stations, as well as calculated data for the 5 Yellowstone River streamflow-gaging stations used in the interpolations, are presented in appendix 2.

Summary

The Yellowstone River is one of the longest free-flowing rivers in the lower 48 states. The river supports a wide variety of agricultural, domestic, industrial, and recreational uses. Major floods in 1996 and 1997 intensified public debate about the effects of human activities on the Yellowstone River. In 1999, the Yellowstone River Conservation District Council (YRCDC) was formed to address conservation issues on the river. The YRCDC partnered with the U.S. Army Corps of Engineers (USACE) to carry out a cumulative effects study (CES) on the main stem of the Yellowstone River. The CES is intended to provide a basis for future management decisions in the watershed. Streamflow statistics, such as flow-frequency data calculated for unregulated and regulated streamflow conditions, are a necessary component of the cumulative effects study.

Streamflow statistics for unregulated and regulated conditions for the Yellowstone River Basin have been calculated by the U.S. Geological Survey (USGS) and by the USACE. The USACE calculated peak-flow data, high-flow frequency data, and flow-duration data for unregulated and regulated streamflow conditions for the Yellowstone River main stem in the Upper Yellowstone River subbasin and for the Bighorn River. The USGS calculated peak-flow data, high-flow frequency data, low-flow frequency data, and flow-duration data for unregulated and regulated streamflow conditions for the Yellowstone River main stem in the Lower Yellowstone River subbasin and for the Tongue and Powder Rivers.

To supplement the previous statistical summaries, the USGS, in cooperation with the YRCDC and the USACE, calculated low-flow frequency data and monthly and annual statistics for the Upper Yellowstone and Bighorn Rivers for the 1928–2002 study period; these data are presented in this report. Also included in this report are low-flow frequency data, interpolated for 48 ungaged locations between streamflow-gaging stations on the Upper Yellowstone River, and for 9 ungaged locations on the Lower Yellowstone River.

For the Bighorn River and for the three Yellowstone River sites downstream from Corwin Springs, streamflow datasets were synthesized for two hypothetical streamflow conditions: unregulated and regulated. Unregulated streamflows were estimated by adding historic depletions estimated by the Bureau of Reclamation to the observed streamflows (or to the synthesized streamflows for periods of missing records). Regulated streamflows were estimated by subtracting the 2002-level depletions from the unregulated streamflows. These datasets are more homogenous than the observed streamflow datasets for the sites where streamflows are affected by water-resources development. Data homogeneity is an important criterion for the procedures used in the statistical analyses.

Because of minimal effects from regulation and depletion, only unregulated streamflows were analyzed for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyo.) and streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Mont.), which are the two most upstream sites on the Yellowstone River. For both streamflow-gaging stations, the maximum difference between unregulated and regulated flows was less than 2 cubic feet per second, which is less than 1 percent of the lowest unregulated flow during the study period (380 cubic feet per second).

Low-flow frequency data were developed from an annual series of lowest daily streamflows for specified *n*-day consecutive periods within the calendar year. Monthly and annual streamflow characteristics also were calculated for the unregulated and regulated streamflows.

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Glossary

annual mean streamflow Arithmetic mean of all daily mean streamflows for a single specified year.

annual precipitation Total precipitation for a single specified year.

daily mean streamflow Arithmetic mean streamflow for a single specified day.

mean annual streamflow Arithmetic mean of all annual mean streamflows for the period of record or a specific period of multiple years.

mean annual precipitation Arithmetic mean of all annual precipitation amounts for the period of record or a specific period of multiple years.

mean monthly streamflow Arithmetic mean of all monthly mean streamflows for a specified month for the period of record or for a specific period of multiple years.

monthly mean streamflow Arithmetic mean of all daily mean streamflows for a single specified month in a single specified year.

monthly mean temperature Arithmetic mean of all daily mean temperatures for a single specified month in a single specified year.

Appendixes

Streamflow statistics for selected streamflow-gaging stations (appendix 1) are included as part of this report. Appendix 2, presented in Excel spreadsheets, contains information about locations and drainage areas for selected streamflow-gaging stations and reach locations on the Yellowstone River, Montana and Wyoming. Appendix 2 also contains annual *n*-day low-flow frequency data for unregulated and regulated streamflow conditions for selected streamflow-gaging stations and reach locations on the Yellowstone River, Montana and Wyoming. The excel files are named *sir2014-5155_APP_2.1_loc_and_da.xlsx and sir2014-5155_APP_2.2_lowflowfreq.xlsx*. Locations of the streamflow-gaging stations and reach locations are shown on figures 2 and 3 (main report).

Appendix 1. Statistics for Unregulated and Regulated Streamflow Conditions for Selected Streamflow-Gaging Stations on the Upper Yellowstone and Bighorn Rivers, Montana and Wyoming, 1928–2002

Appendix 1 contains tables and figures showing statistics for six selected streamflow-gaging stations. Locations of the streamflow-gaging stations are shown in figure 2 (main report). Data in tables 1-6-1 and 1-6-2 and figures 1-6-1 through 1-6-17 are from Chase (2013).

Appendix 1–1. Statistics for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming)

Table 1–1–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Unregulated: Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	325	227	184	152	143	121	103
30	348	247	200	165	156	131	111
Winter (January–March)							
7	342	238	192	158	149	126	107
30	355	249	201	167	157	132	113
Spring (April–June)							
7	516	389	318	261	245	202	167
30	552	439	376	324	310	269	235
Summer (July–September)							
7	985	769	665	586	564	504	453
30	1,190	912	783	685	658	584	522
Fall (October–December)							
7	412	317	274	242	234	210	191
30	458	355	307	272	262	235	212
Monthly							
7 (January)	360	259	214	182	173	150	132
7 (February)	352	245	197	163	153	129	109
7 (March)	409	285	226	181	170	138	113
7 (April)	516	389	318	261	245	202	167
7 (May)	654	538	488	452	442	415	393
7 (June)	2,430	1,780	1,510	1,310	1,260	1,120	1,010
7 (July)	3,180	2,290	1,890	1,590	1,510	1,300	1,130
7 (August)	1,630	1,220	1,040	898	860	758	674
7 (September)	985	769	665	586	564	504	453
7 (October)	691	541	471	417	402	362	328
7 (November)	532	416	363	322	311	280	255
7 (December)	412	317	274	242	234	210	191

Table 1–1–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second]

Period	Unregulated: Streamflow, in ft^3/s, or year, for indicated streamflow characteristic					
	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	778	1951	243	1989	481	136
February	699	1998	165	1937	420	131
March	736	1986	140	1935	456	130
April	874	1972	200	1937	563	122
May	3,200	1928	692	1953	1,410	485
June	7,470	1997	1,580	1977	3,480	1,060
July	9,140	1997	1,650	1934	4,770	1,560
August	6,750	1982	1,290	1934	3,890	1,270
September	4,240	1982	838	1934	2,280	738
October	1,950	1951	559	1934	1,240	343
November	1,260	1950	335	1988	804	210
December	1,000	1950	280	1988	607	160
Annual	2,290	1997	659	1934	1,330	324

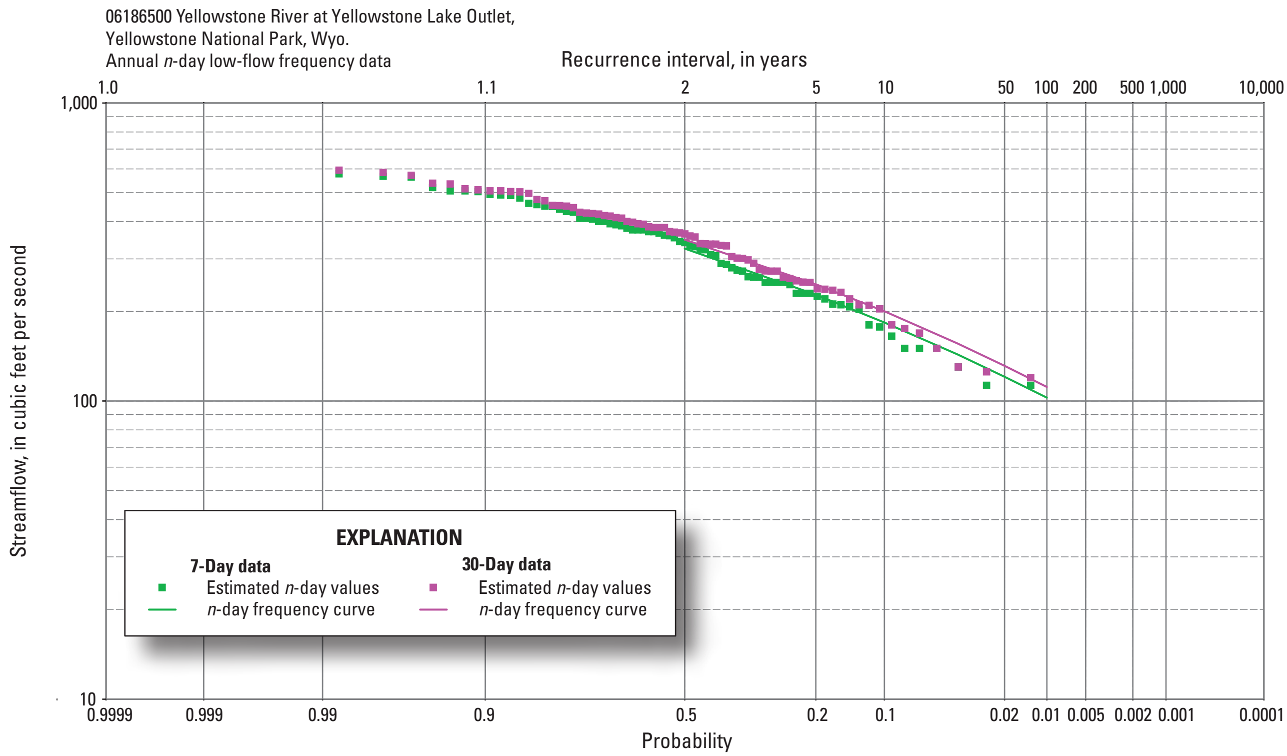


Figure 1–1–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

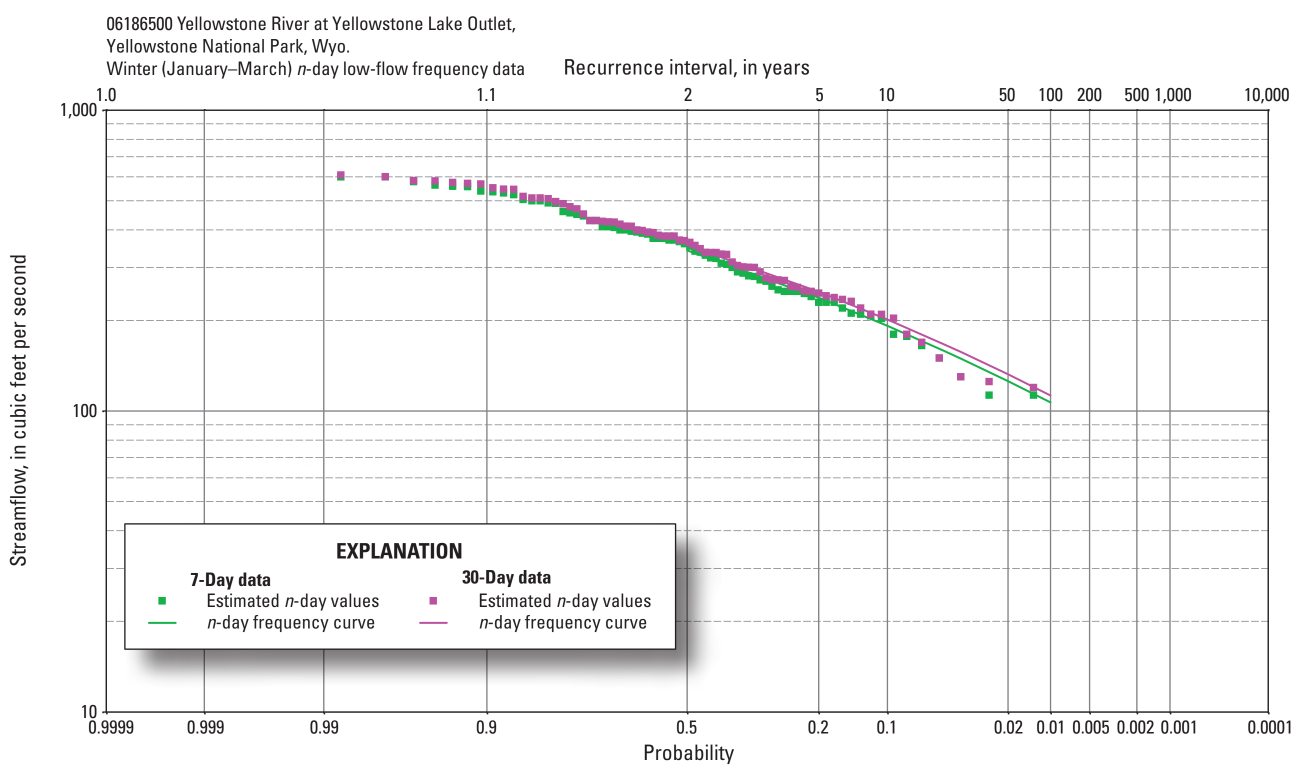


Figure 1–1–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

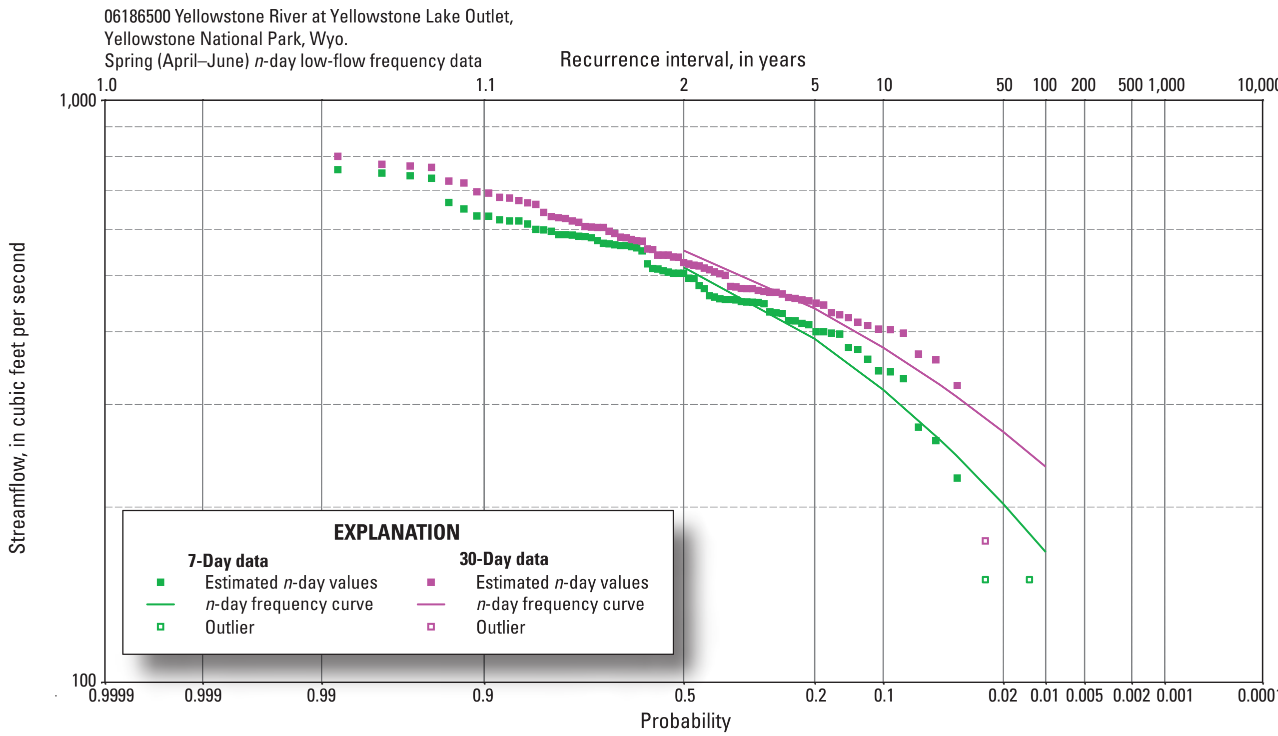


Figure 1–1–3. Spring (April–June) n-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

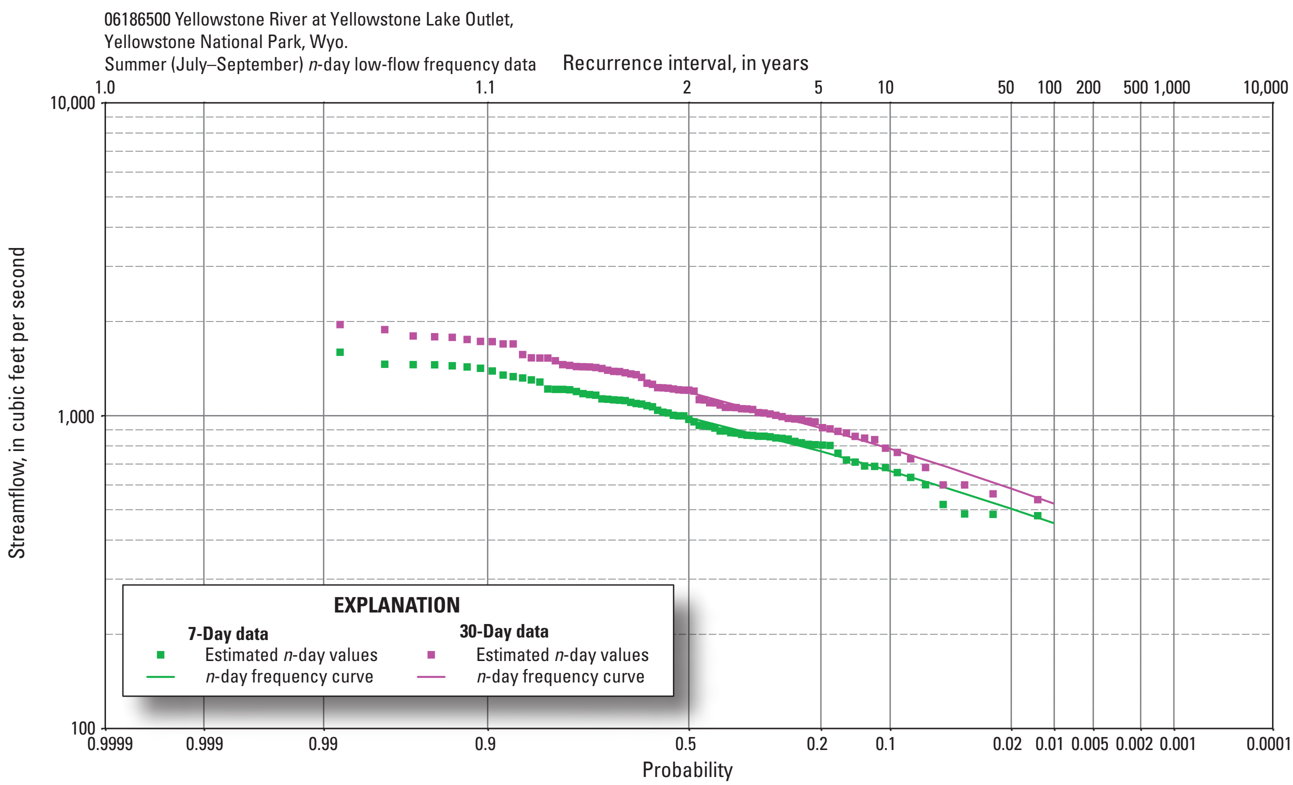


Figure 1–1–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

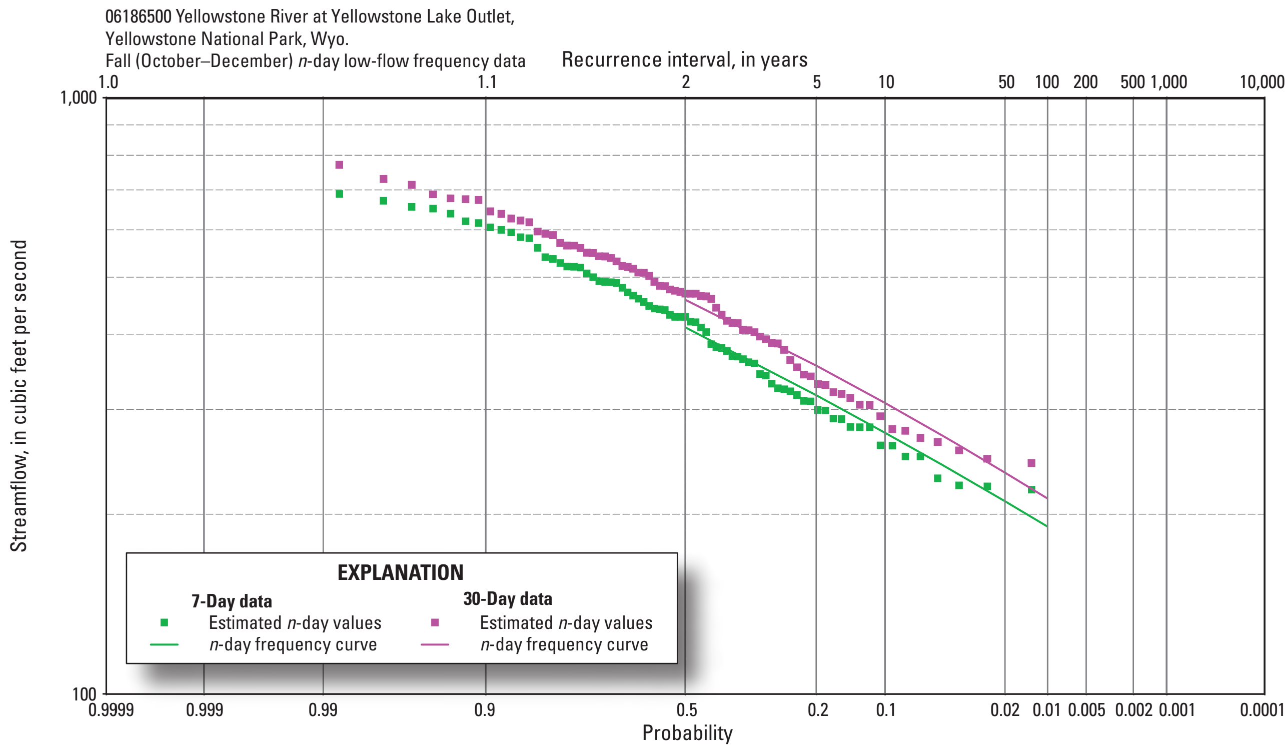


Figure 1–1–5. Fall (October–December) *n*-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

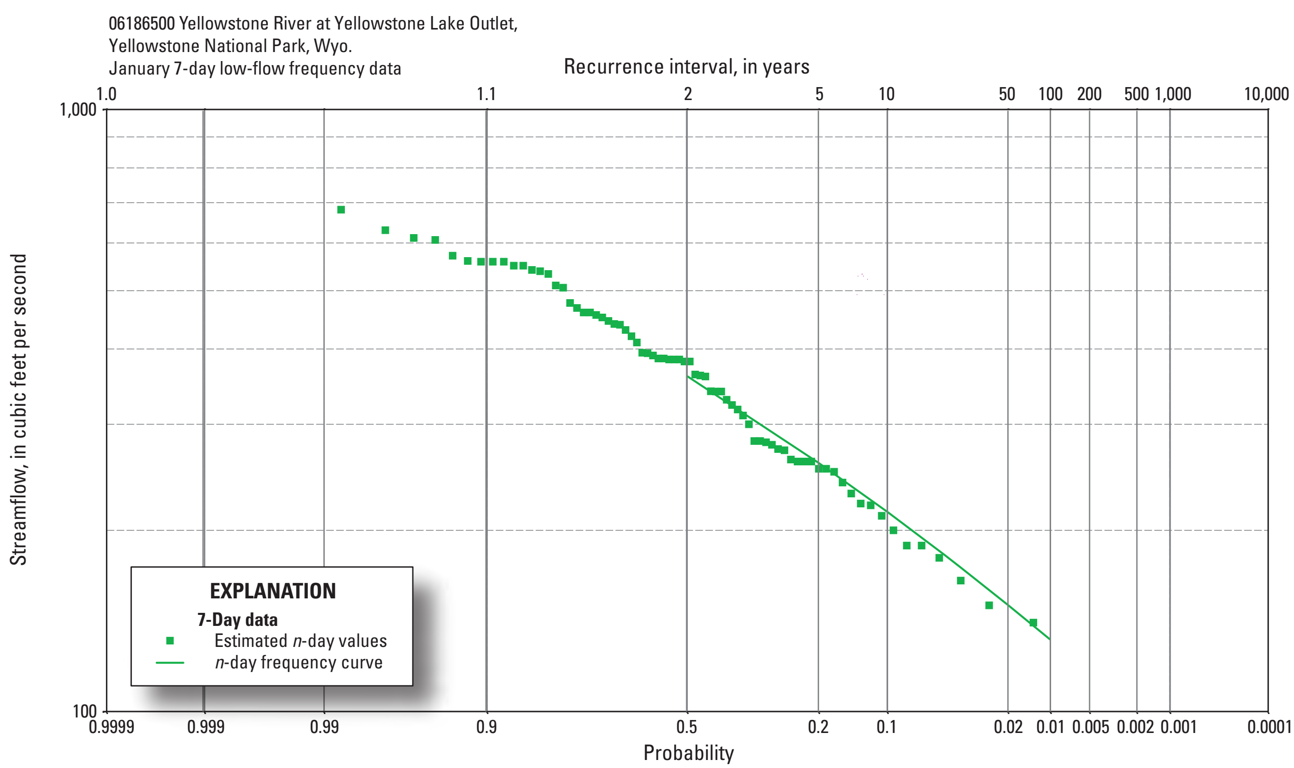


Figure 1–1–6. January 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

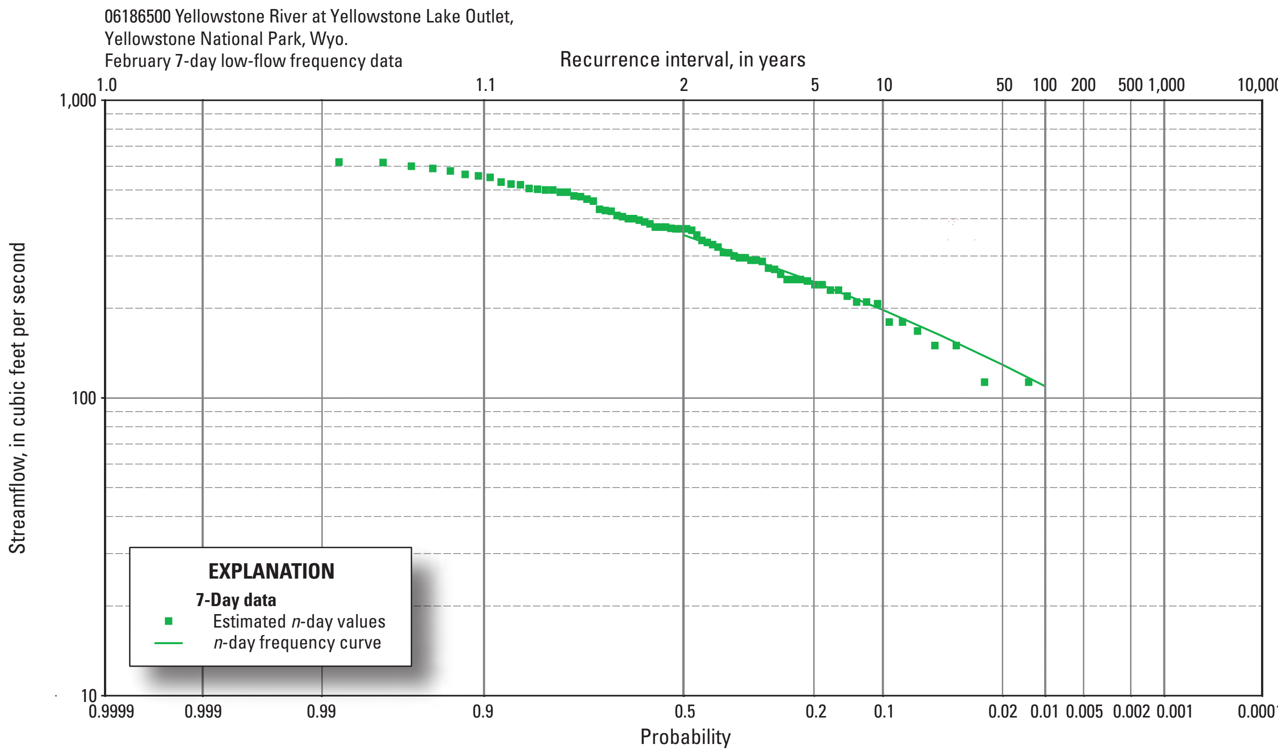


Figure 1–1–7. February 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

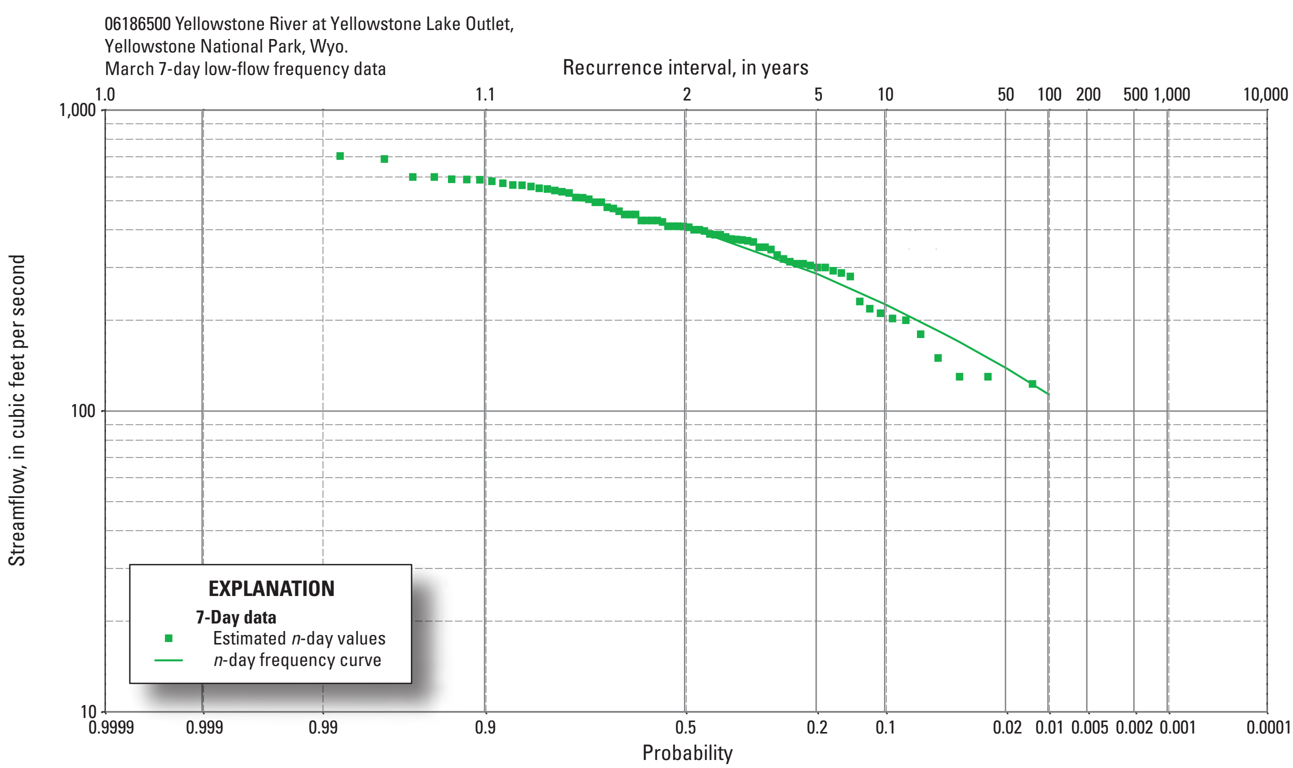


Figure 1–1–8. March 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

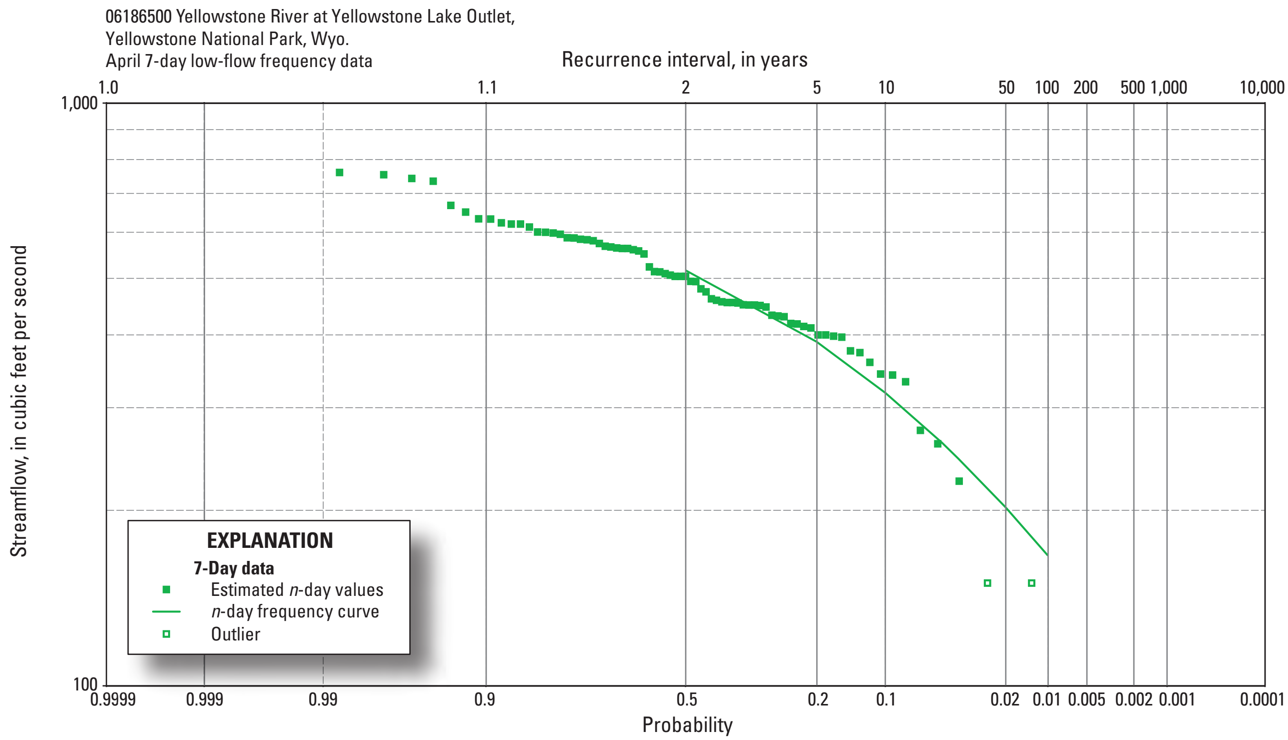


Figure 1–1–9. April 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

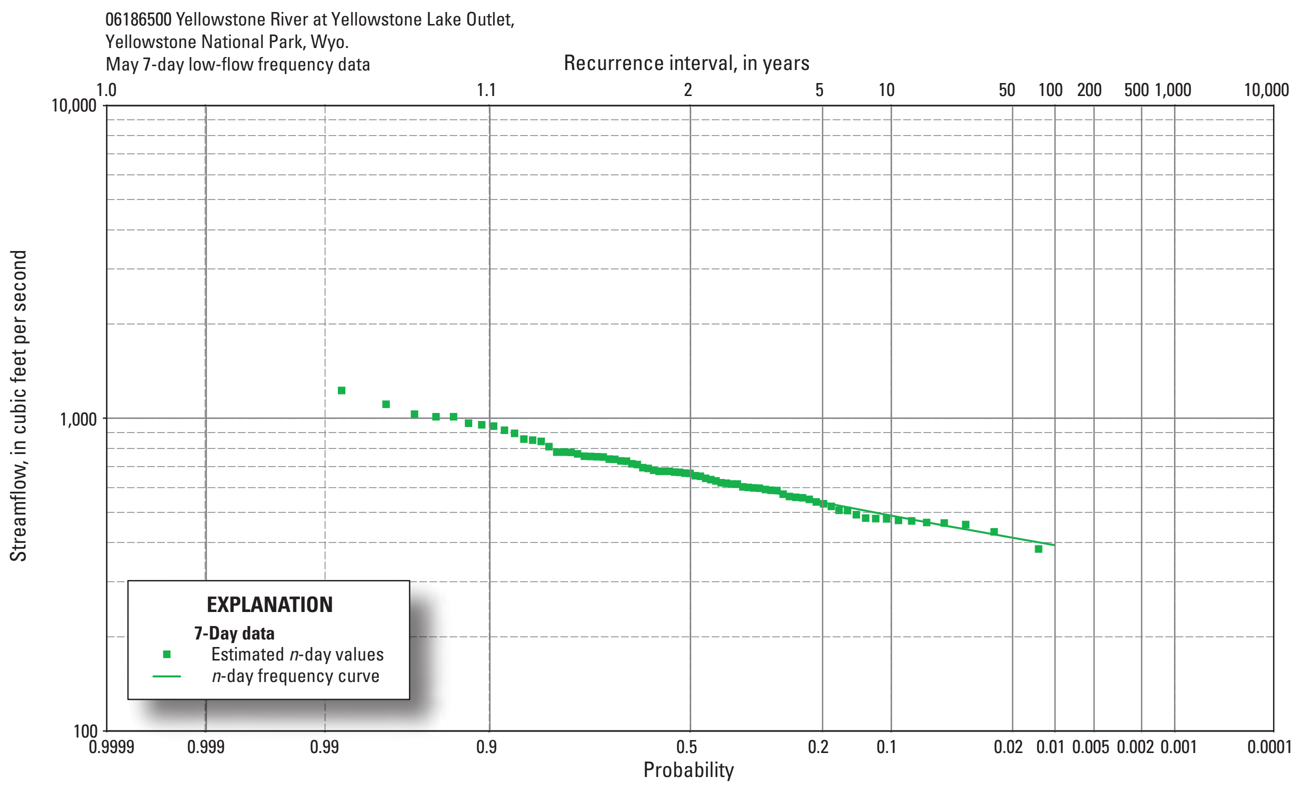


Figure 1–1–10. May 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

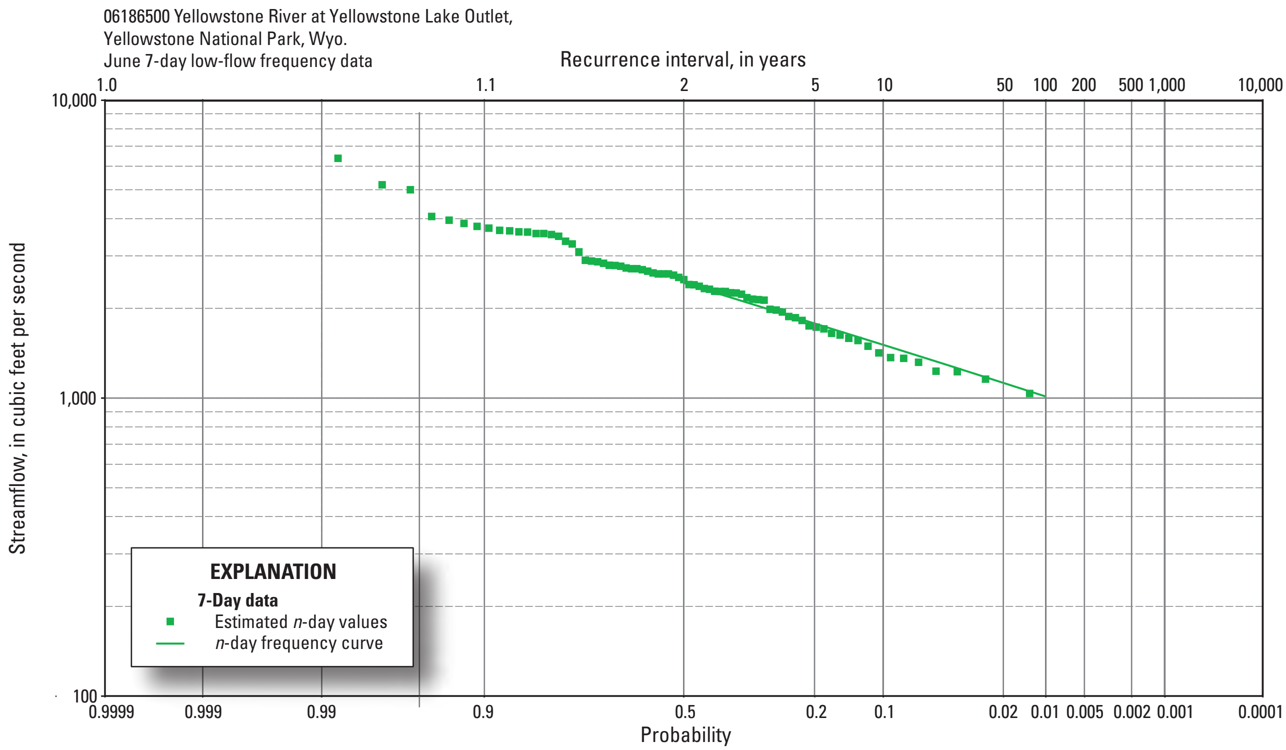


Figure 1–1–11. June 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

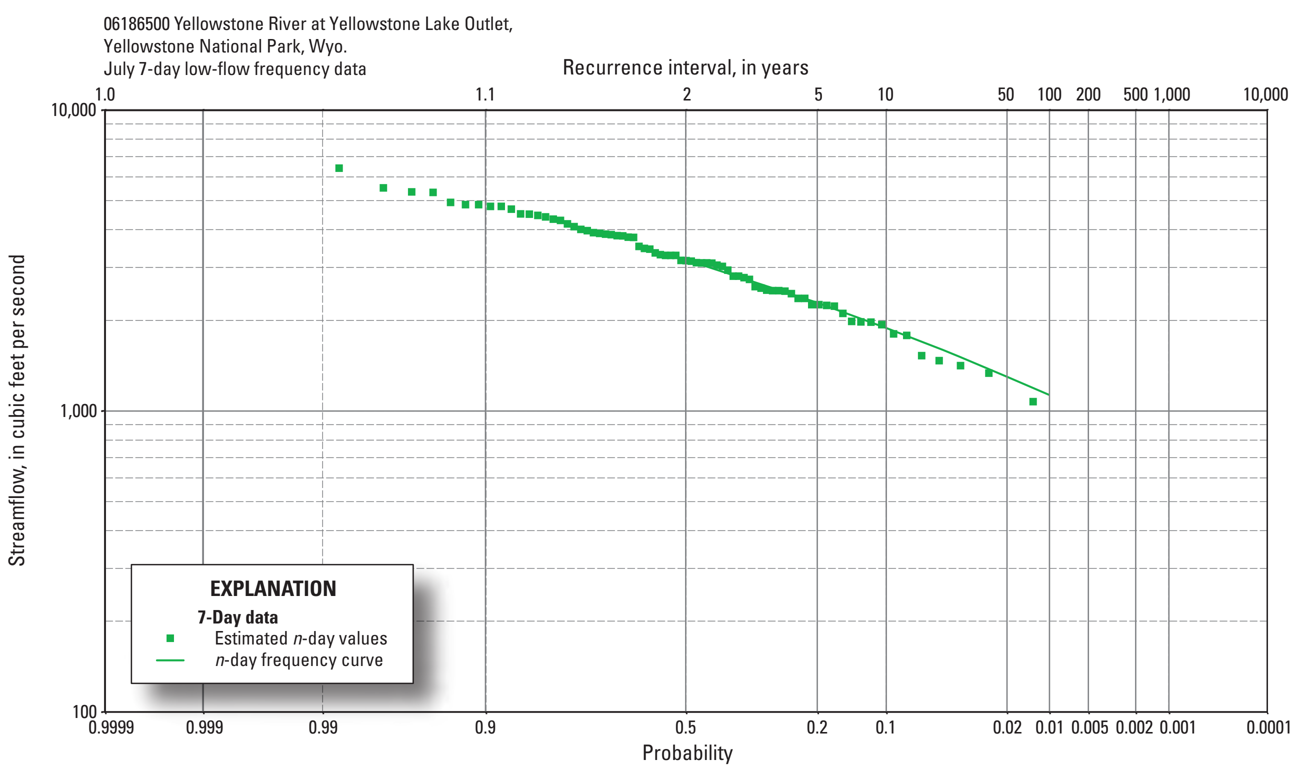


Figure 1–1–12. July 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

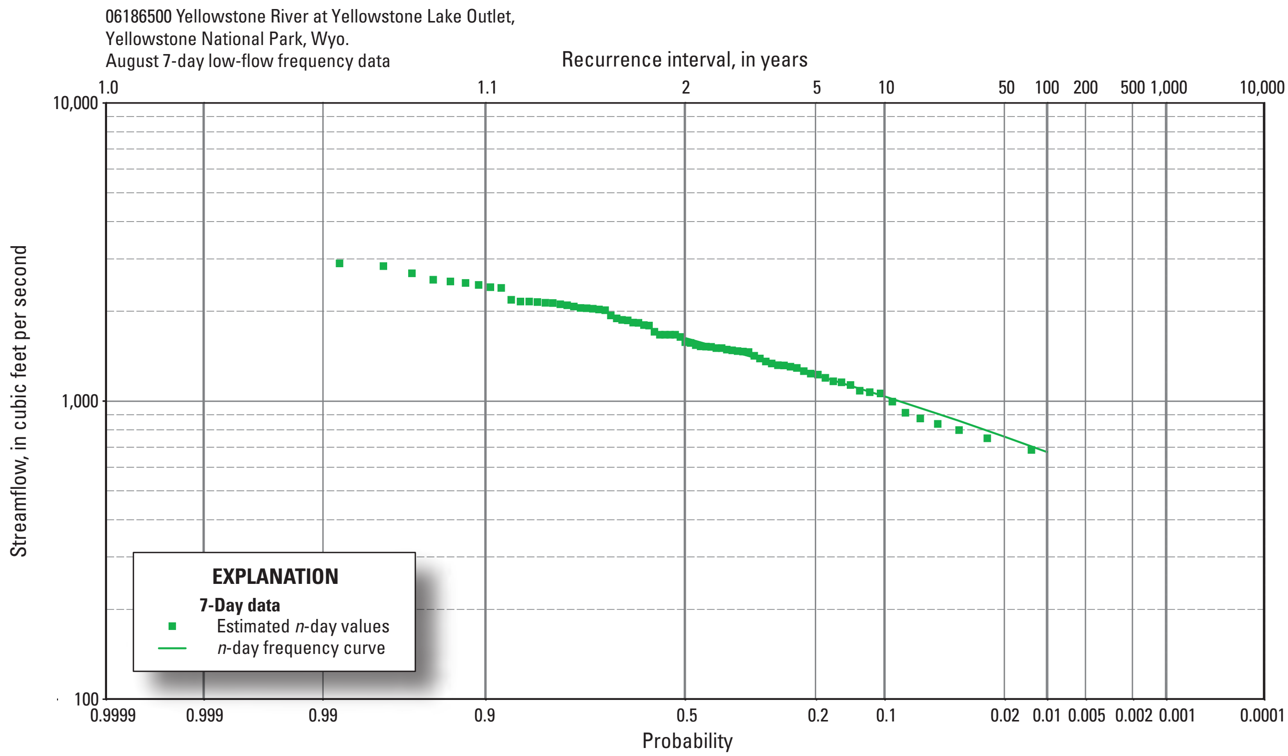


Figure 1–1–13. August 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

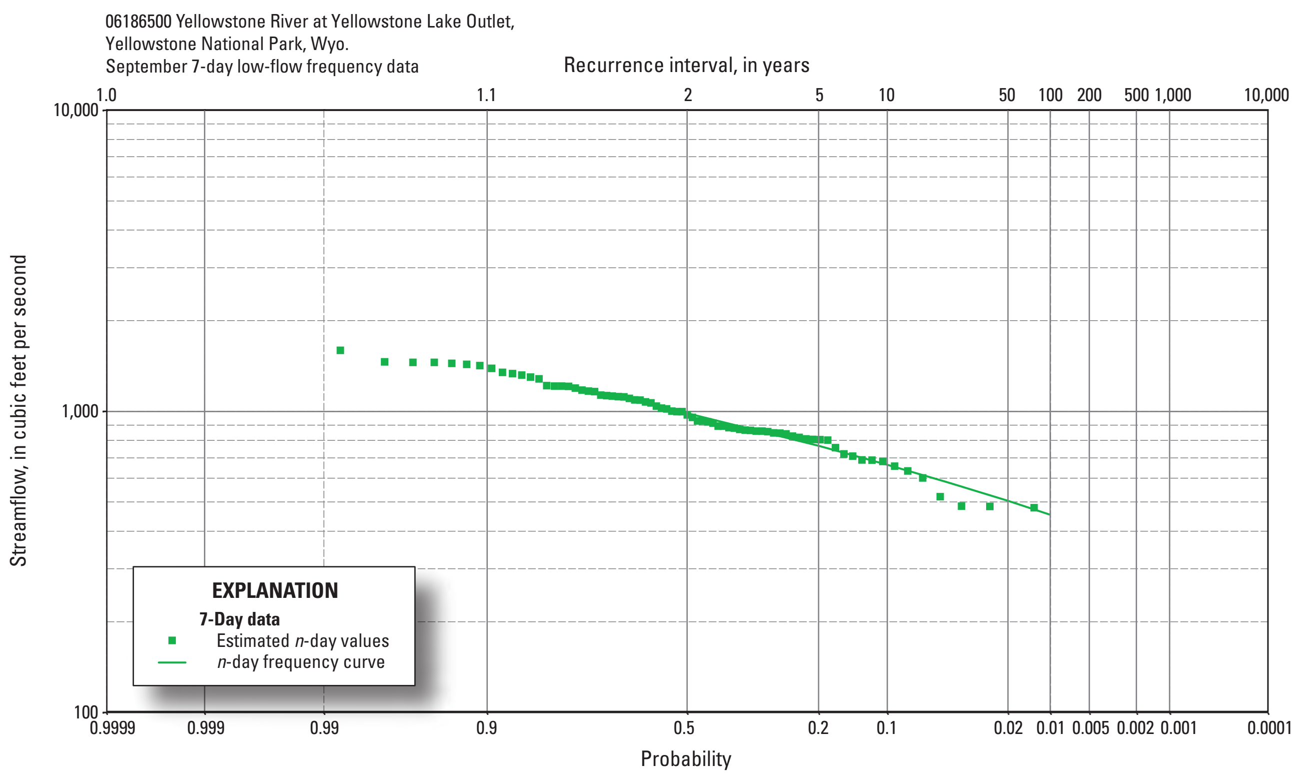


Figure 1–1–14. September 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

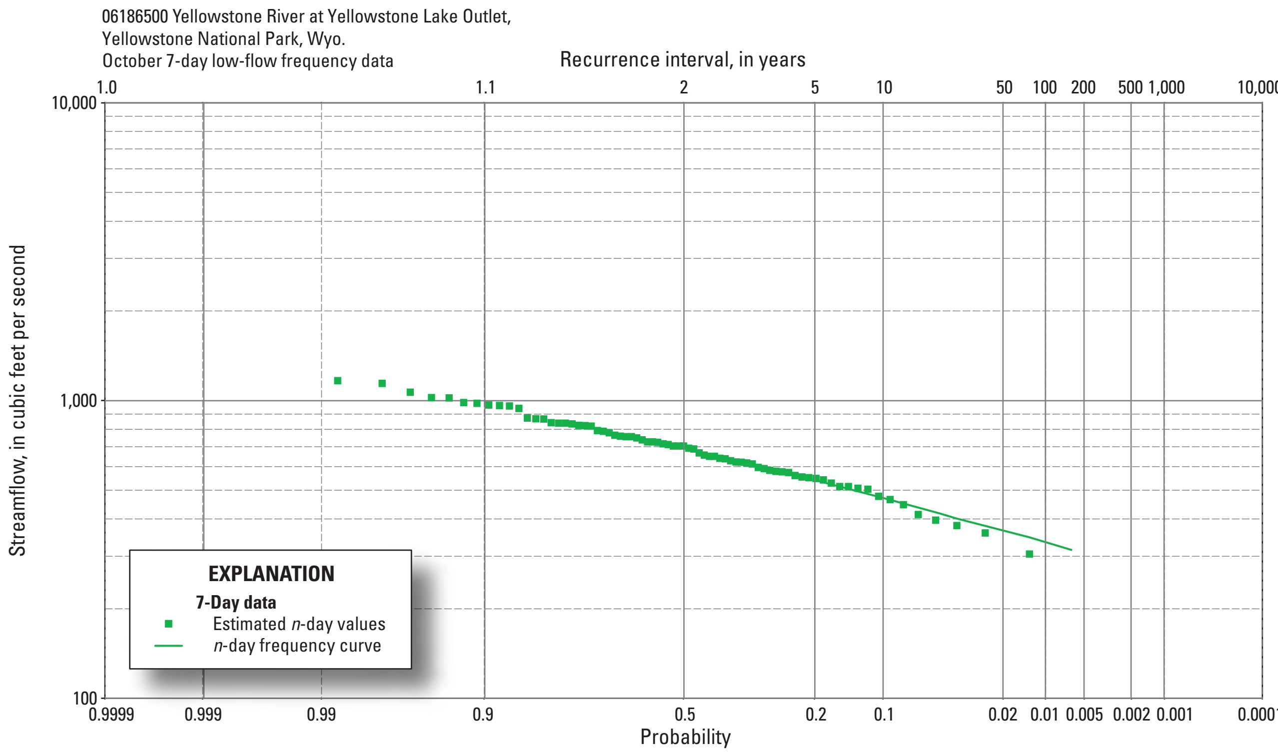


Figure 1–1–15. October 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

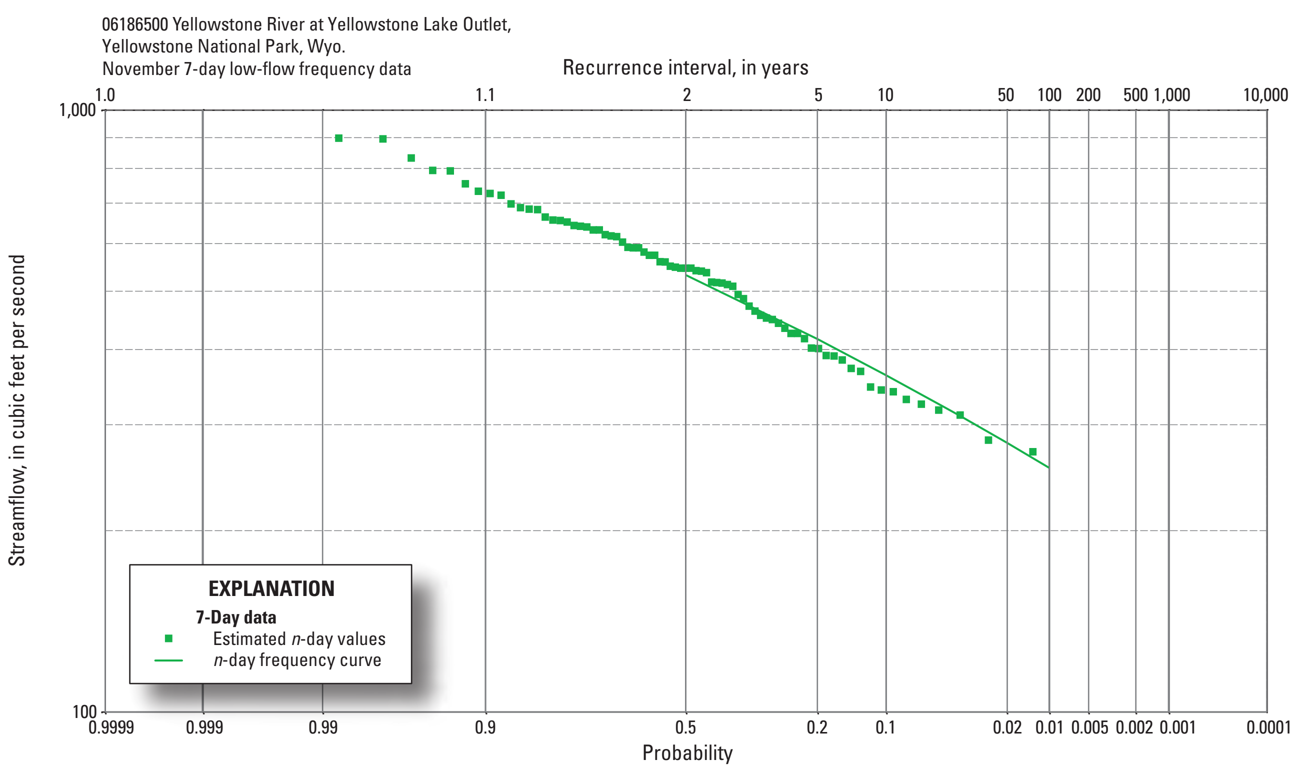


Figure 1–1–16. November 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

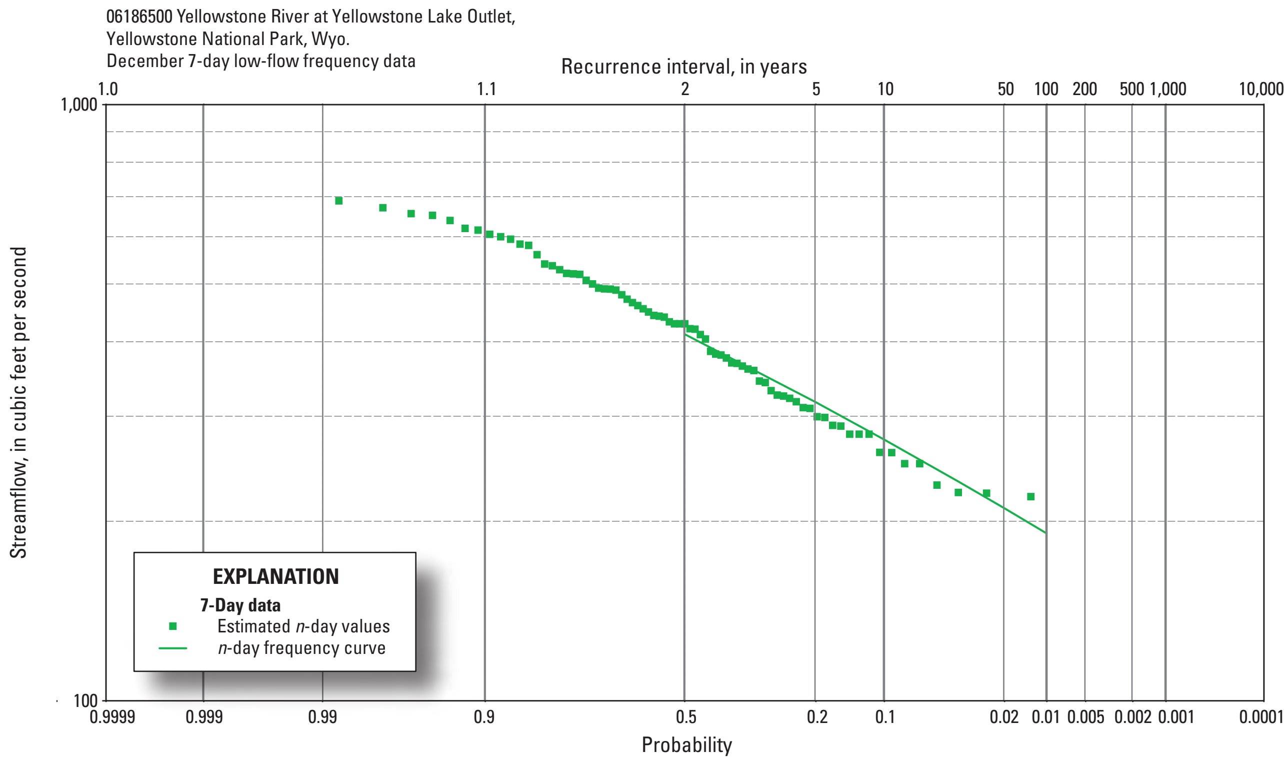


Figure 1–1–17. December 7-day low-flow frequency data for streamflow-gaging station 06186500 (Yellowstone River at Yellowstone Lake Outlet, Yellowstone National Park, Wyoming) for unregulated streamflow conditions, 1928–2002.

Appendix 1–2. Statistics for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana)

Table 1–2–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Unregulated: Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	675	553	497	454	442	409	381
30	739	607	545	497	484	448	417
Winter (January–March)							
7	695	563	504	459	447	414	386
30	742	605	543	496	483	447	418
Spring (April–June)							
7	1,030	829	733	657	636	578	528
30	1,440	1,090	947	847	821	751	694
Summer (July–September)							
7	1,610	1,290	1,140	1,030	1,000	916	845
30	1,860	1,470	1,290	1,150	1,120	1,010	925
Fall (October–December)							
7	799	672	613	567	555	520	490
30	899	759	694	645	632	594	562
Monthly							
7 (January)	727	589	526	479	466	431	401
7 (February)	738	597	532	482	469	431	400
7 (March)	803	654	581	524	508	464	426
7 (April)	1,030	829	733	657	636	578	528
7 (May)	2,600	1,740	1,430	1,230	1,180	1,050	942
7 (June)	8,480	6,250	5,260	4,520	4,310	3,770	3,330
7 (July)	4,420	3,190	2,660	2,270	2,170	1,890	1,670
7 (August)	2,360	1,810	1,560	1,380	1,330	1,190	1,080
7 (September)	1,610	1,290	1,140	1,030	1,000	916	845
7 (October)	1,280	1,040	932	851	829	768	717
7 (November)	1,010	833	756	699	683	640	604
7 (December)	802	674	614	568	555	519	489

Table 1–2–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second]

	Unregulated					
	Streamflow, in ft^3/s, or year, for indicated streamflow characteristic					
Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	1,360	1997	448	1937	814	196
February	1,340	1997	411	1937	806	194
March	1,380	1997	412	1937	889	184
April	3,540	1990	576	1937	1,550	570
May	13,600	1928	2,570	1975	6,320	2,060
June	22,500	1997	4,250	1934	11,400	3,580
July	13,300	1982	2,100	1934	6,630	2,600
August	5,690	1982	1,390	1934	3,110	970
September	3,210	1968	938	1988	1,900	493
October	2,430	1972	781	1988	1,460	370
November	1,960	1983	702	1988	1,150	263
December	1,420	1983	551	1936	922	187
Annual	5,250	1997	1,872	1934	3,080	698

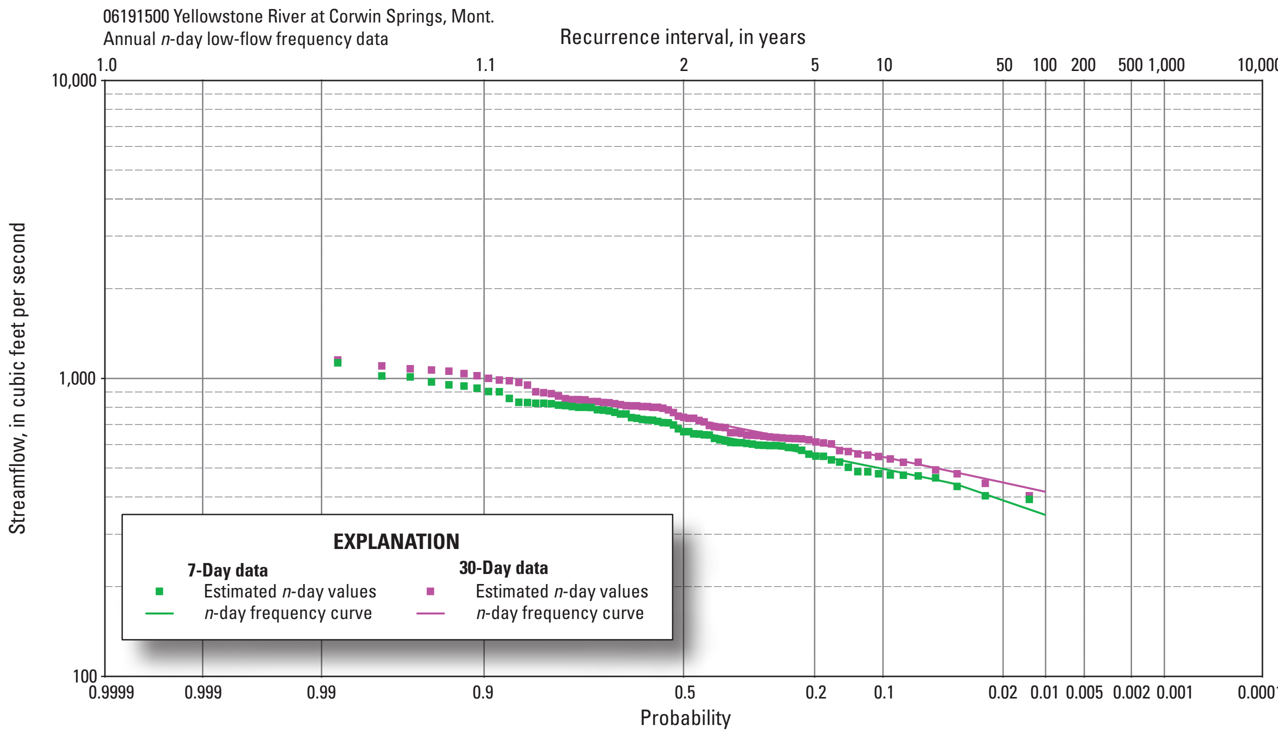


Figure 1–2–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

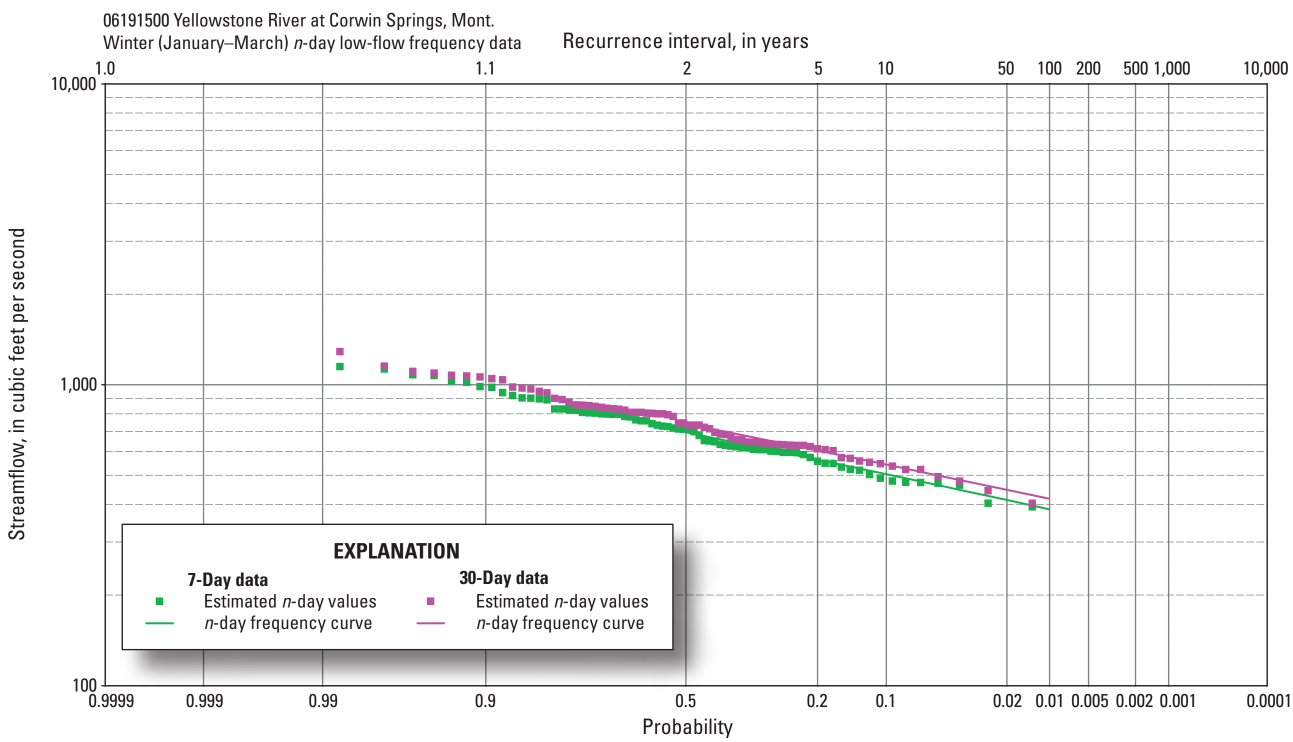


Figure 1–2–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

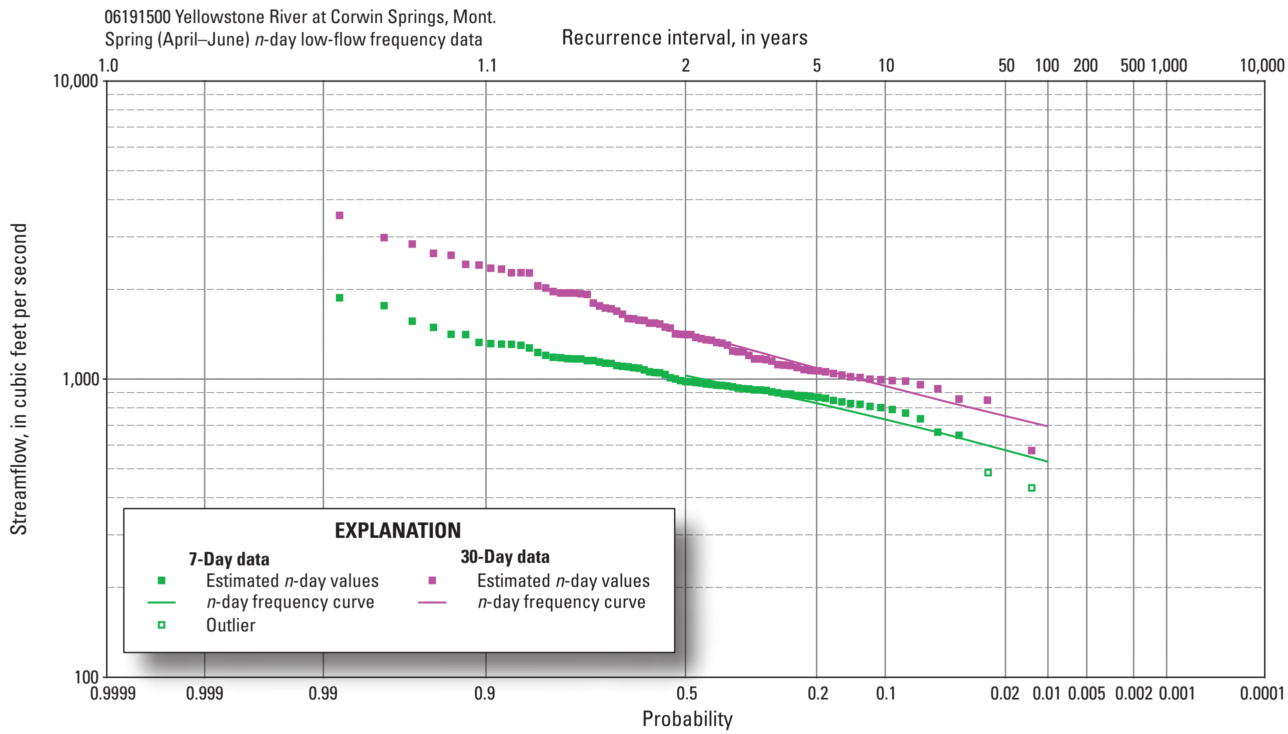


Figure 1–2–3. Spring (April–June) *n*-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

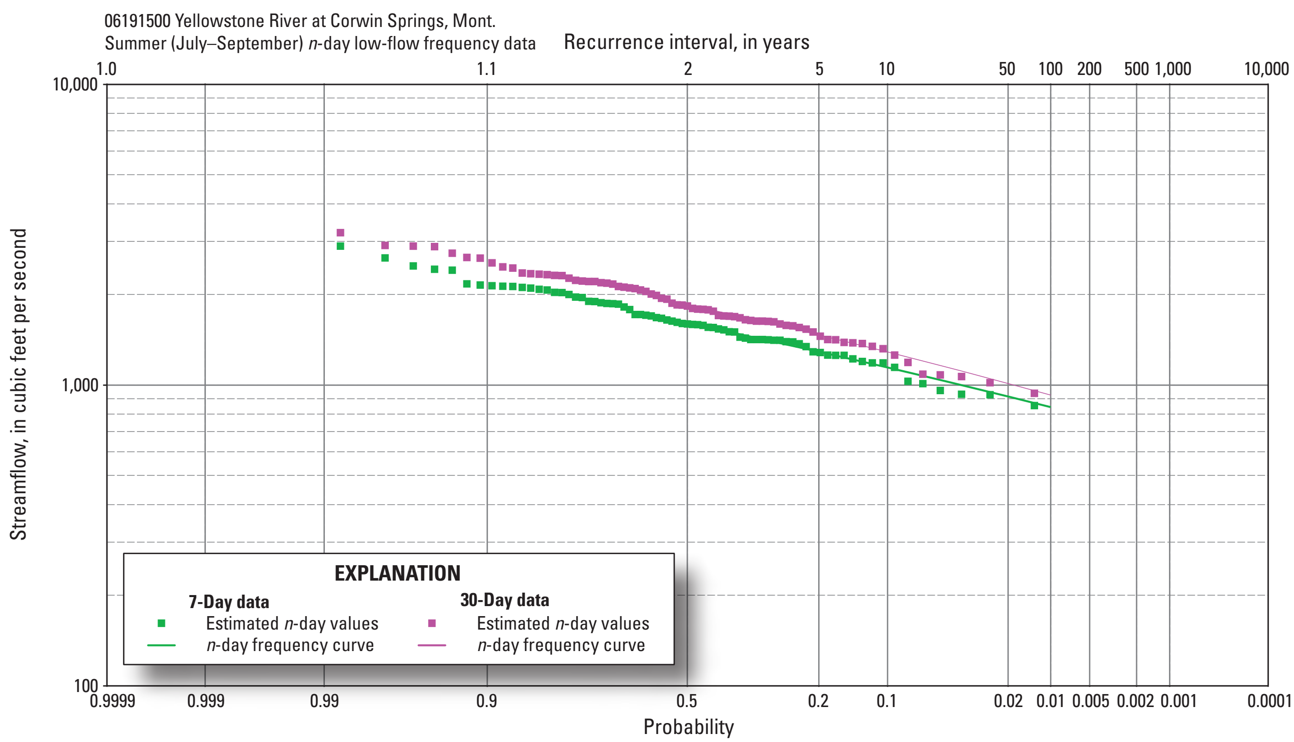


Figure 1–2–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

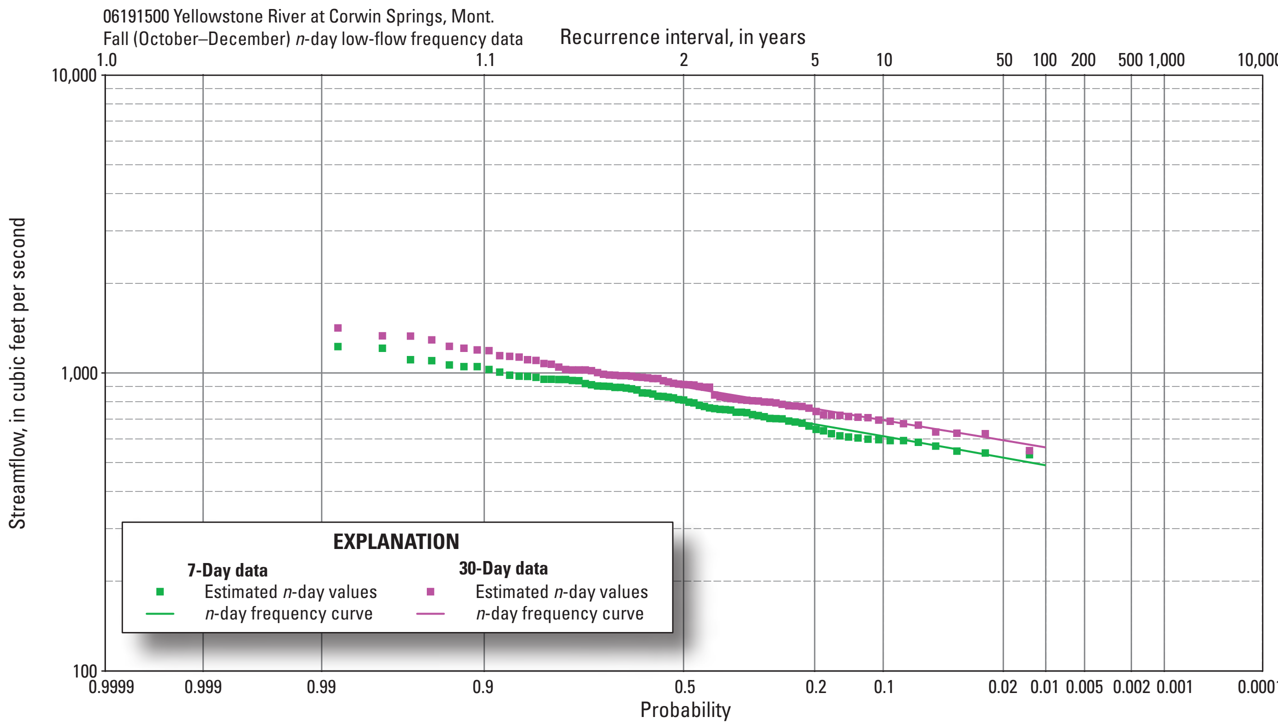


Figure 1–2–5. Fall (October–December) 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

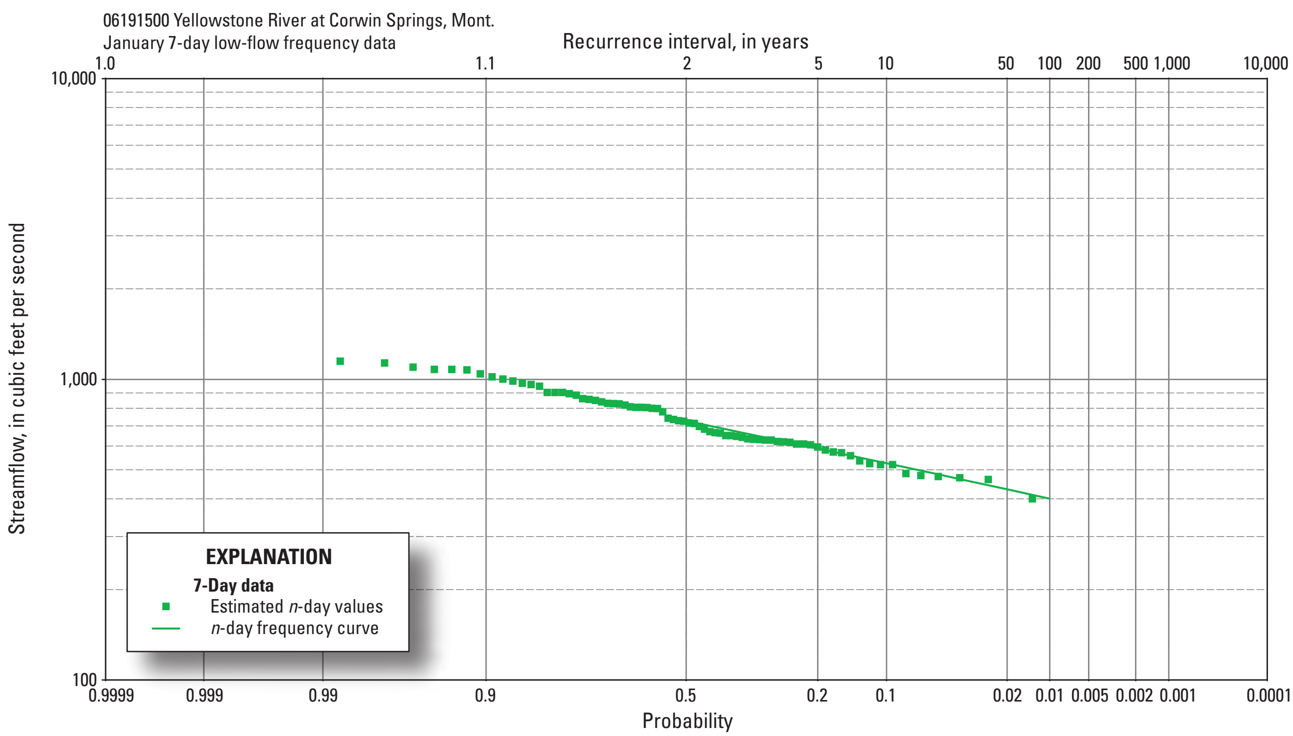


Figure 1–2–6. January 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

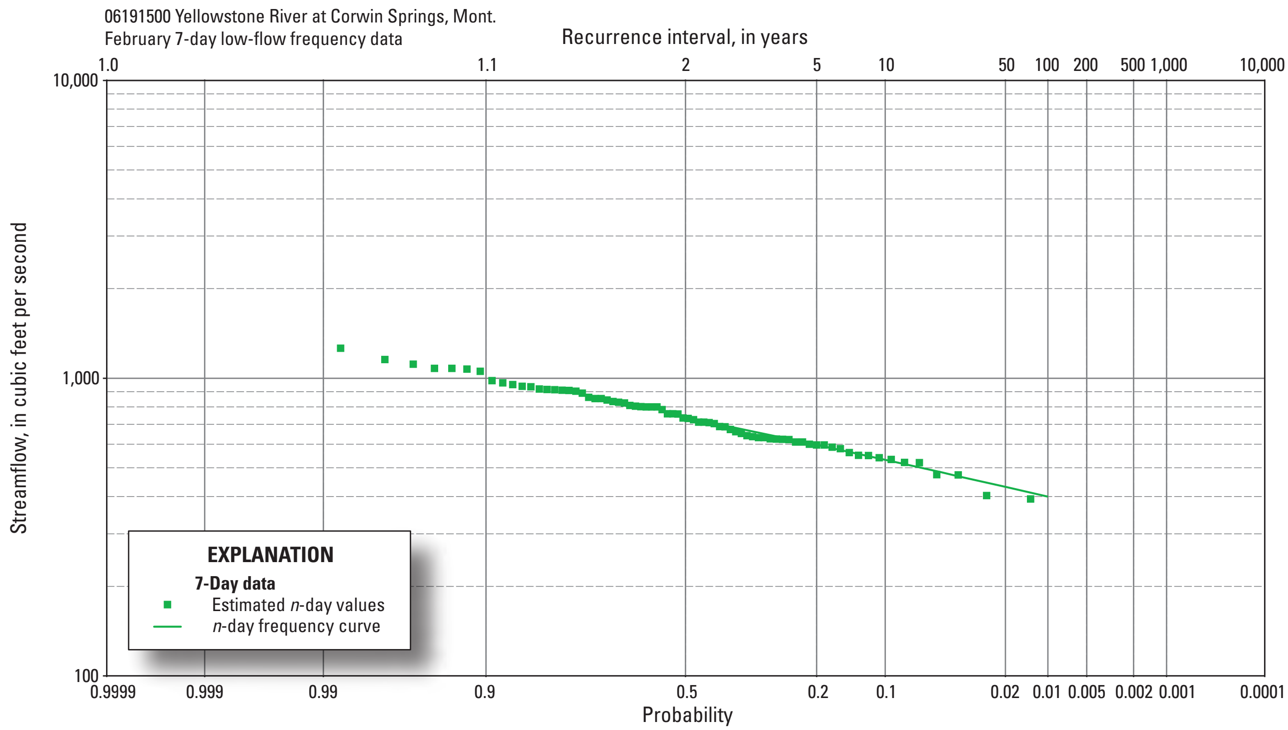


Figure 1–2–7. February 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

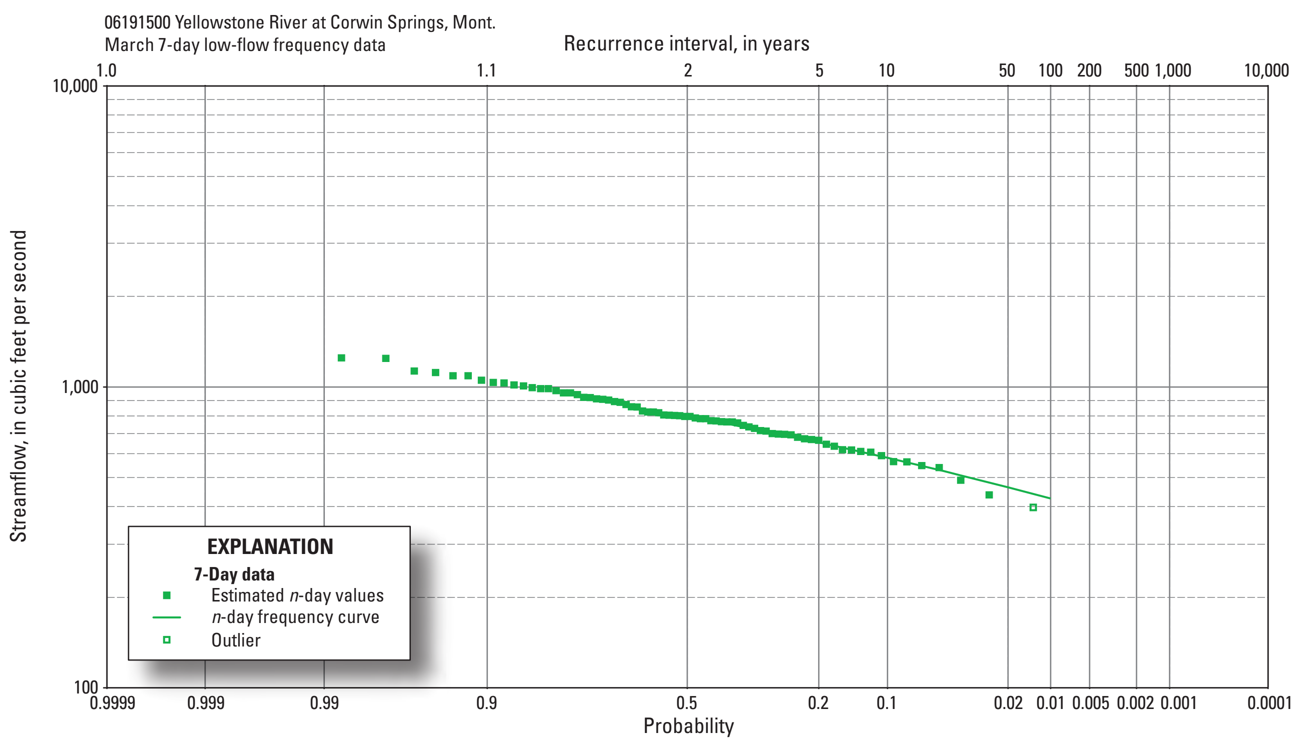


Figure 1–2–8. March 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

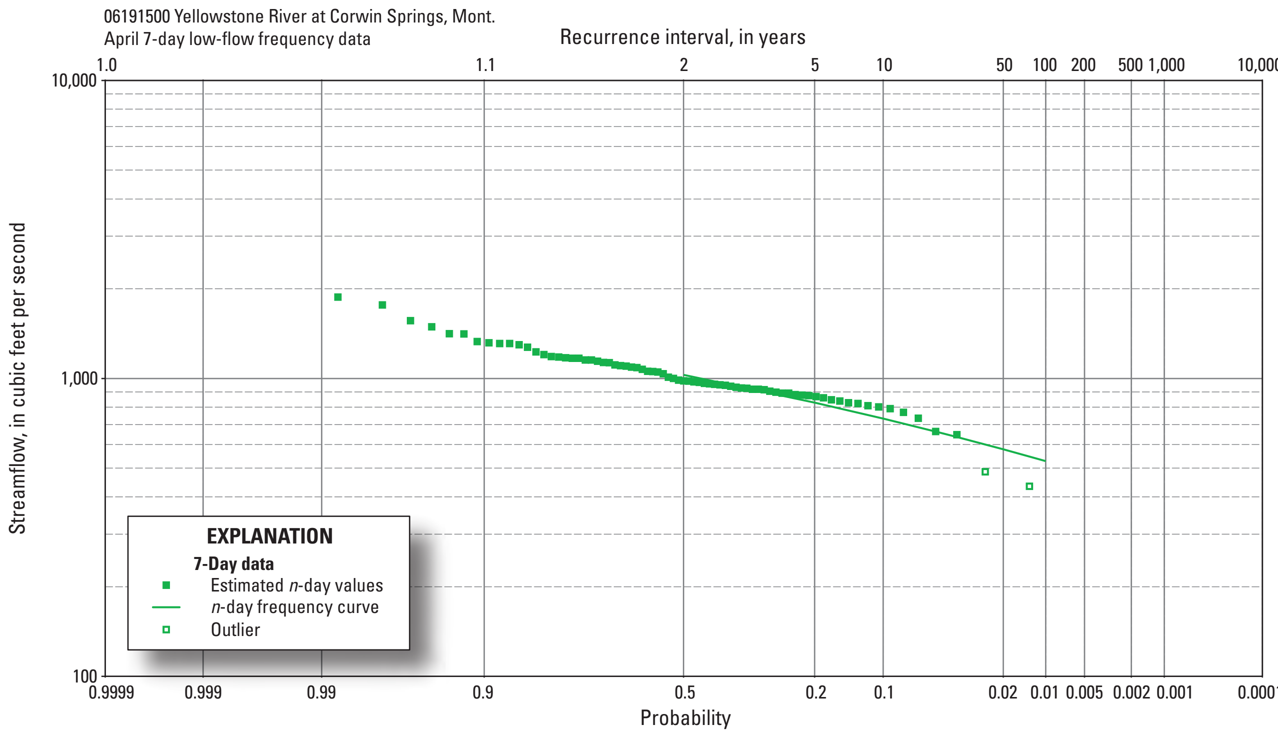


Figure 1–2–9. April 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

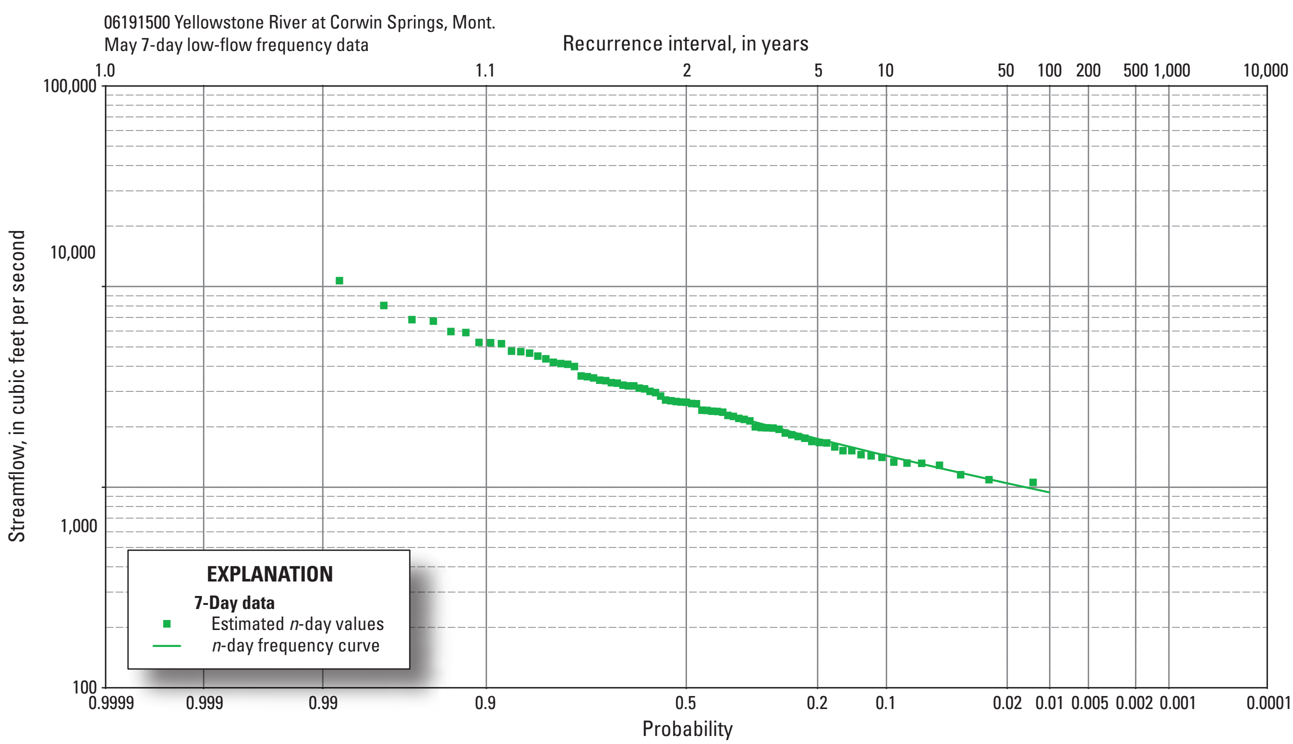


Figure 1–2–10. May 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

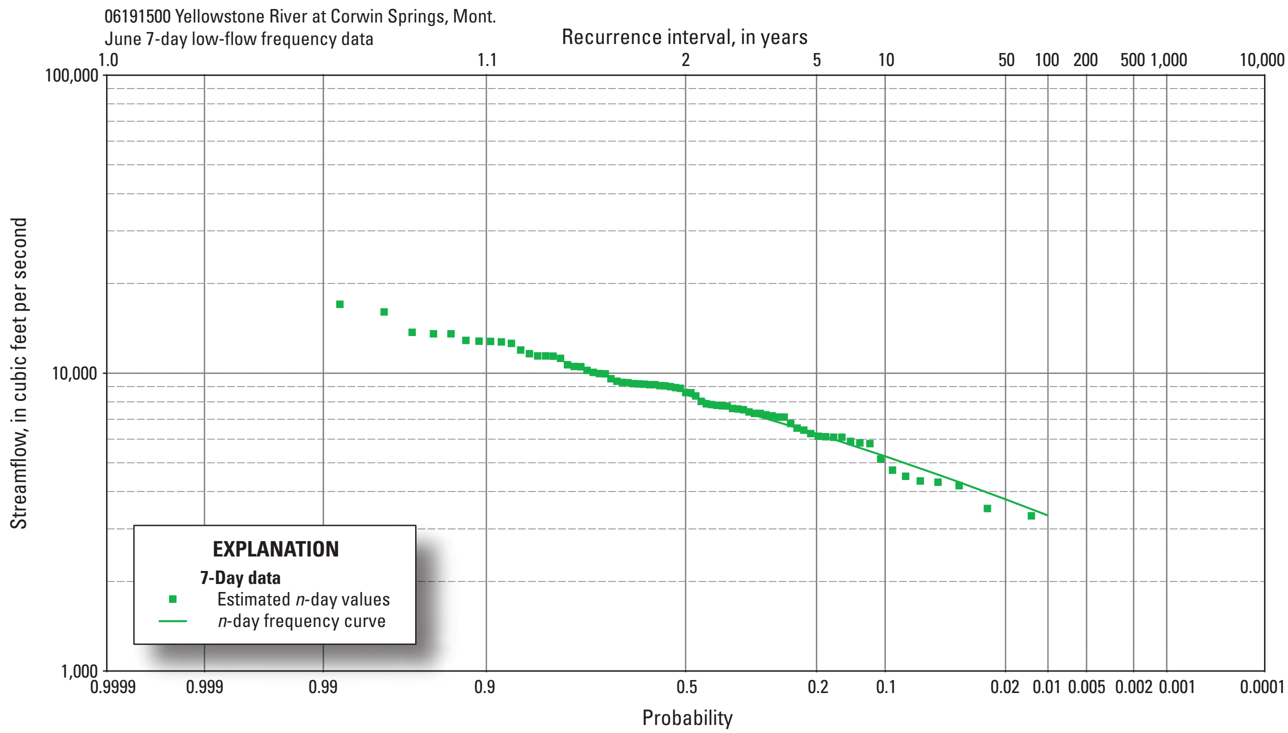


Figure 1–2–11. June 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

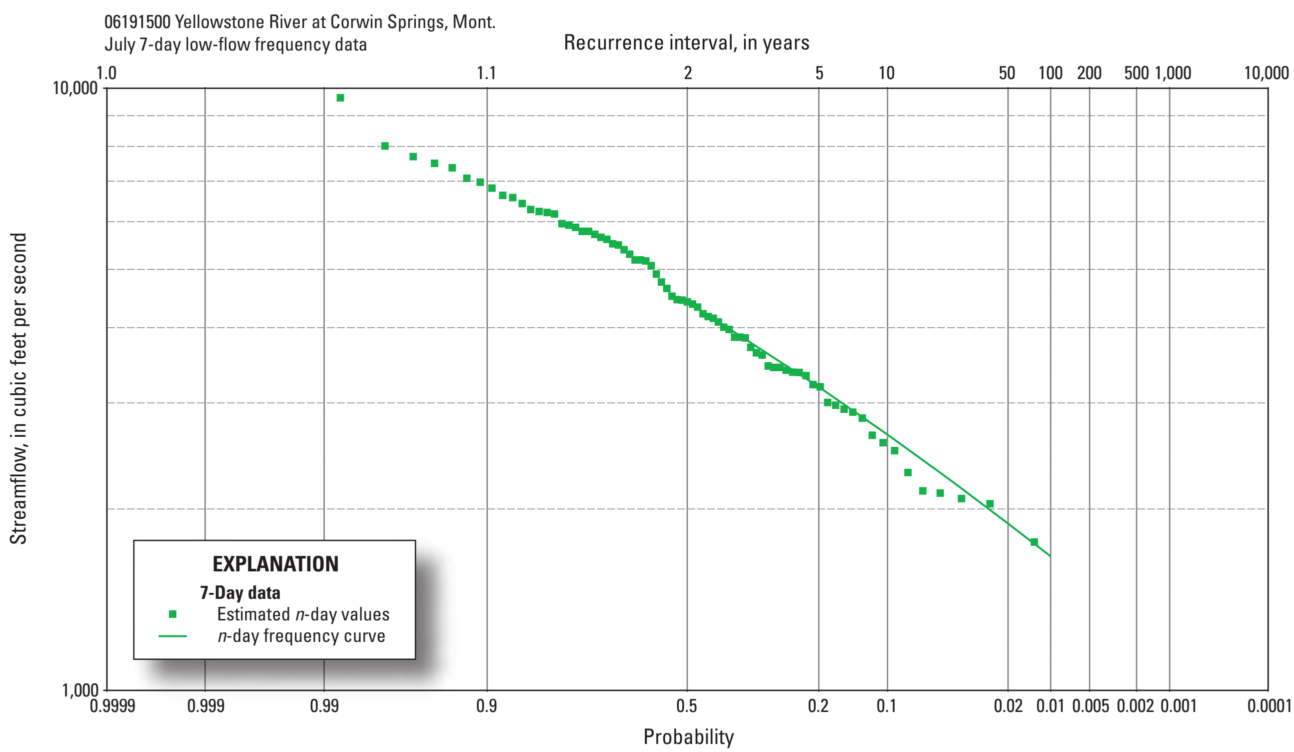


Figure 1–2–12. July 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

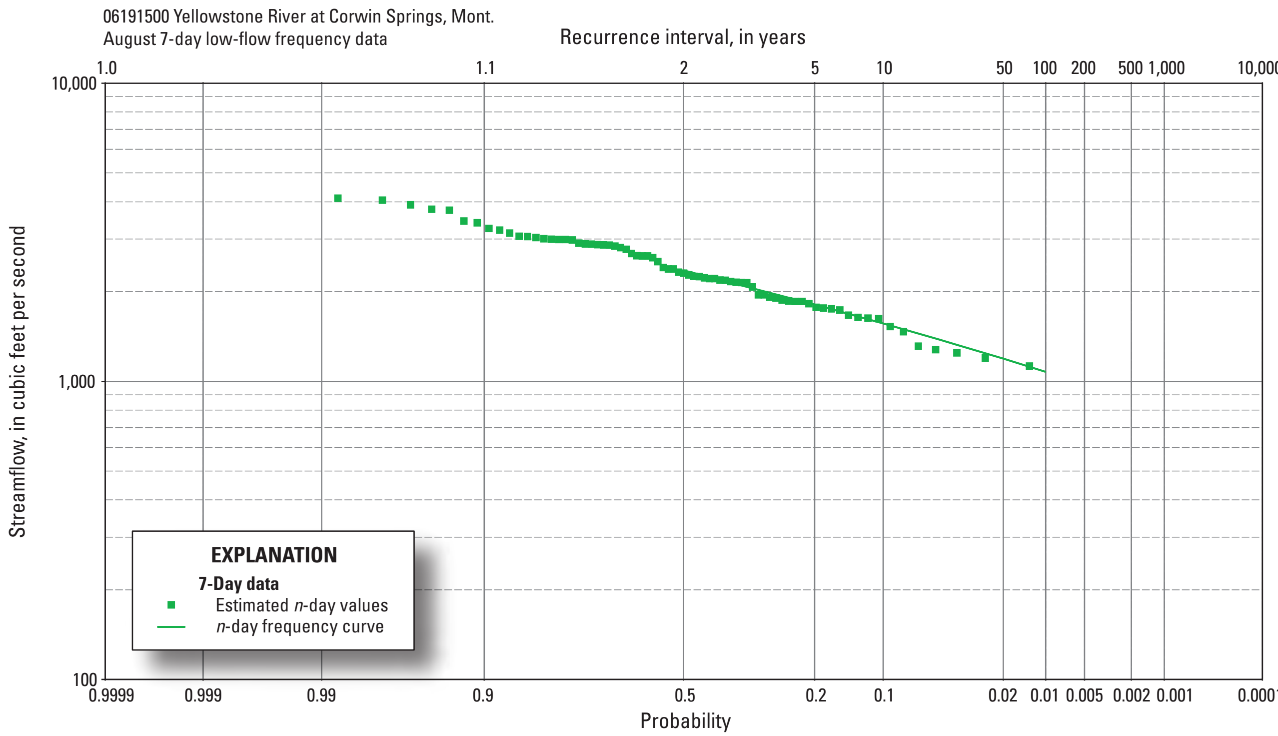


Figure 1–2–13. August 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

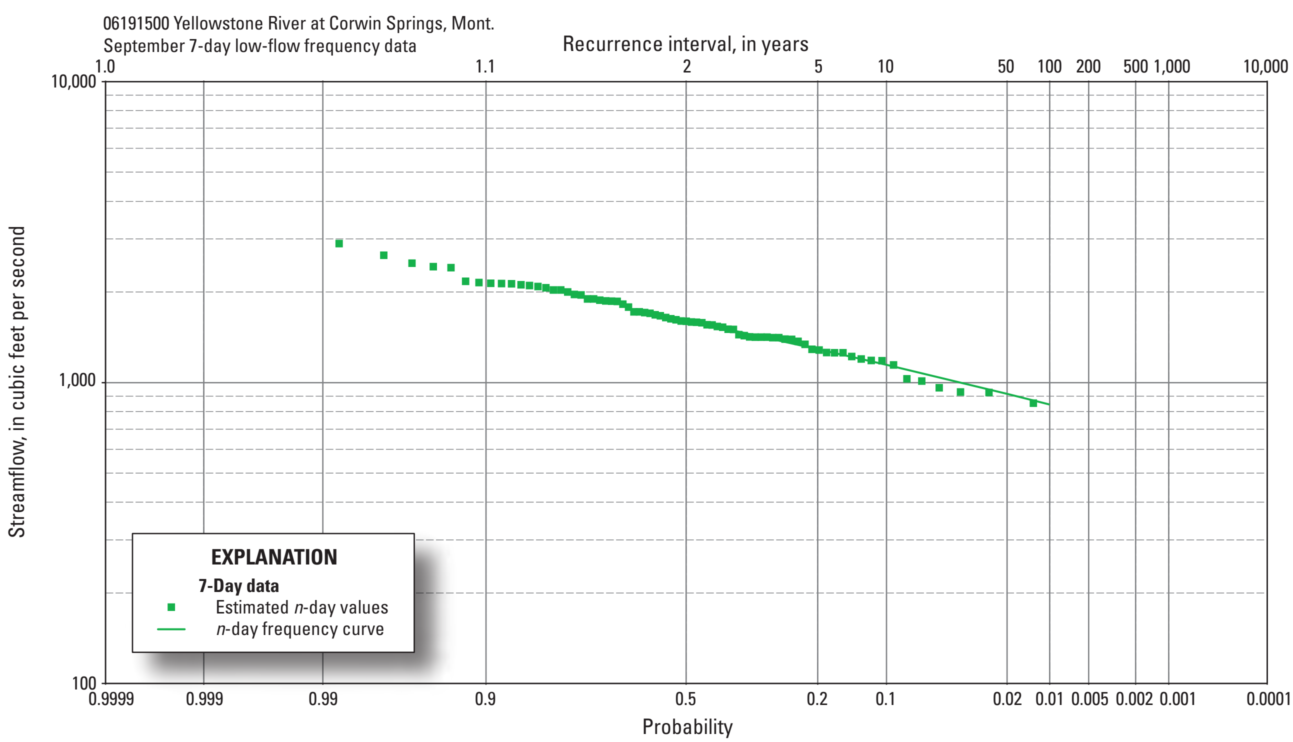


Figure 1–2–14. September 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

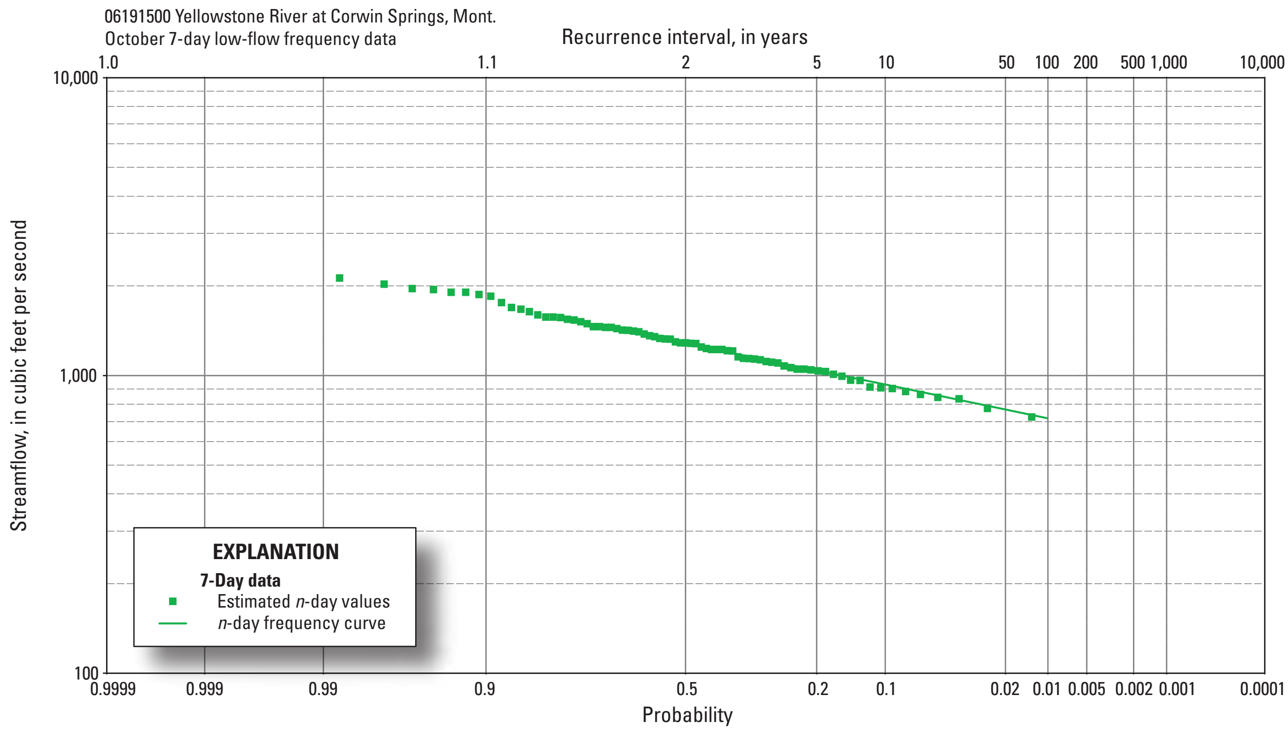


Figure 1–2–15. October 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

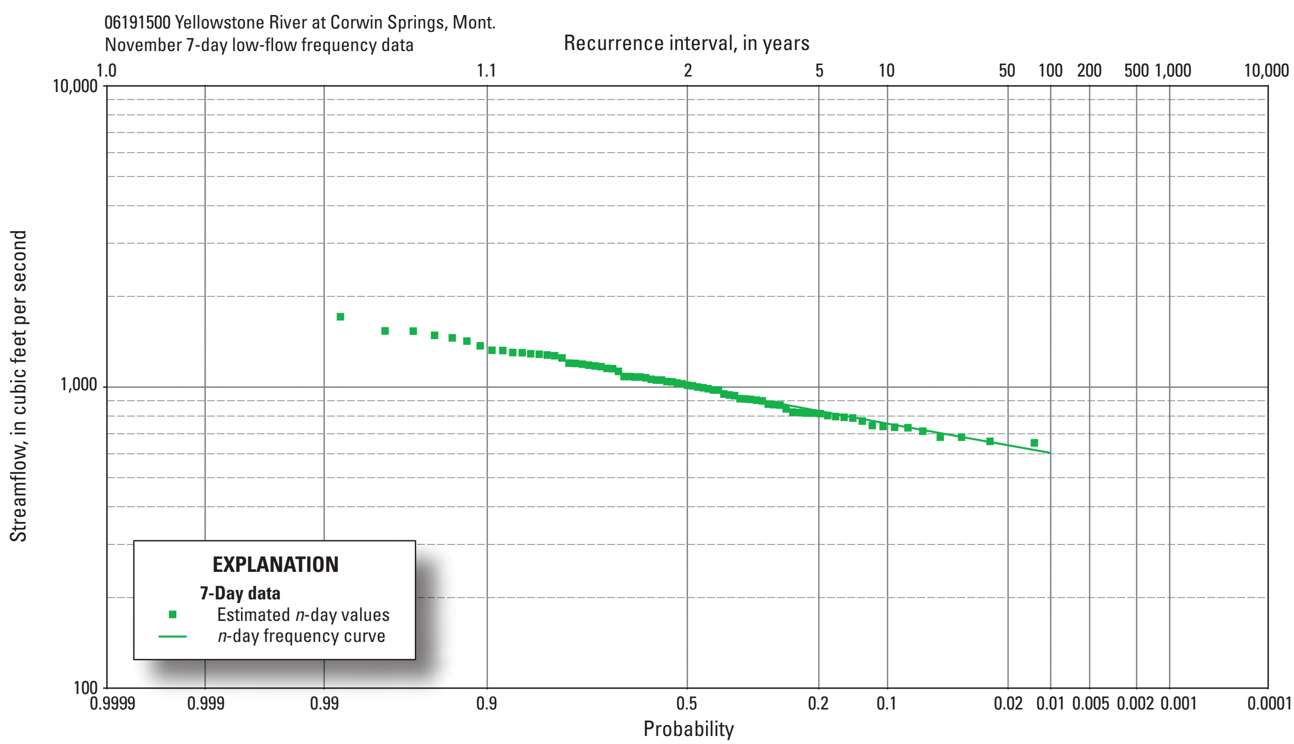


Figure 1–2–16. November 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

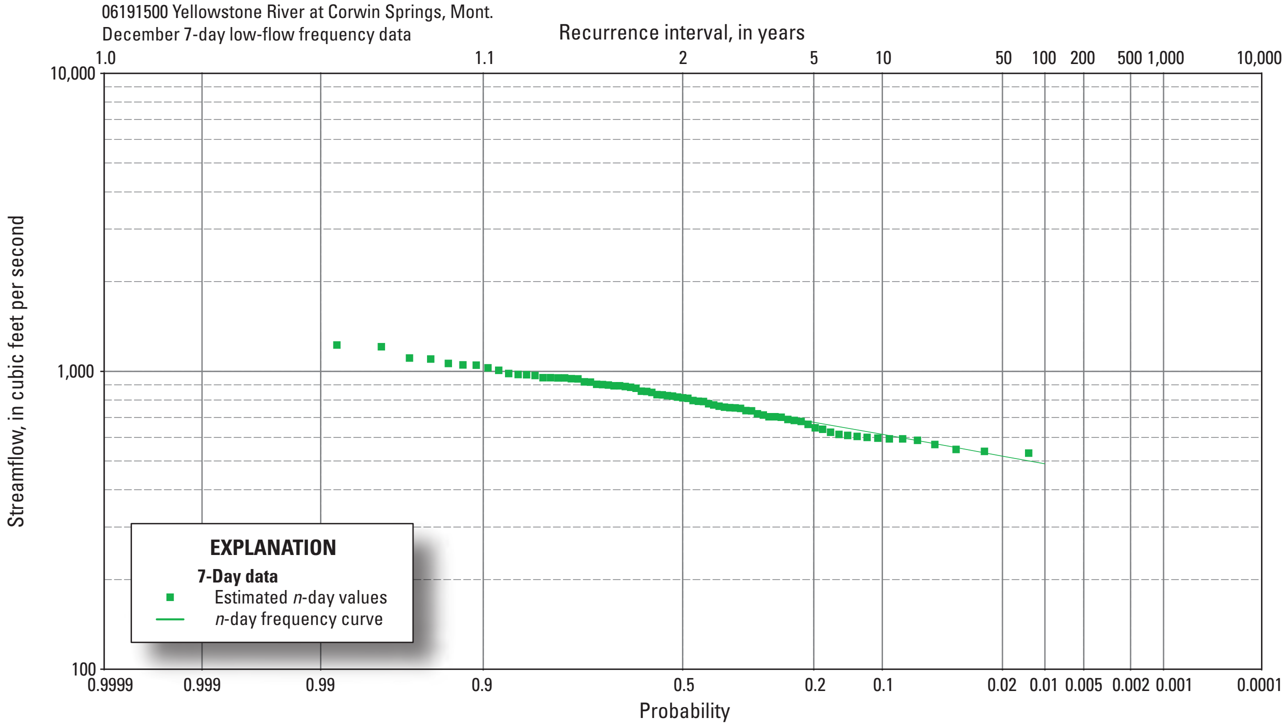


Figure 1–2–17. December 7-day low-flow frequency data for streamflow-gaging station 06191500 (Yellowstone River at Corwin Springs, Montana) for unregulated streamflow conditions, 1928–2002.

Appendix 1–3. Statistics for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana)

Table 1–3–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Unregulated						
	Streamflow, in ft³/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	991	833	756	695	678	630	589
30	1,110	937	853	787	768	716	671
Winter (January–March)							
7	1,012	844	764	701	684	635	594
30	1,110	937	852	785	766	714	669
Spring (April–June)							
7	1,420	1,190	1,080	992	967	897	837
30	1,880	1,470	1,300	1,190	1,150	1,070	1,000
Summer (July–September)							
7	2,140	1,730	1,550	1,400	1,360	1,250	1,160
30	2,390	1,930	1,710	1,540	1,490	1,370	1,260
Fall (October–December)							
7	1,171	996	911	844	826	773	728
30	1,330	1,140	1,060	985	966	911	864
Monthly							
7 (January)	1,060	881	796	729	710	658	614
7 (February)	1,090	909	821	752	732	678	632
7 (March)	1,170	988	898	827	807	750	700
7 (April)	1,420	1,190	1,080	992	967	897	837
7 (May)	3,090	2,140	1,800	1,580	1,520	1,370	1,260
7 (June)	9,700	7,210	6,120	5,310	5,090	4,500	4,020
7 (July)	5,130	3,780	3,200	2,770	2,650	2,340	2,090
7 (August)	2,910	2,290	2,010	1,790	1,730	1,560	1,420
7 (September)	2,140	1,730	1,550	1,400	1,360	1,250	1,160
7 (October)	1,790	1,480	1,340	1,230	1,200	1,110	1,040
7 (November)	1,470	1,230	1,130	1,040	1,020	955	901
7 (December)	1,170	999	914	846	827	774	729

Table 1–3–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for unregulated and regulated streamflow conditions, 1928–2002.—Continued

[ft^3/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Regulated						
	Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
				Annual			
7	1,000	840	762	701	684	635	594
30	1,110	940	860	790	780	720	680
				Winter (January–March)			
7	1,020	850	770	710	691	642	601
30	1,120	940	860	790	770	720	680
				Spring (April–June)			
7	1,400	1,180	1,070	980	960	890	830
30	1,840	1,450	1,280	1,170	1,140	1,060	990
				Summer (July–September)			
7	2,090	1,680	1,500	1,360	1,320	1,210	1,120
30	2,320	1,860	1,640	1,480	1,430	1,310	1,200
				Fall (October–December)			
7	1,180	1,010	920	857	838	785	739
30	1,350	1,160	1,070	1,000	980	920	880
				Monthly			
7 (January)	1,070	889	804	737	718	666	621
7 (February)	1,100	916	827	758	739	685	639
7 (March)	1,170	993	903	832	812	755	706
7 (April)	1,400	1,180	1,070	980	956	888	829
7 (May)	2,990	2,080	1,750	1,540	1,480	1,340	1,230
7 (June)	9,530	7,030	5,930	5,120	4,900	4,320	3,830
7 (July)	4,950	3,610	3,030	2,600	2,490	2,190	1,900
7 (August)	2,800	2,180	1,890	1,670	1,610	1,450	1,320
7 (September)	2,090	1,680	1,500	1,360	1,320	1,210	1,120
7 (October)	1,810	1,490	1,350	1,240	1,210	1,120	1,050
7 (November)	1,490	1,250	1,150	1,060	1,040	974	919
7 (December)	1,190	1,010	926	858	839	786	740

Table 1–3–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second]

Unregulated

Period	Streamflow, in ft^3/s, or year, for indicated streamflow characteristic					
	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	1,750	1984	721	1989	1,195	235
February	1,722	1997	691	1937	1,186	230
March	1,800	1997	696	1937	1,268	212
April	3,880	1990	926	1937	2,000	632
May	15,700	1928	3,360	1953	7,170	2,320
June	27,300	1997	5,210	1934	13,300	4,270
July	15,200	1975	2,810	1934	7,760	3,010
August	5,890	1982	1,860	1988	3,710	1,060
September	3,860	1968	1,342	1988	2,430	574
October	3,100	1972	1,123	1988	1,980	454
November	2,580	1983	1,013	1936	1,640	329
December	1,970	1983	842	1936	1,354	238
Annual	6,290	1997	2,341	1931	3,740	807

Regulated

Period	Streamflow, in ft^3/s, or year, for indicated streamflow characteristic					
	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	1,760	1984	727	1989	1,200	235
February	1,730	1997	697	1937	1,190	230
March	1,800	1997	698	1937	1,270	211
April	3,850	1990	889	1937	1,960	614
May	15,500	1928	3,270	1953	7,000	2,300
June	27,100	1997	4,990	1987	13,100	4,300
July	15,000	1975	2,630	1934	7,500	3,010
August	5,720	1982	1,710	1988	3,560	1,050
September	3,810	1968	1,280	2001	2,370	583
October	3,120	1972	1,130	1988	1,990	454
November	2,600	1983	1,030	1936	1,660	329
December	1,990	1983	853	1936	1,370	238
Annual	6,230	1997	2,270	1931	3,670	811

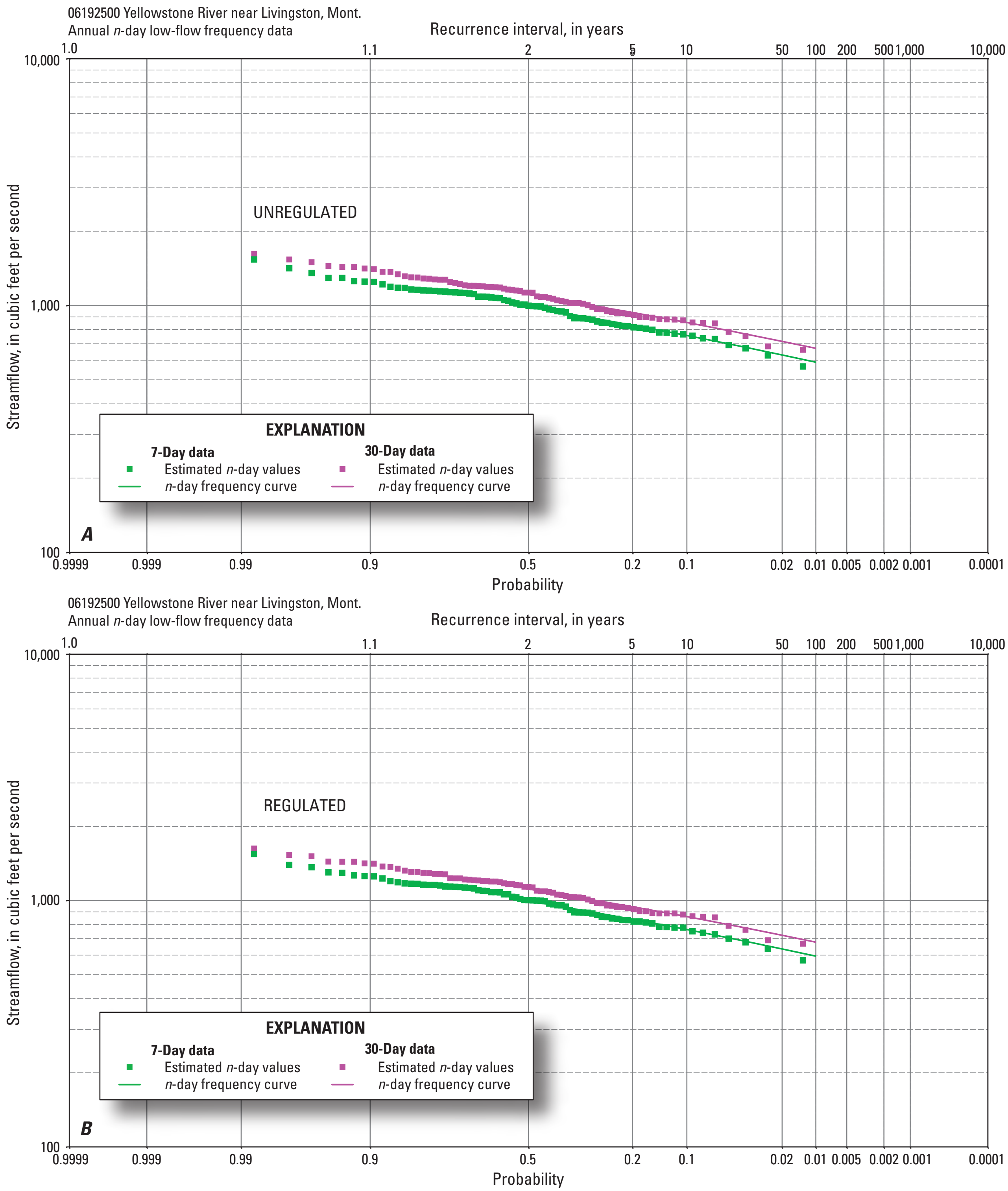


Figure 1–3–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

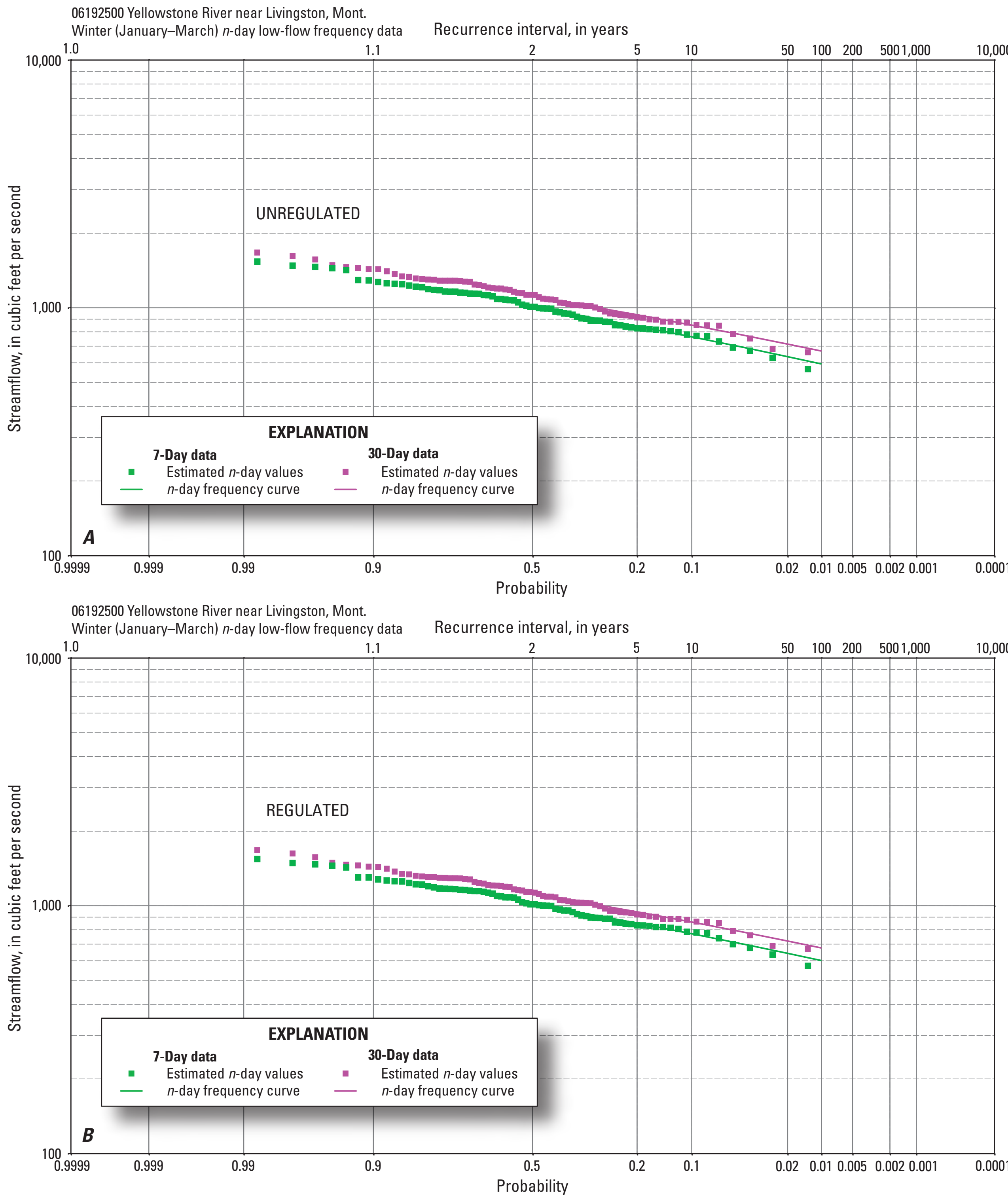


Figure 1–3–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

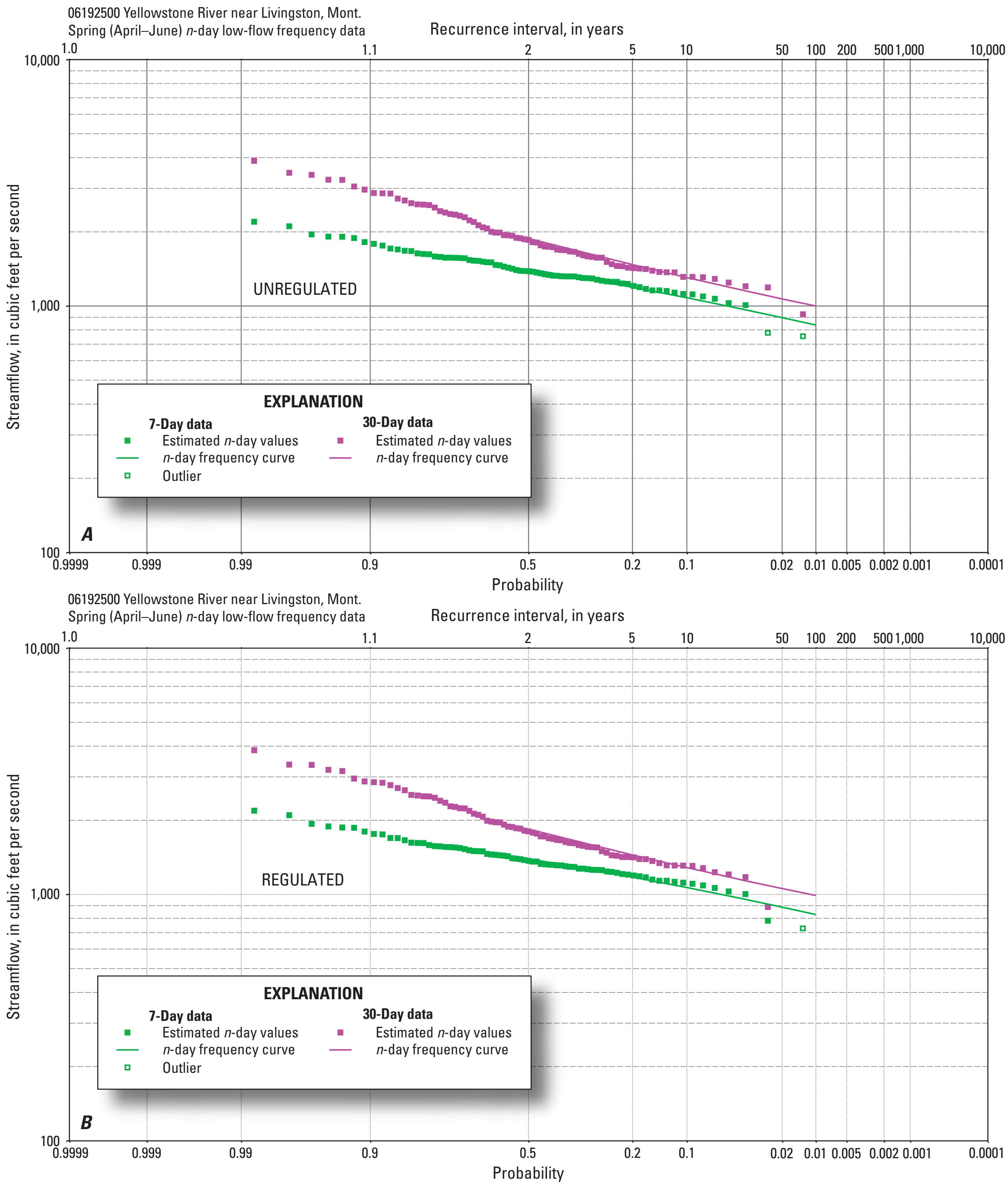


Figure 1–3–3. Spring (April–June) *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

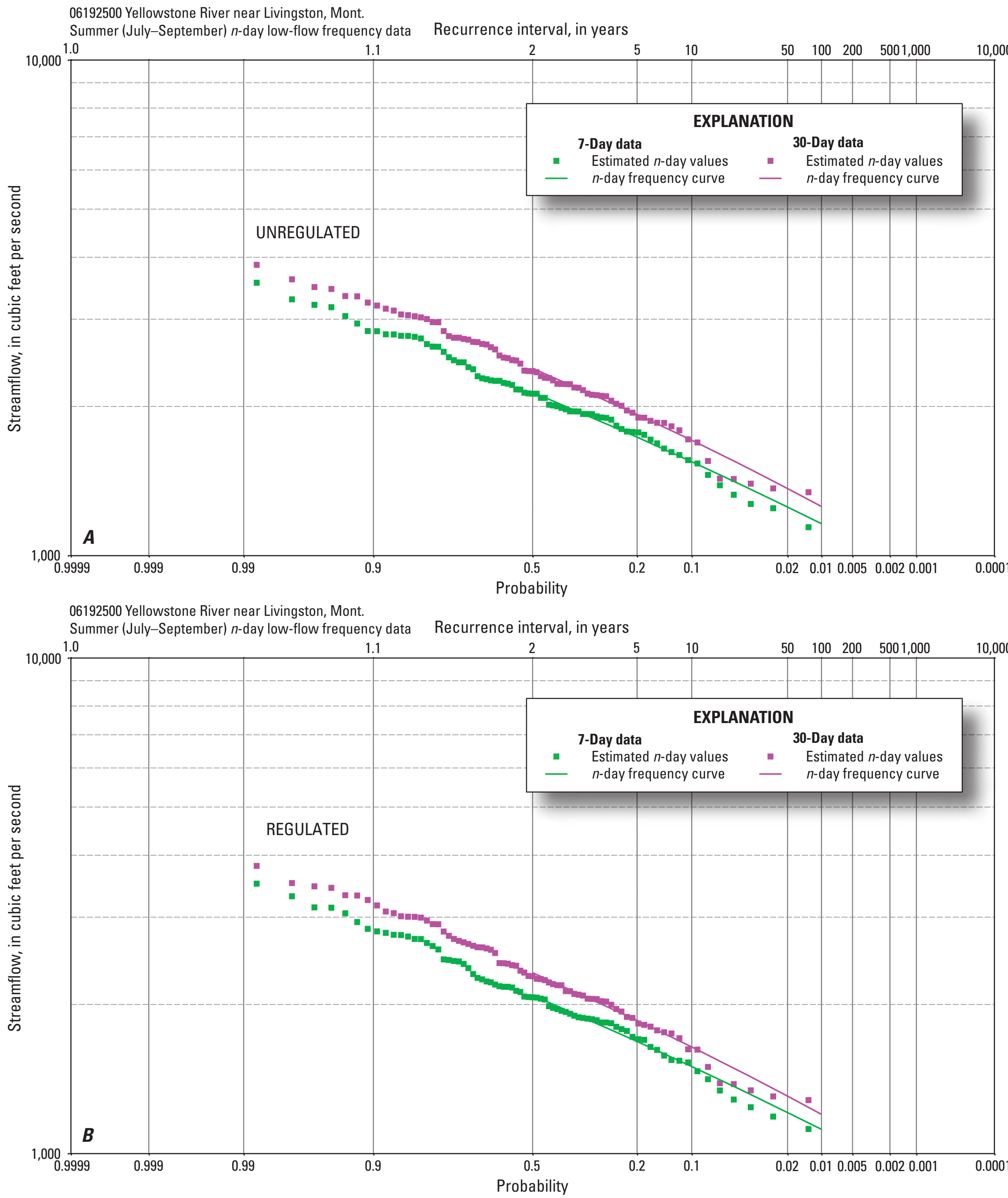
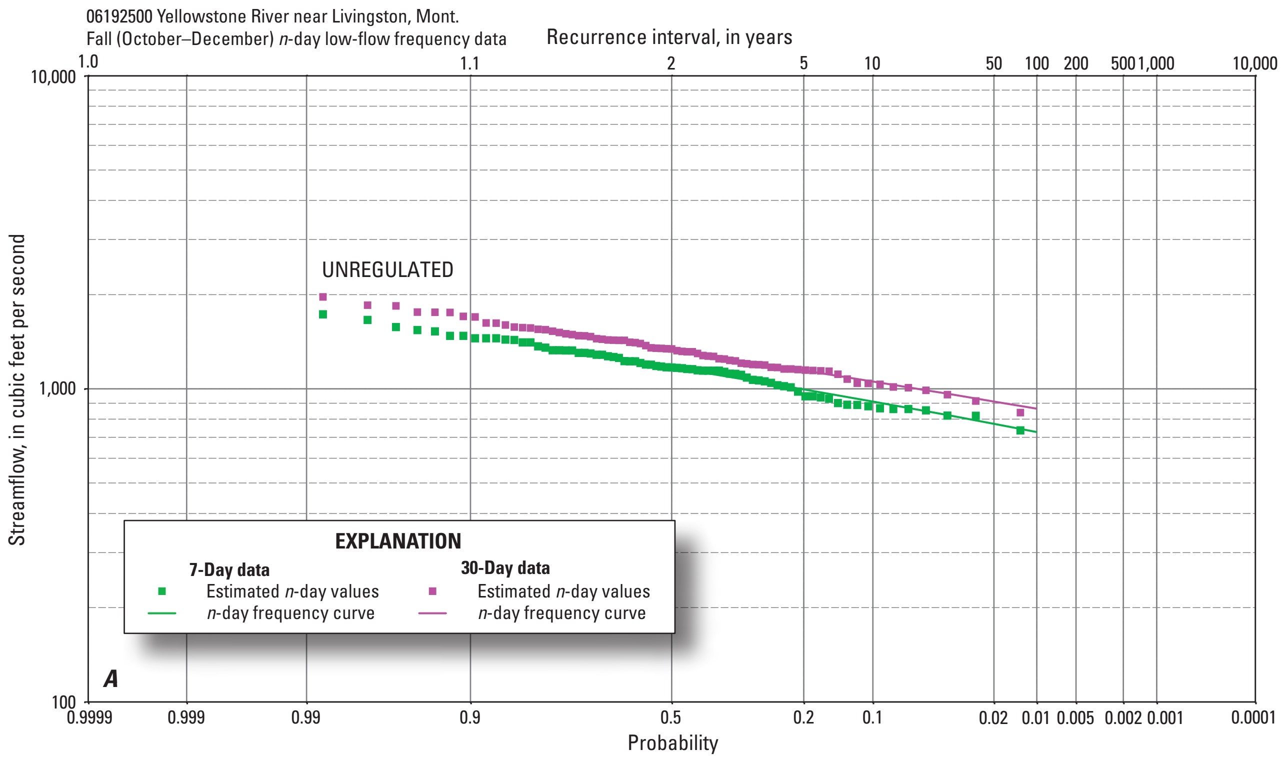


Figure 1–3–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



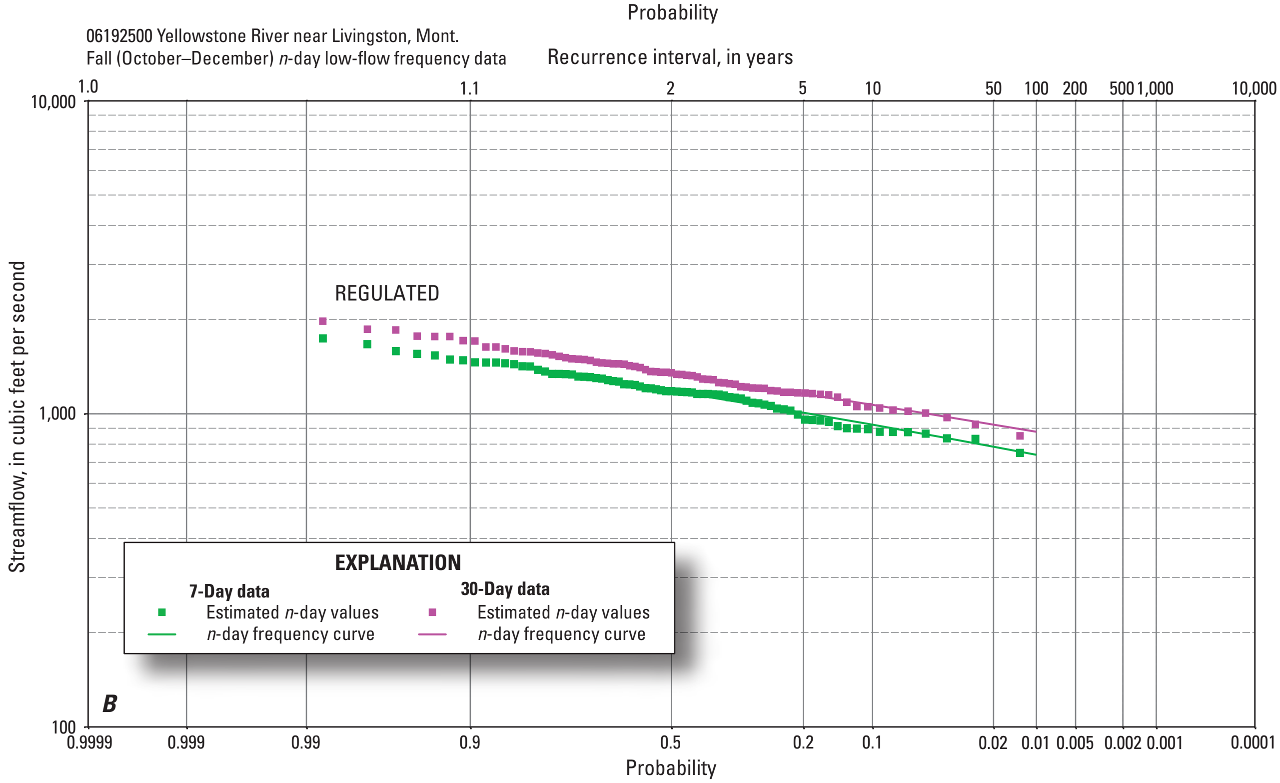


Figure 1–3–5. Fall (October–December) *n*-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

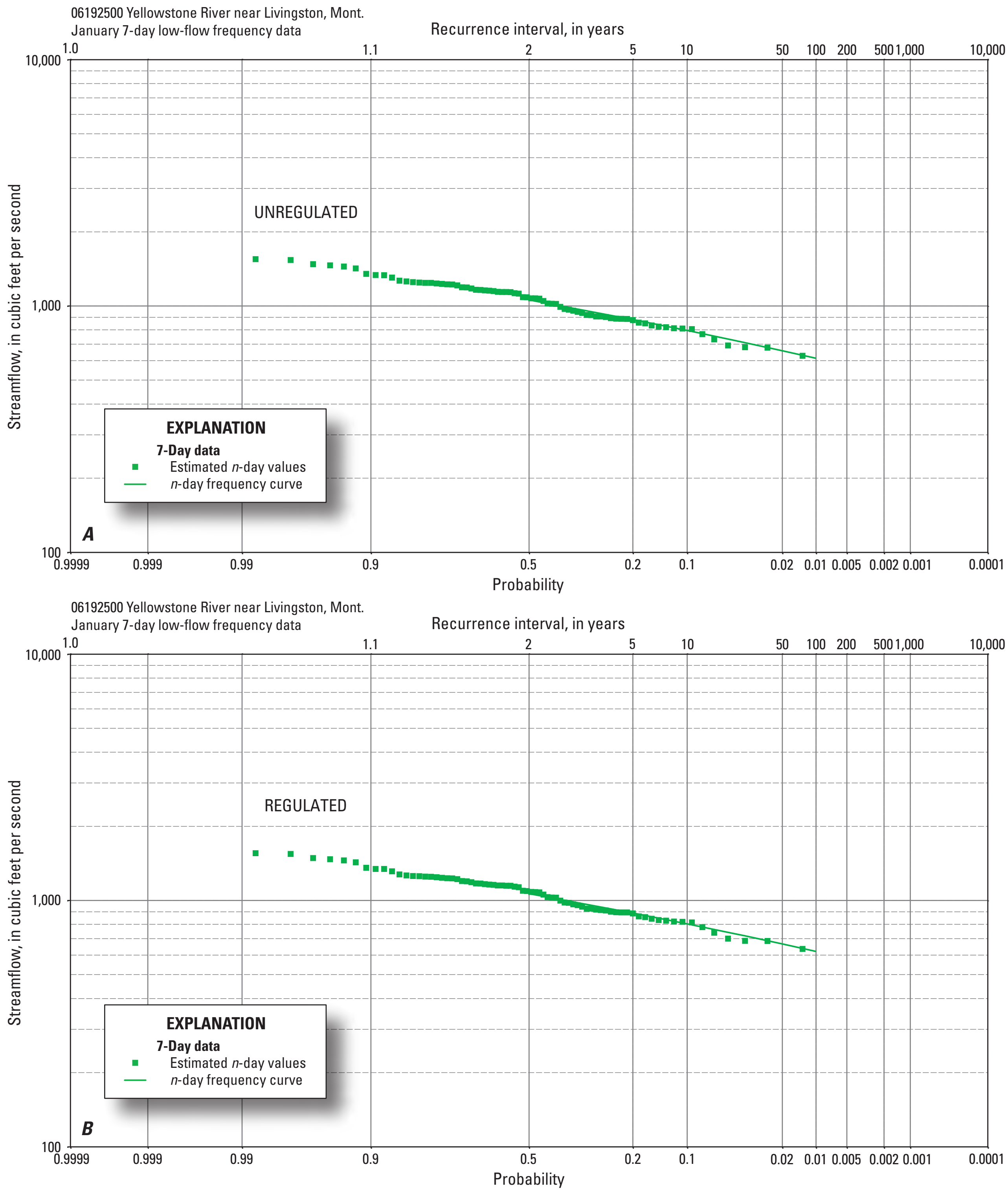
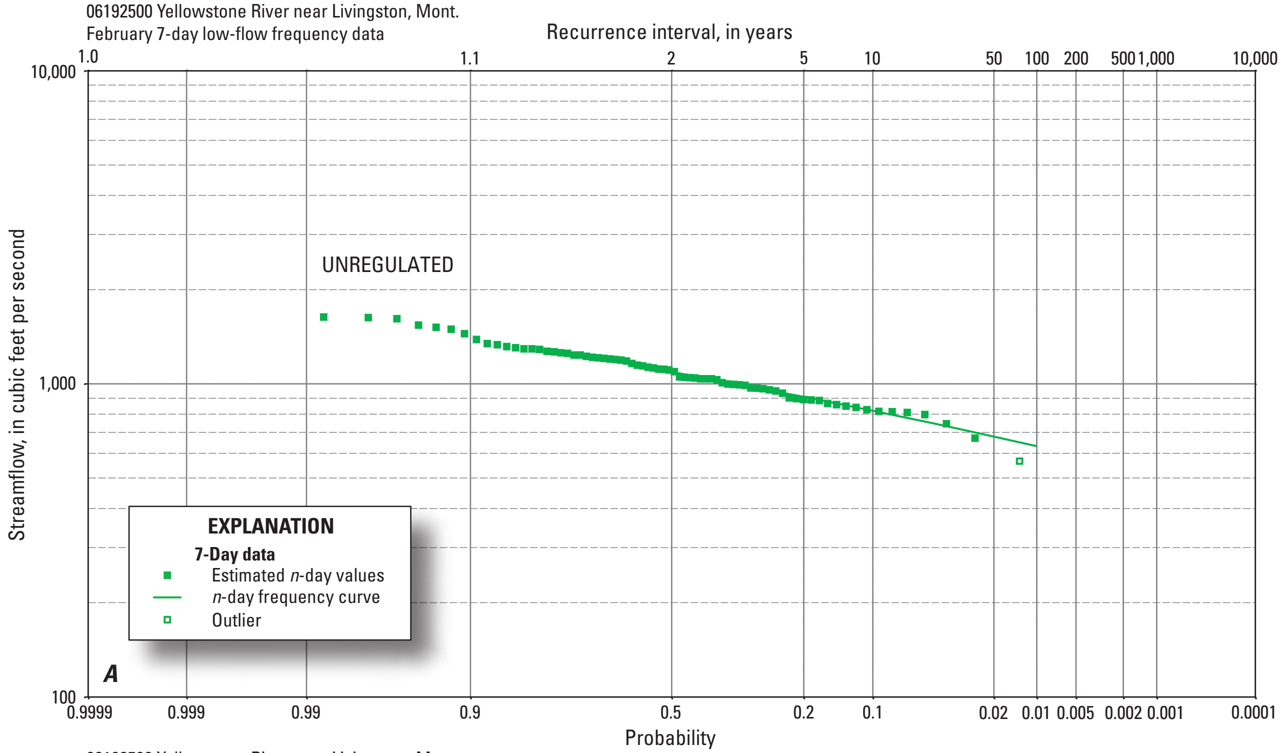


Figure 1–3–6. January 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



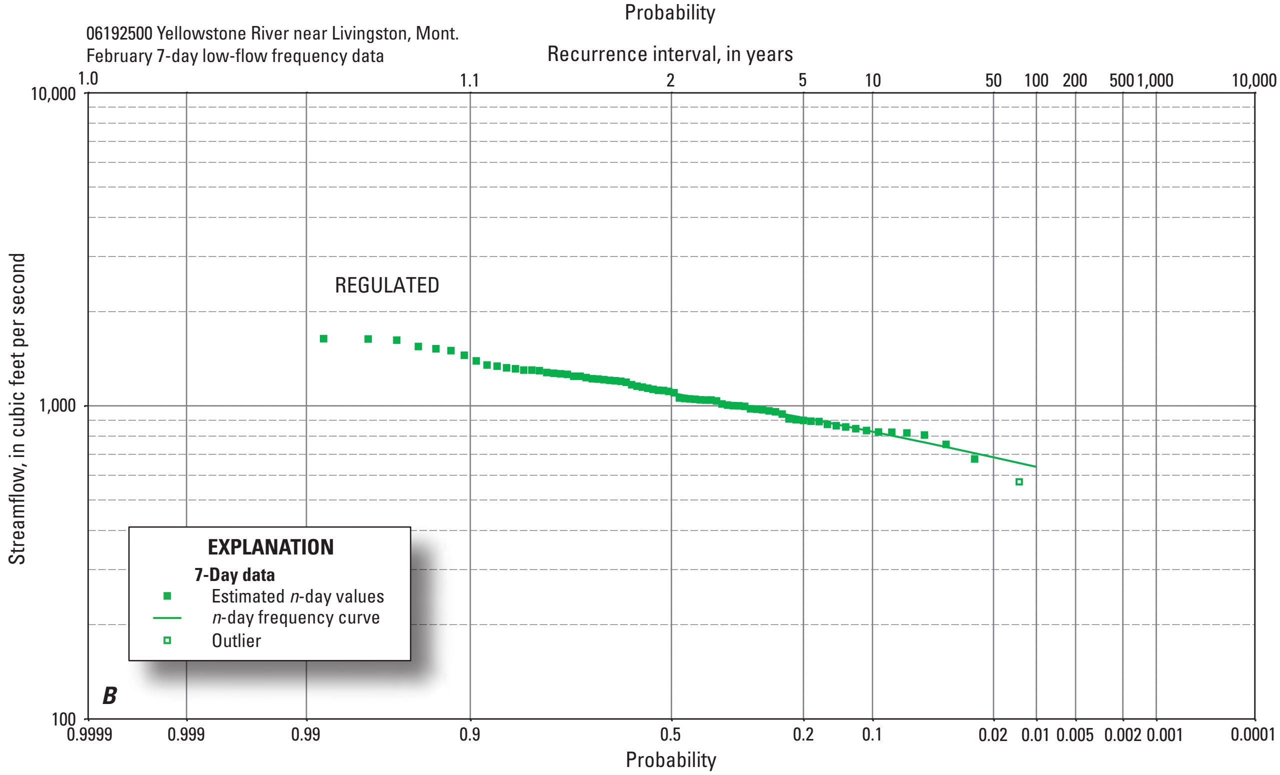
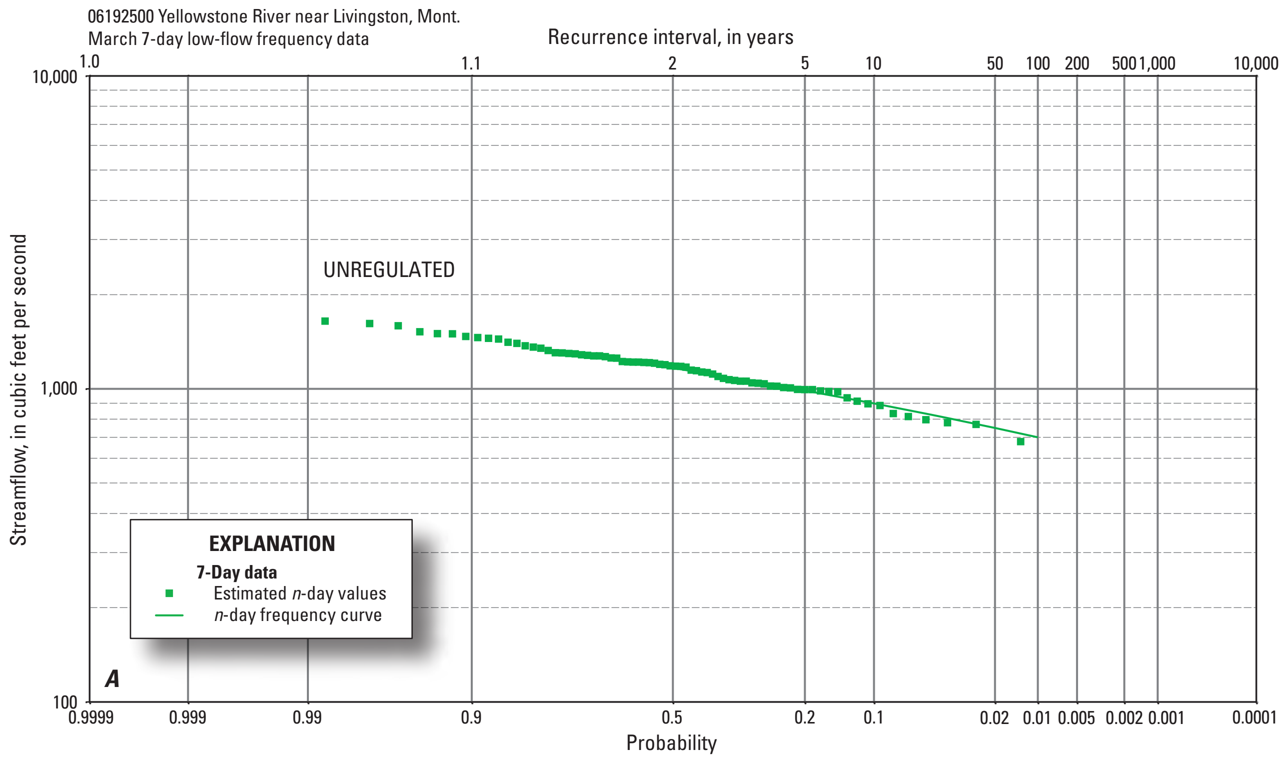


Figure 1–3–7. February 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



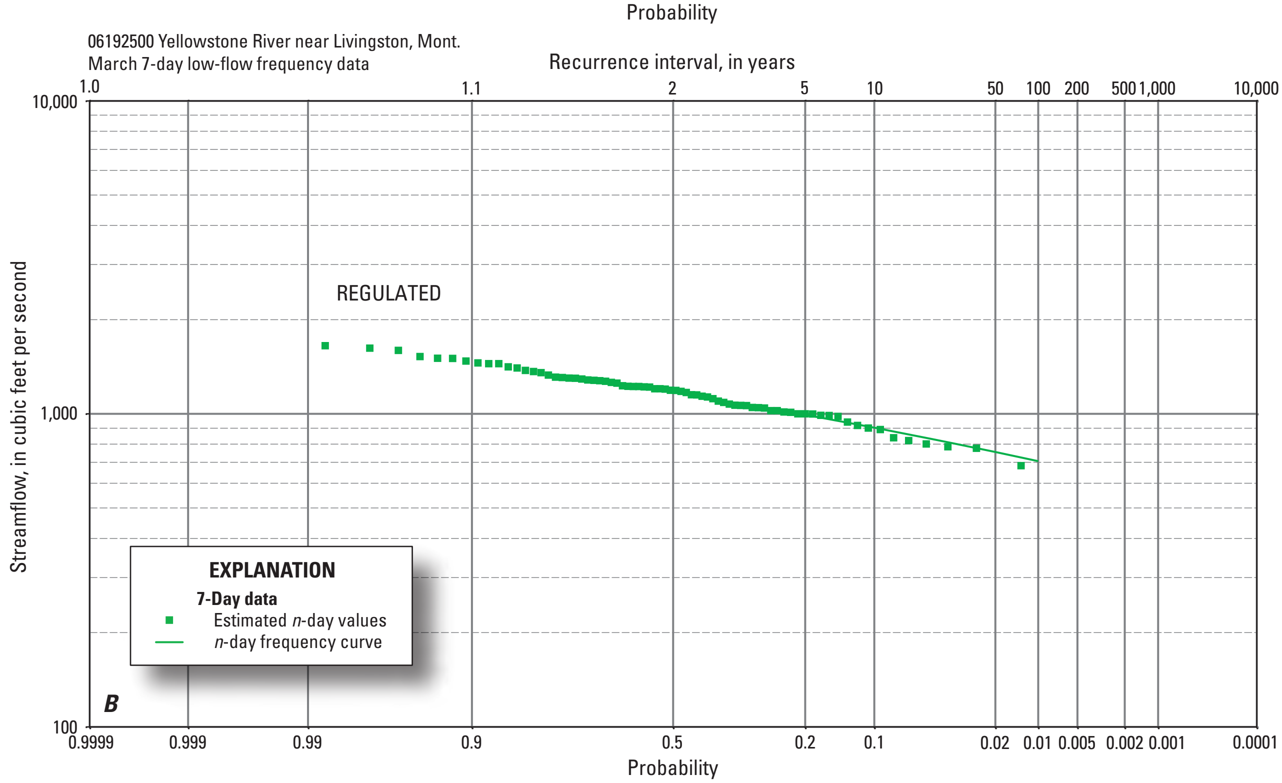


Figure 1–3–8. March 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

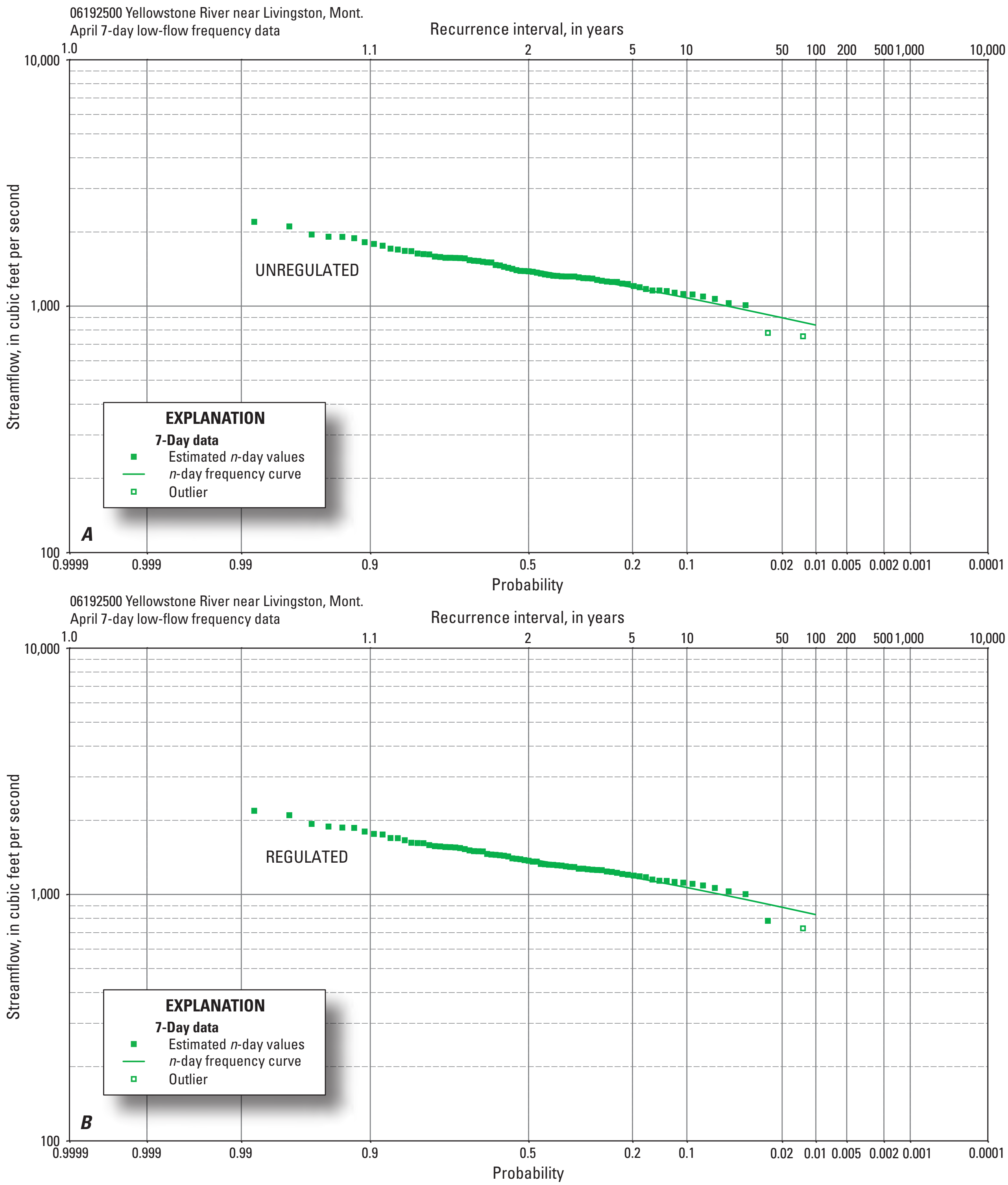


Figure 1–3–9. April 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

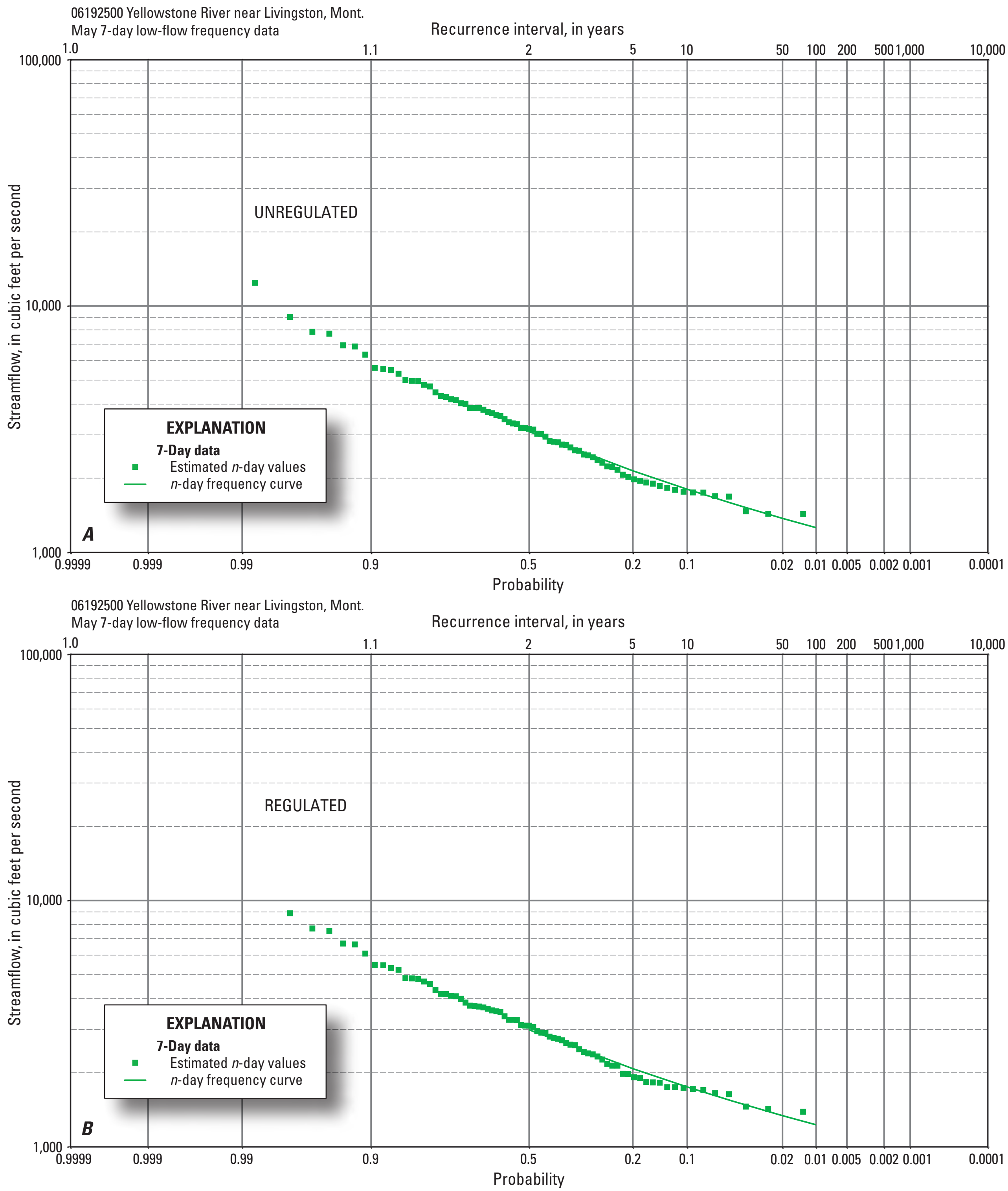
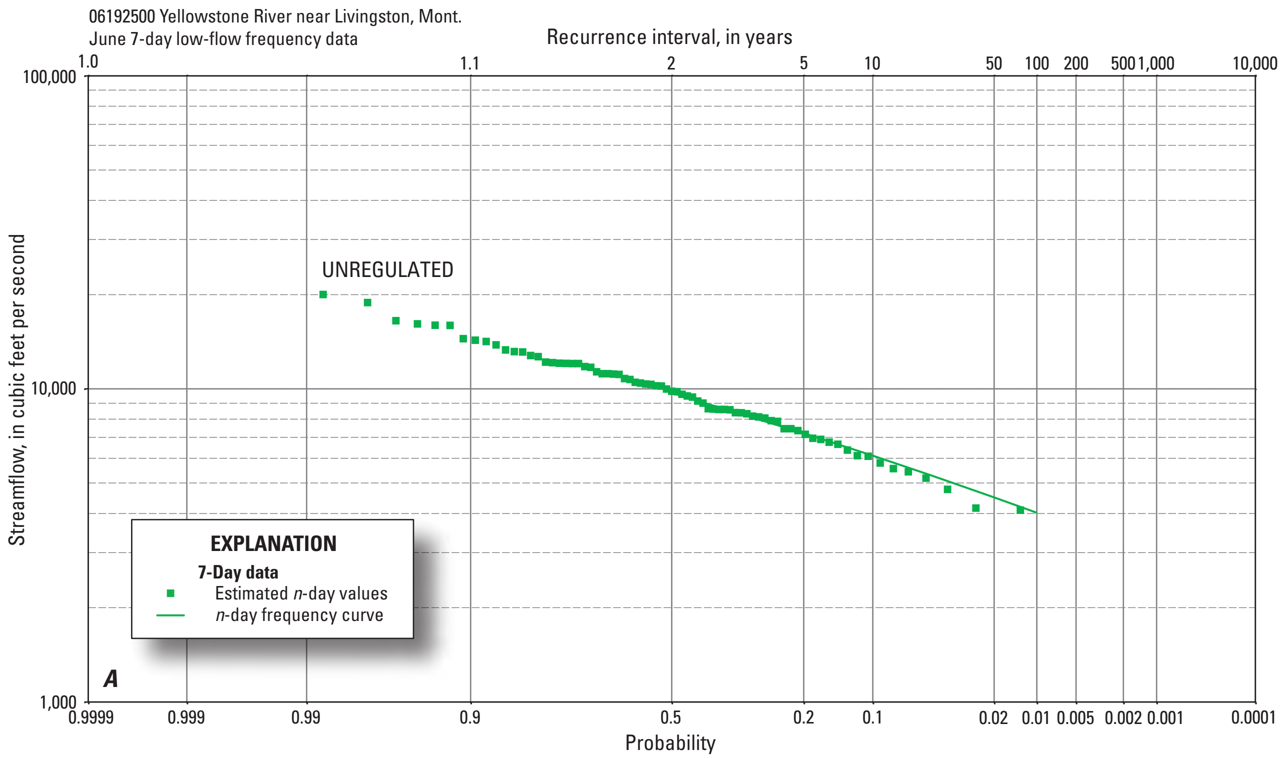


Figure 1–3–10. May 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



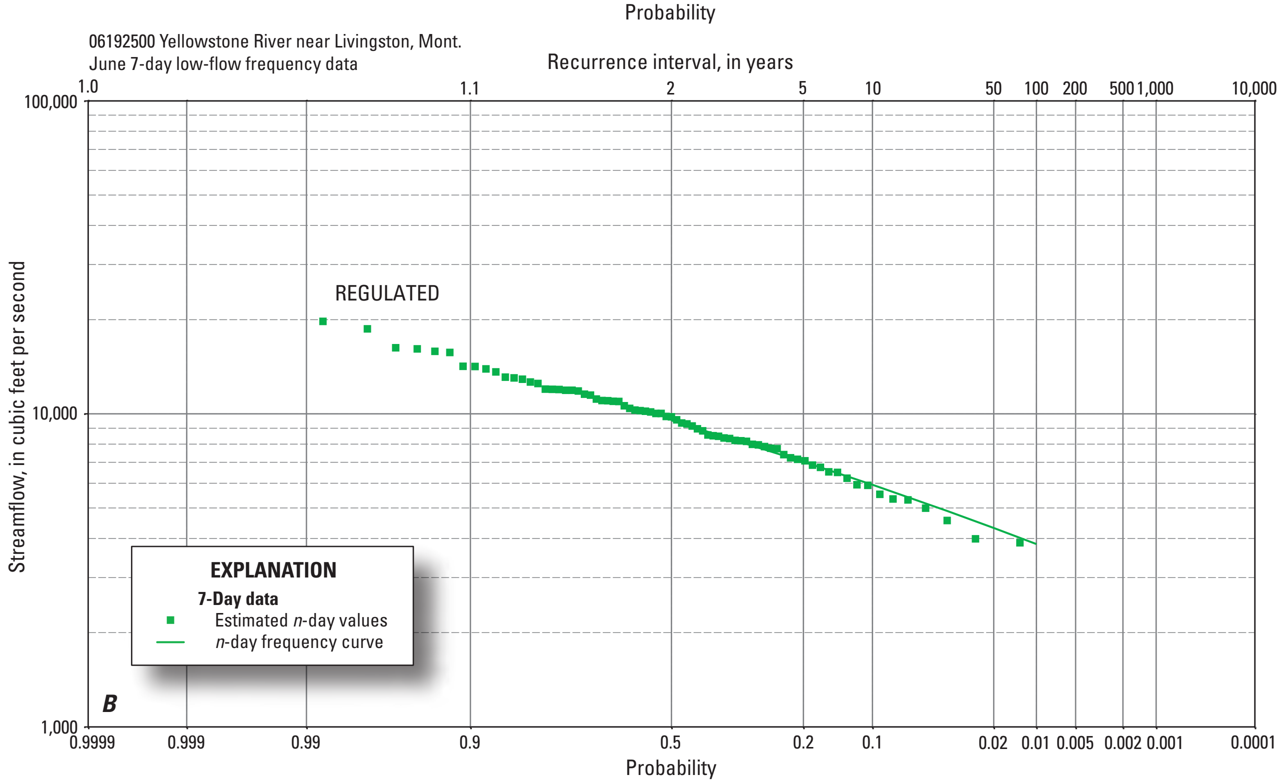


Figure 1–3–11. June 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

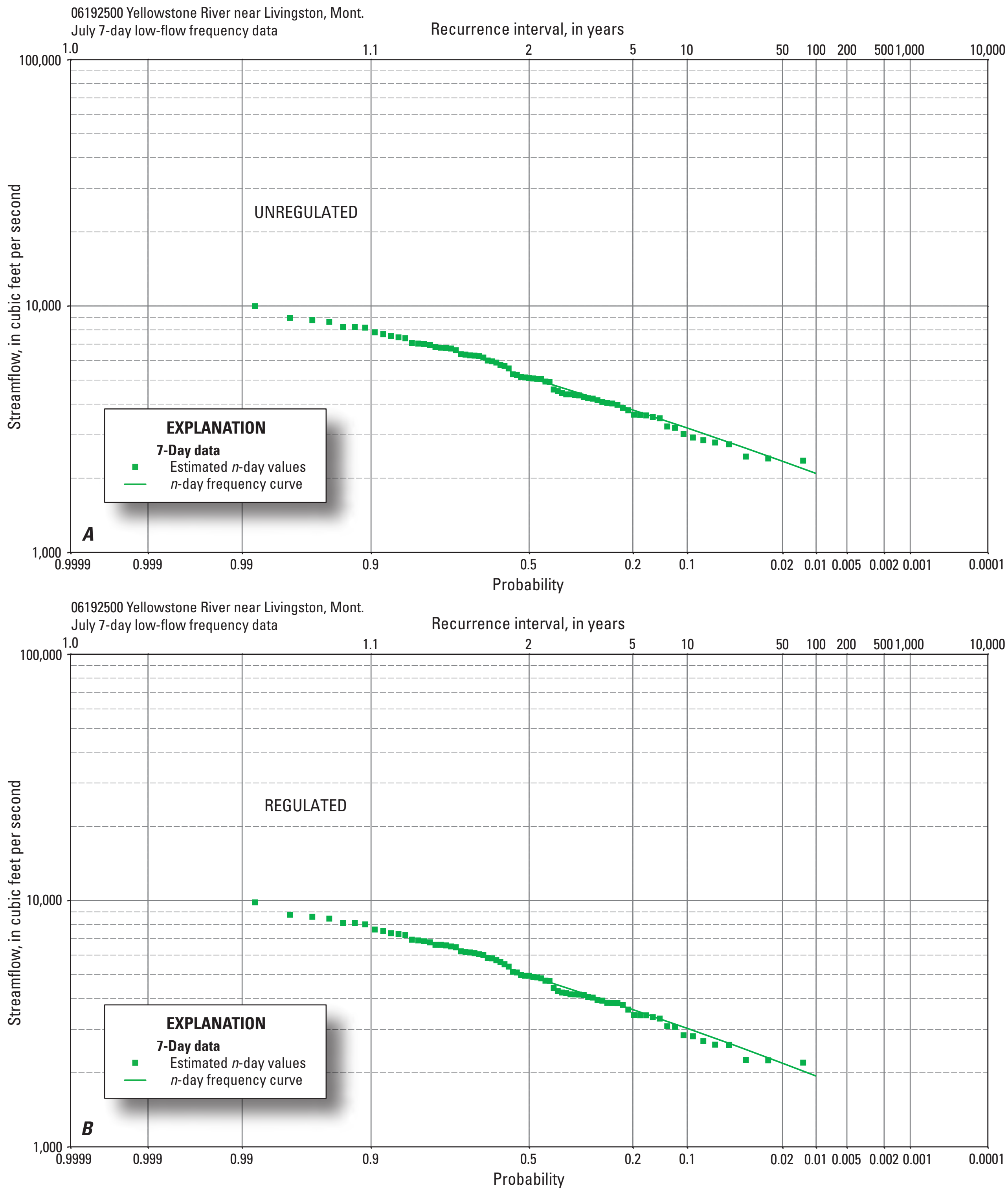


Figure 1–3–12. July 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

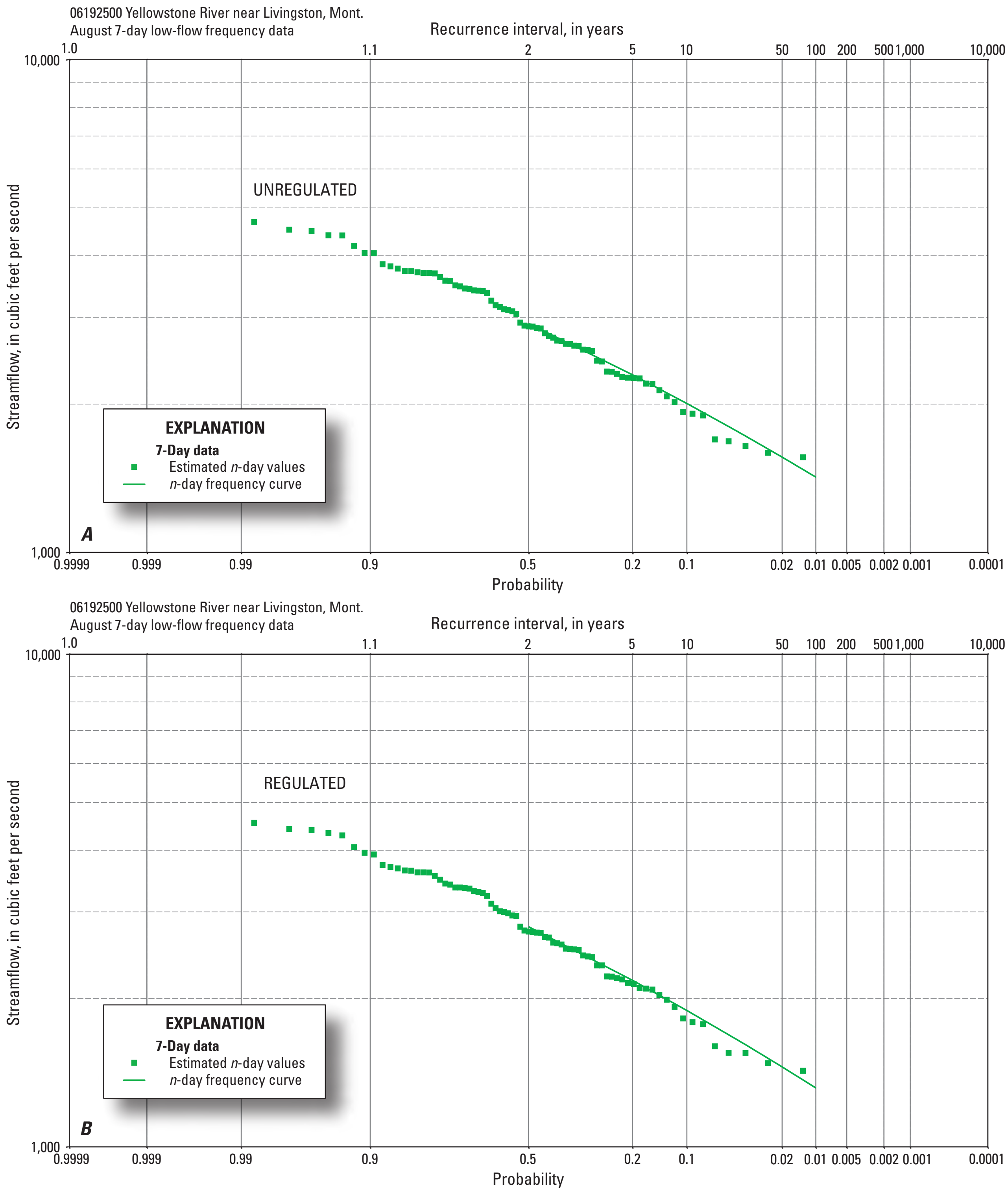
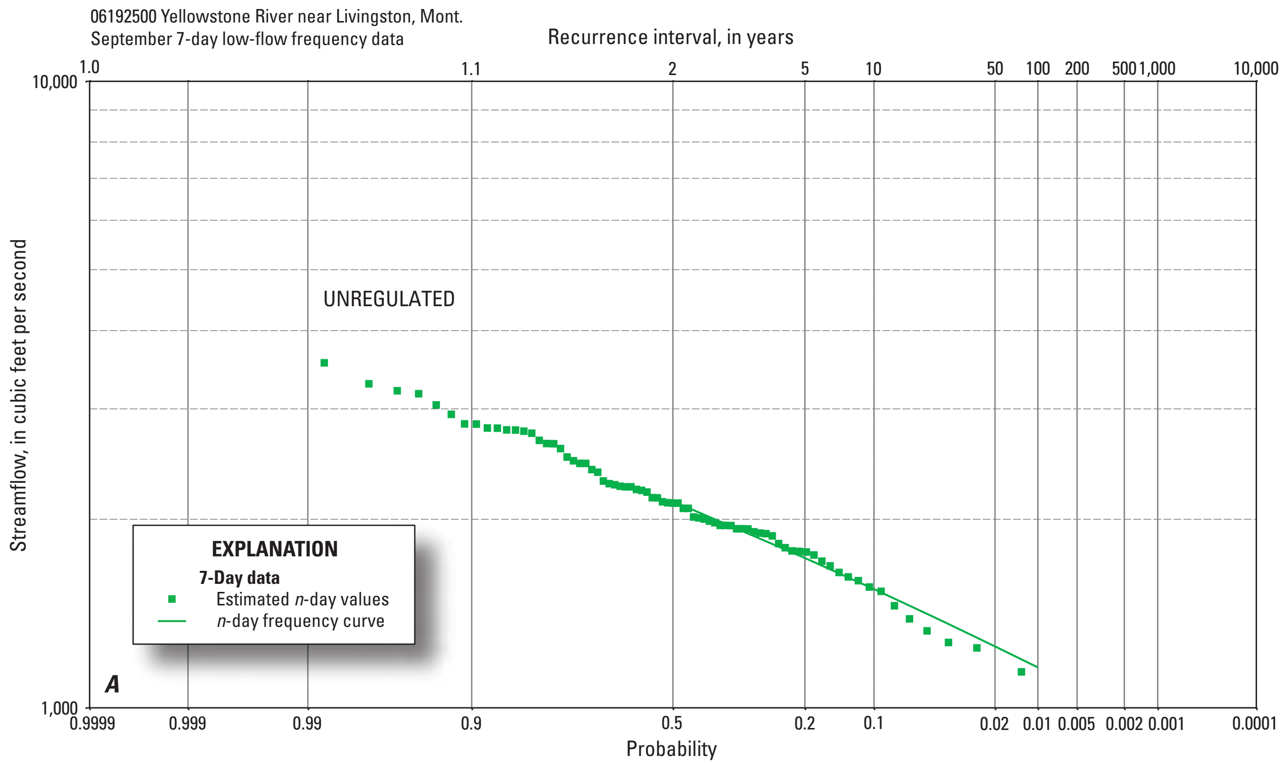


Figure 1–3–13. August 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



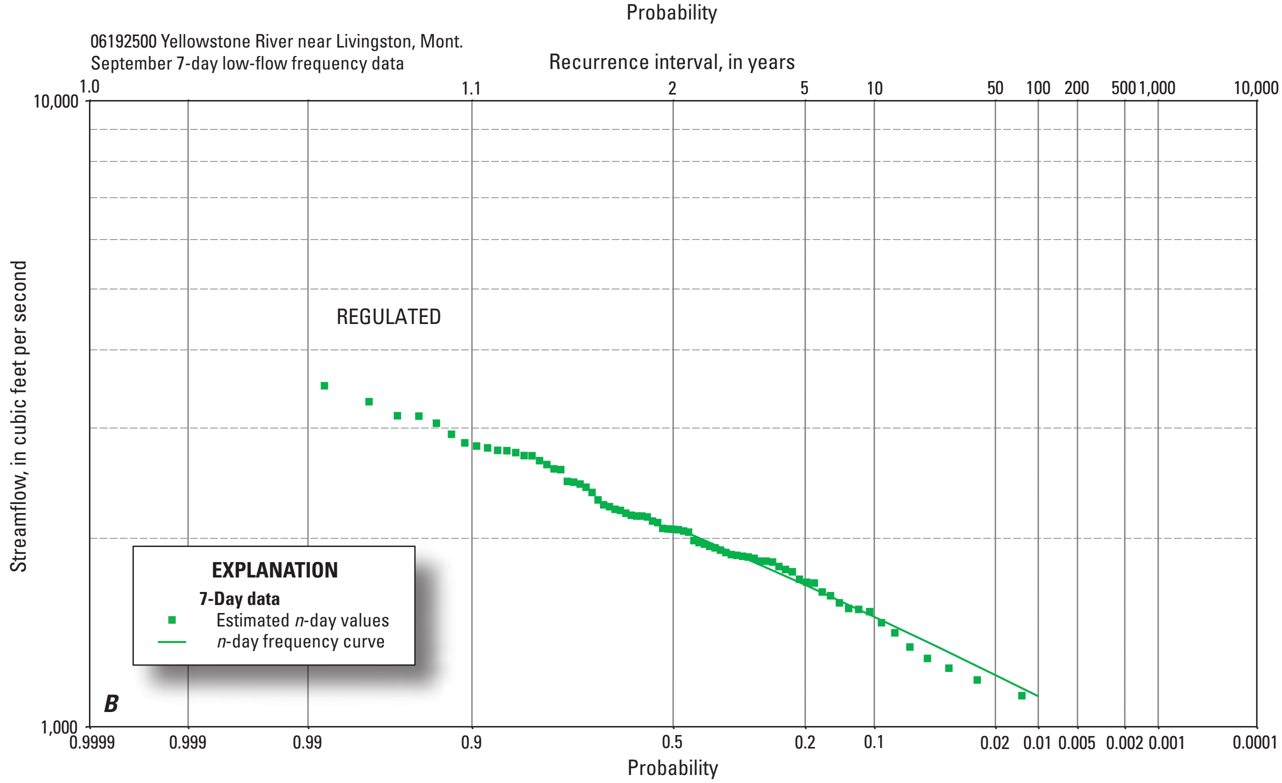


Figure 1–3–14. September 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

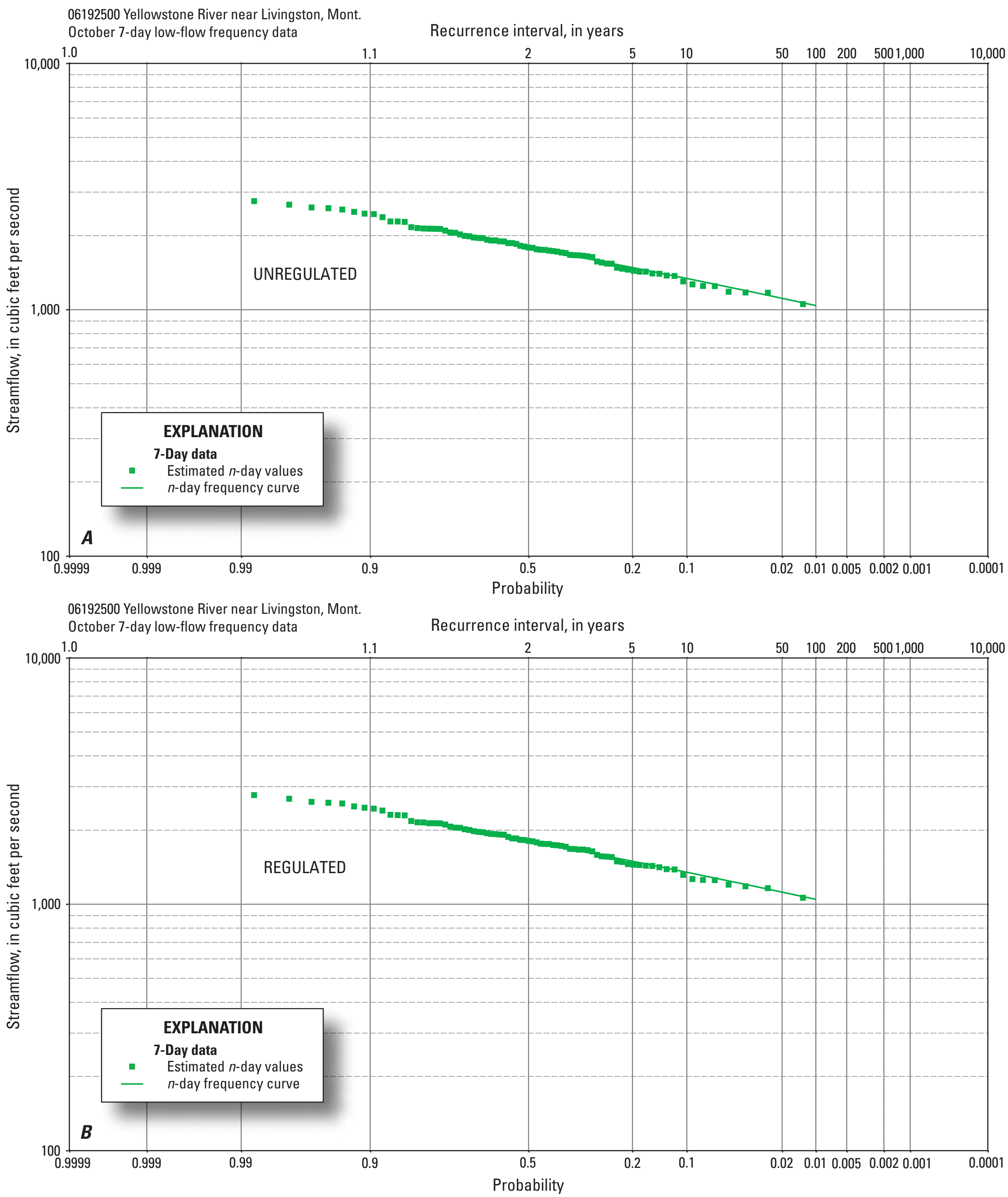
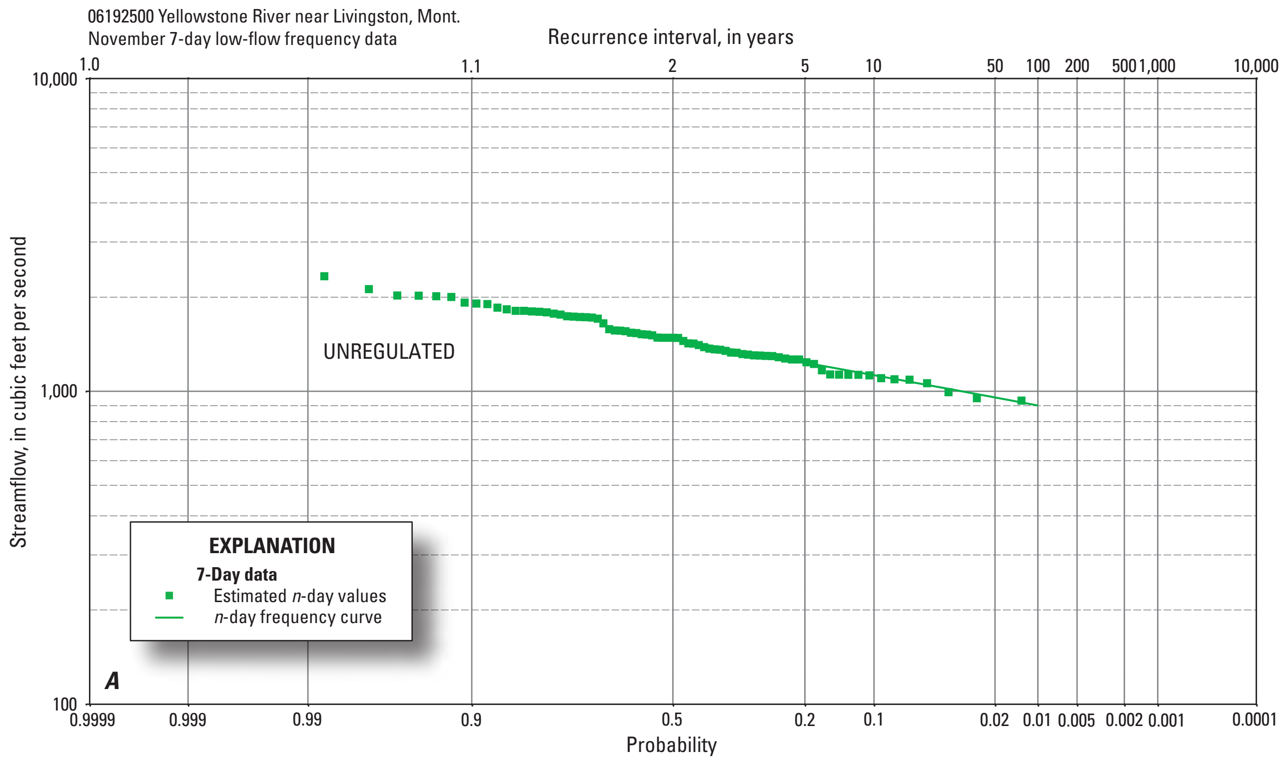


Figure 1–3–15. October 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



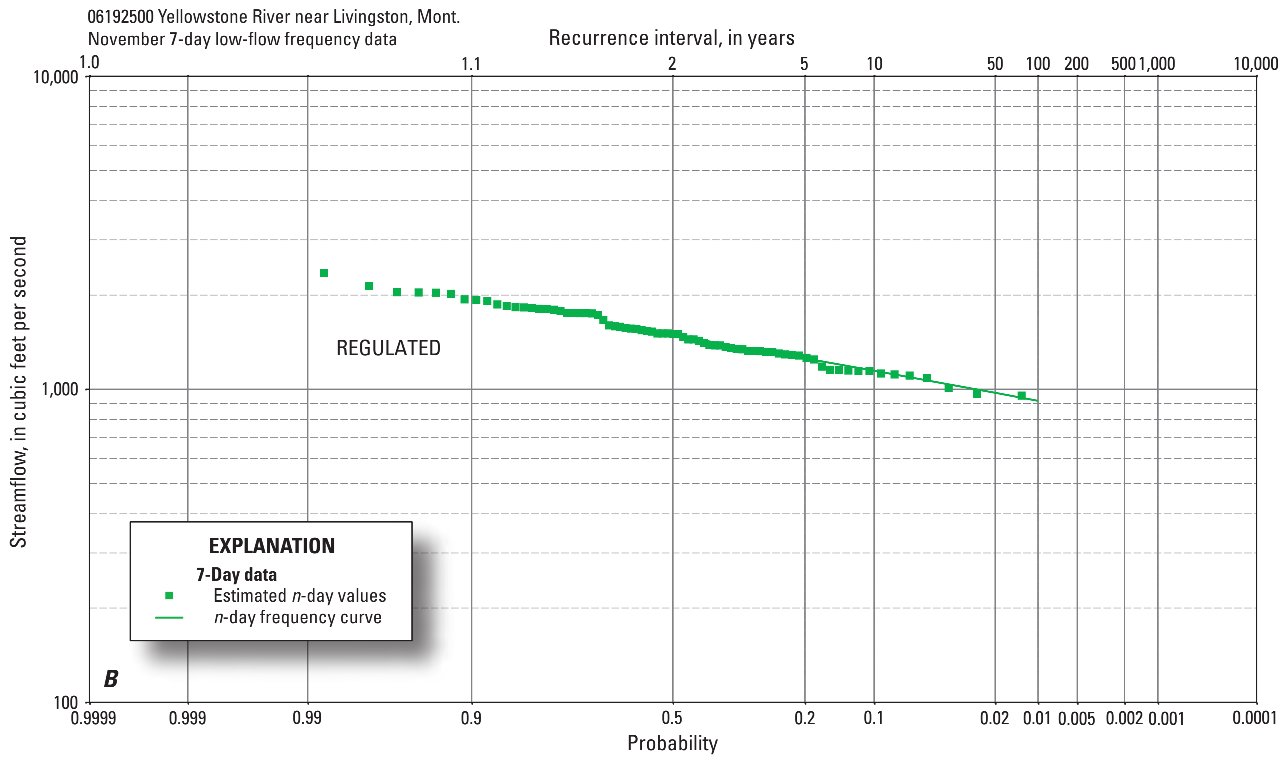


Figure 1–3–16. November 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

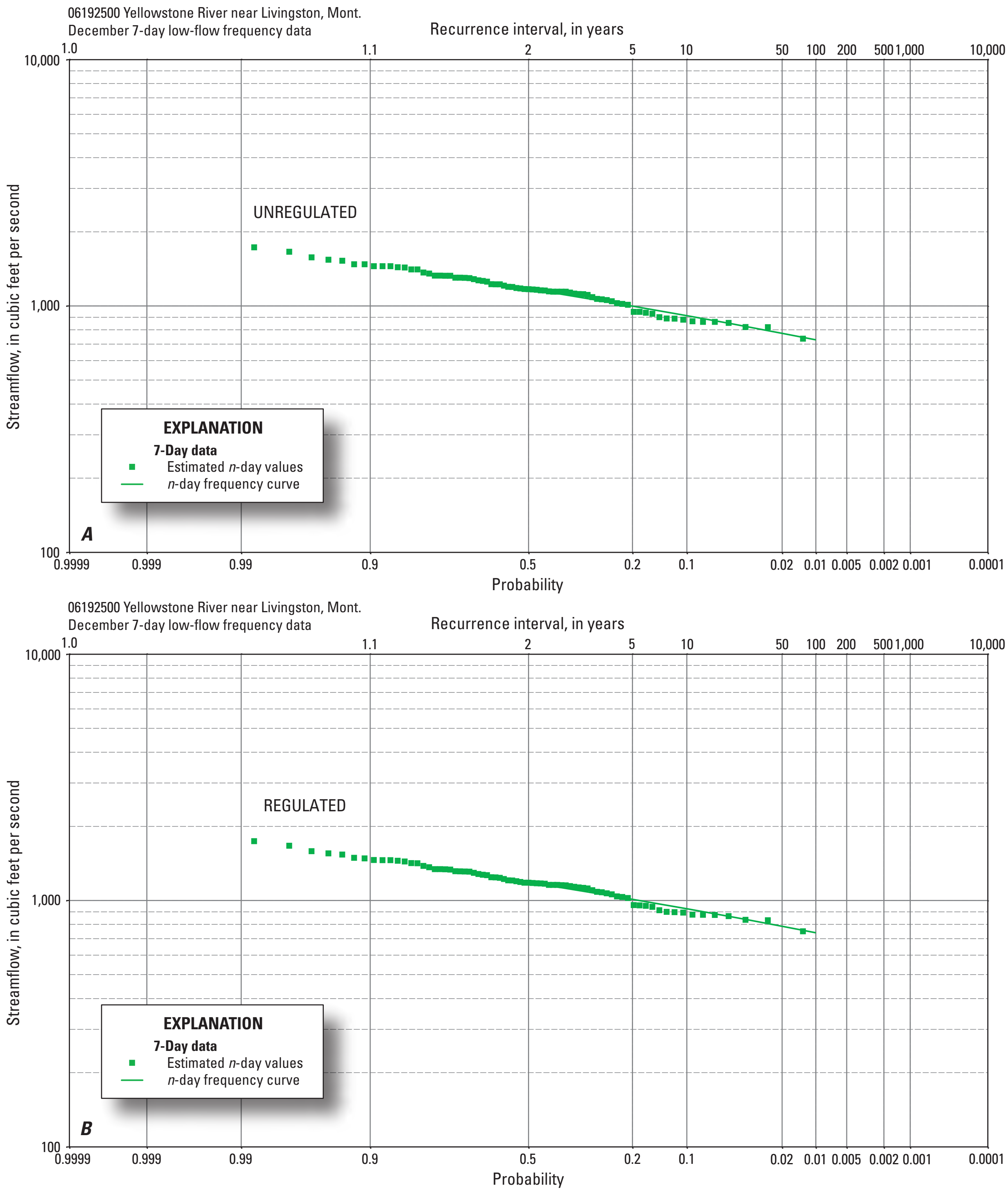


Figure 1–3–17. December 7-day low-flow frequency data for streamflow-gaging station 06192500 (Yellowstone River near Livingston, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

Appendix 1–4. Statistics for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana)

Table 1–4–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft^3/s, cubic feet per second; %, percent]

	Unregulated						
n, period of consecutive days (month, for monthly frequency data)	Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	1,460	1,140	995	883	852	767	696
30	2,070	1,690	1,500	1,350	1,310	1,190	1,090
Winter (January–March)							
7	1,590	1,240	1,080	950	916	821	741
30	2,120	1,750	1,580	1,440	1,400	1,300	1,200
Spring (April–June)							
7	3,290	2,540	2,190	1,920	1,850	1,650	1,480
30	4,460	3,370	2,900	2,550	2,460	2,210	2,010
Summer (July–September)							
7	4,110	3,290	2,910	2,630	2,540	2,330	2,140
30	4,890	3,920	3,460	3,100	3,000	2,720	2,480
Fall (October–December)							
7	1,880	1,400	1,190	1,020	979	859	760
30	2,520	2,070	1,860	1,690	1,640	1,520	1,410
Monthly							
7 (January)	1,800	1,390	1,180	1,020	978	856	755
7 (February)	1,980	1,530	1,320	1,160	1,120	1,000	901
7 (March)	2,350	1,940	1,740	1,600	1,560	1,450	1,350
7 (April)	3,290	2,540	2,190	1,920	1,850	1,650	1,480
7 (May)	7,270	5,140	4,250	3,610	3,440	2,990	2,630
7 (June)	19,900	15,000	12,800	11,100	10,700	9,440	8,420
7 (July)	10,260	7,400	6,170	5,290	5,050	4,420	3,910
7 (August)	5,510	4,330	3,800	3,390	3,280	2,980	2,730
7 (September)	4,140	3,310	2,930	2,640	2,550	2,330	2,140
7 (October)	3,400	2,680	2,360	2,110	2,050	1,860	1,710
7 (November)	2,830	2,150	1,820	1,550	1,480	1,280	1,110
7 (December)	1,940	1,450	1,220	1,050	1,010	879	774

Table 1–4–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for unregulated and regulated streamflow conditions, 1928–2002.—Continued

[ft^3/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Regulated						
	Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
				Annual			
7	1,570	1,250	1,100	991	959	874	801
30	2,180	1,780	1,580	1,420	1,380	1,260	1,150
				Winter (January–March)			
7	1,690	1,340	1,180	1,050	1,020	920	839
30	2,230	1,860	1,690	1,560	1,520	1,410	1,320
				Spring (April–June)			
7	3,010	2,330	2,000	1,740	1,670	1,480	1,320
30	3,980	3,040	2,620	2,310	2,220	1,990	1,800
				Summer (July–September)			
7	3,200	2,370	2,000	1,730	1,660	1,460	1,300
30	3,700	2,700	2,260	1,940	1,850	1,620	1,420
				Fall (October–December)			
7	2,060	1,580	1,360	1,190	1,150	1,020	914
30	2,730	2,280	2,060	1,890	1,840	1,700	1,580
				Monthly			
7 (January)	1,920	1,500	1,300	1,140	1,090	968	863
7 (February)	2,080	1,620	1,410	1,250	1,200	1,080	977
7 (March)	2,400	1,990	1,800	1,660	1,620	1,500	1,410
7 (April)	3,010	2,330	2,000	1,750	1,680	1,480	1,320
7 (May)	5,830	4,290	3,730	3,350	3,250	2,990	2,790
7 (June)	17,300	12,400	10,200	8,650	8,220	7,080	6,150
7 (July)	7,750	4,950	3,820	3,050	2,850	2,330	1,900
7 (August)	3,770	2,650	2,170	1,830	1,740	1,500	1,310
7 (September)	3,330	2,450	2,060	1,770	1,700	1,490	1,320
7 (October)	3,540	2,760	2,410	2,140	2,070	1,870	1,700
7 (November)	3,120	2,450	2,110	1,850	1,770	1,560	1,390
7 (December)	2,110	1,620	1,390	1,210	1,160	1,020	912

Table 1–4–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second]

Unregulated

Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
January	3,720	1984	1,200	1940	2,350	513
February	4,281	1997	1,440	1932	2,550	655
March	5,450	1979	1,700	2002	2,970	728
April	9,600	1943	1,650	1961	4,640	1,520
May	32,300	1928	7,020	1953	15,280	4,630
June	56,300	1997	12,900	2001	28,600	8,350
July	39,900	1975	6,650	1934	17,050	6,620
August	11,960	1997	3,940	1988	7,500	2,100
September	8,130	1968	2,400	1988	5,010	1,180
October	6,600	1941	2,080	2001	3,900	1,060
November	4,890	1983	1,890	1931	3,230	720
December	4,290	1975	1,380	1932	2,580	547
Annual	13,100	1997	4,690	2001	7,980	1,695

Regulated

Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
January	3,840	1984	1,340	1940	2,480	512
February	4,380	1997	1,540	1932	2,650	652
March	5,480	1979	1,770	2002	3,020	722
April	8,880	1943	1,440	1961	4,140	1,290
May	29,800	1928	5,680	1953	13,000	4,370
June	53,900	1997	9,860	1987	25,400	8,400
July	37,100	1975	3,400	1988	13,800	6,560
August	9,810	1997	1,470	2001	5,300	2,100
September	7,300	1968	1,530	2001	4,110	1,340
October	6,780	1941	2,130	2001	4,000	1,060
November	5,180	1983	2,210	1931	3,540	707
December	4,460	1975	1,550	1932	2,780	542
Annual	12,250	1997	3,610	2001	7,020	1,750

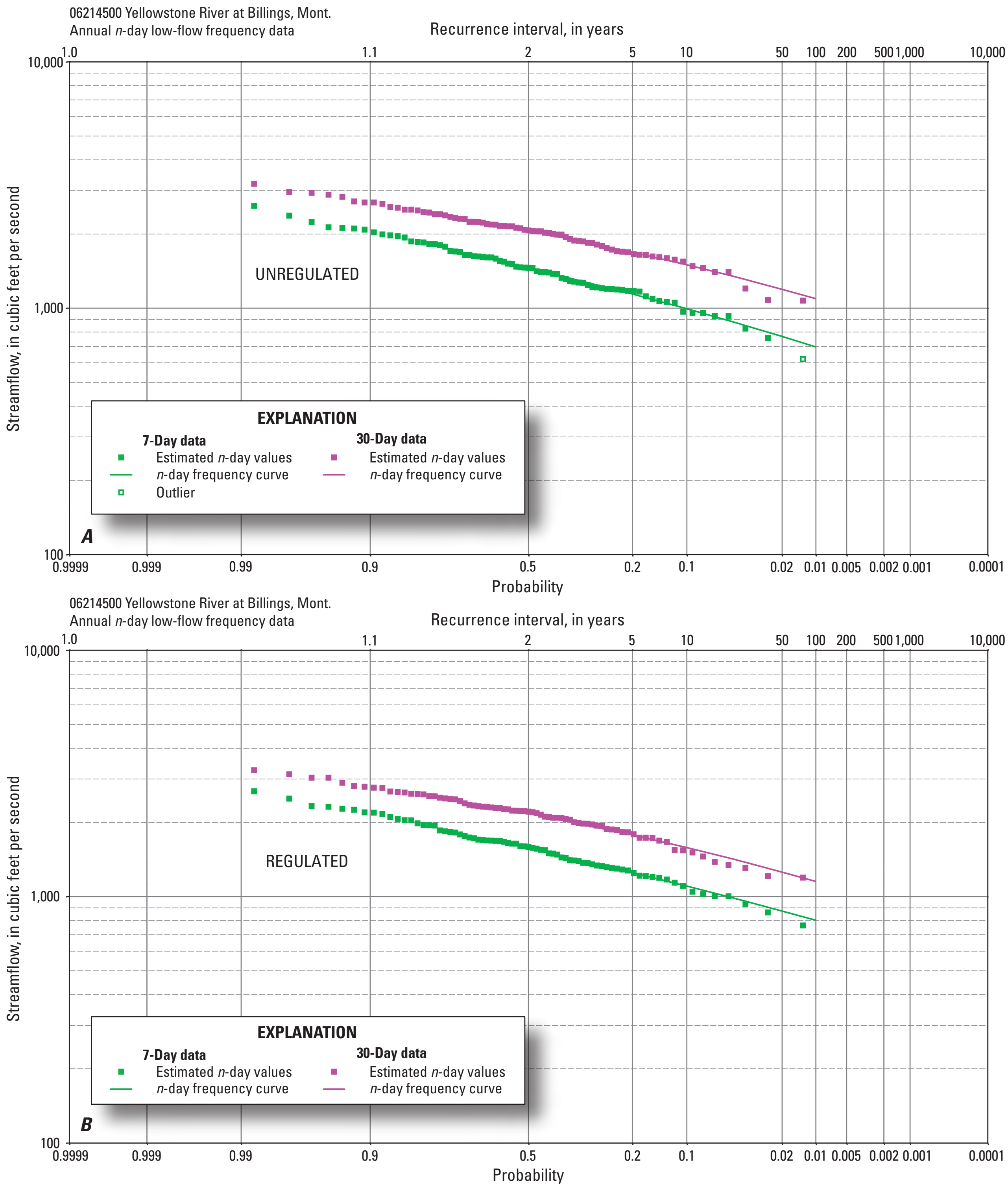
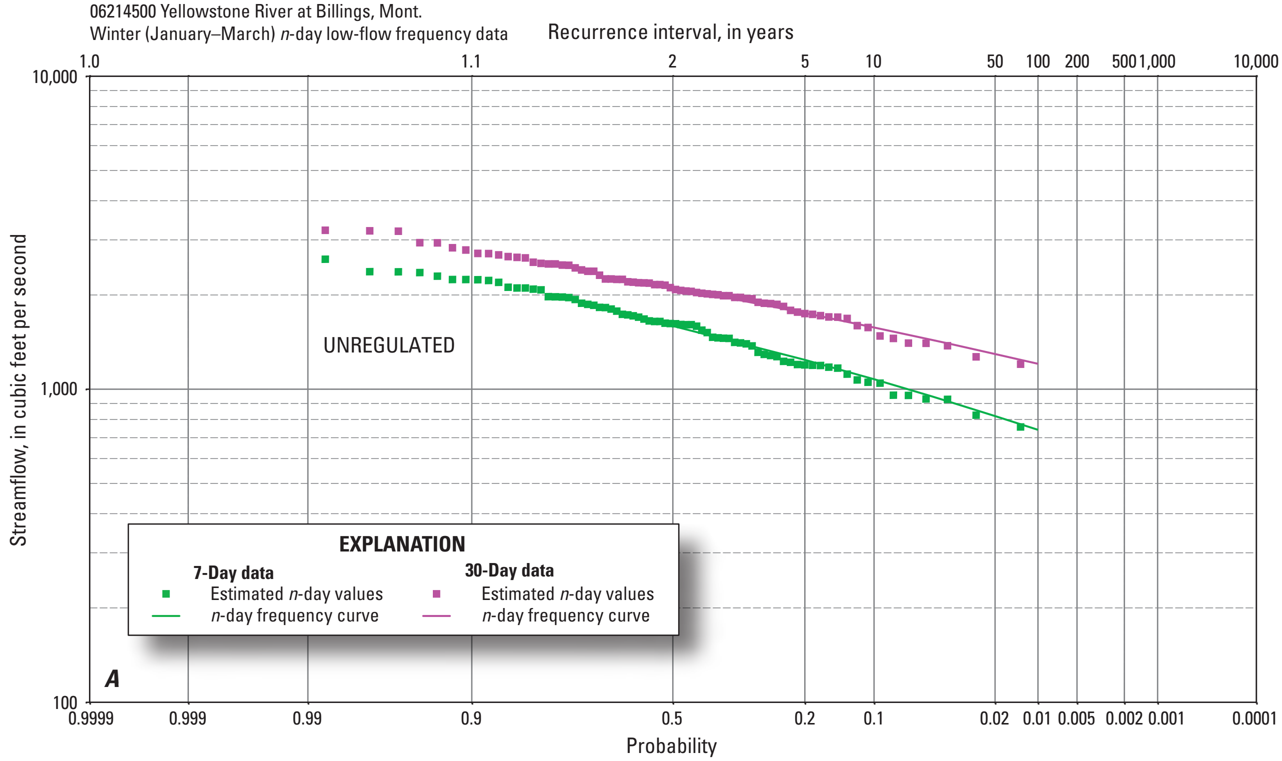


Figure 1–4–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



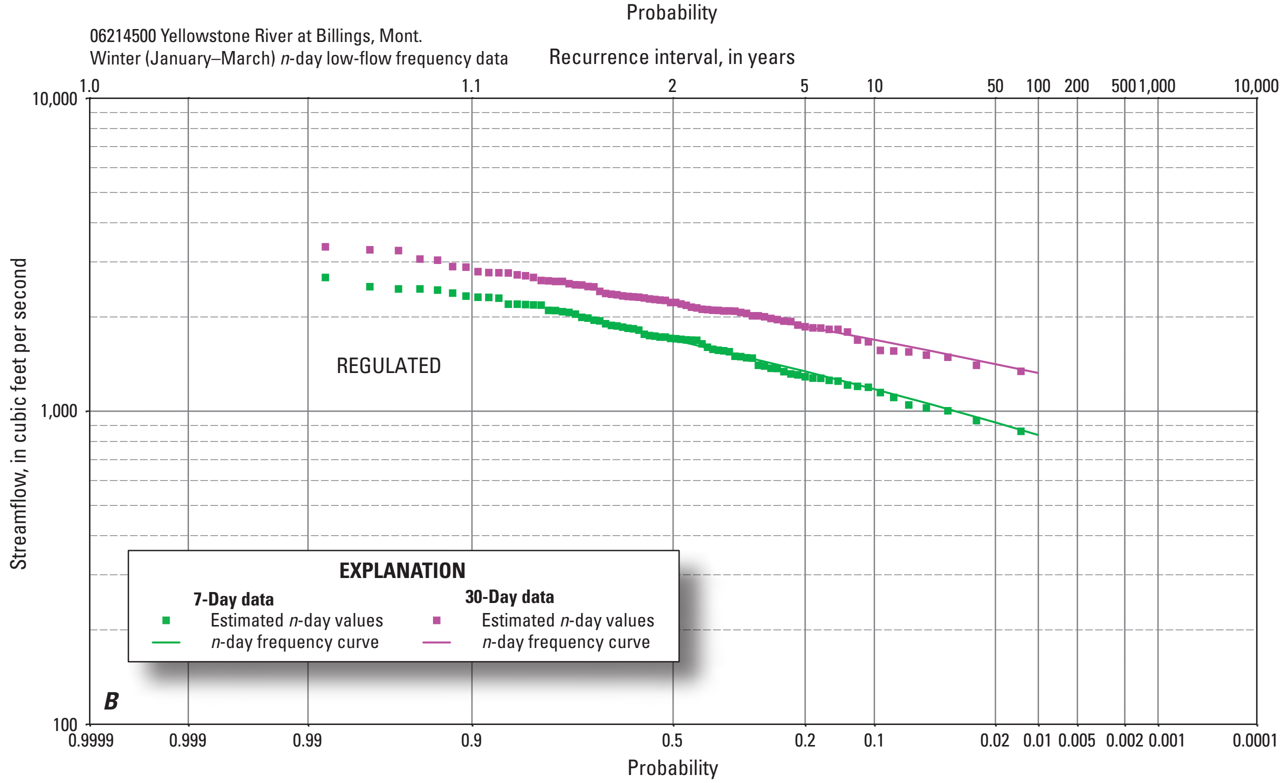


Figure 1–4–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

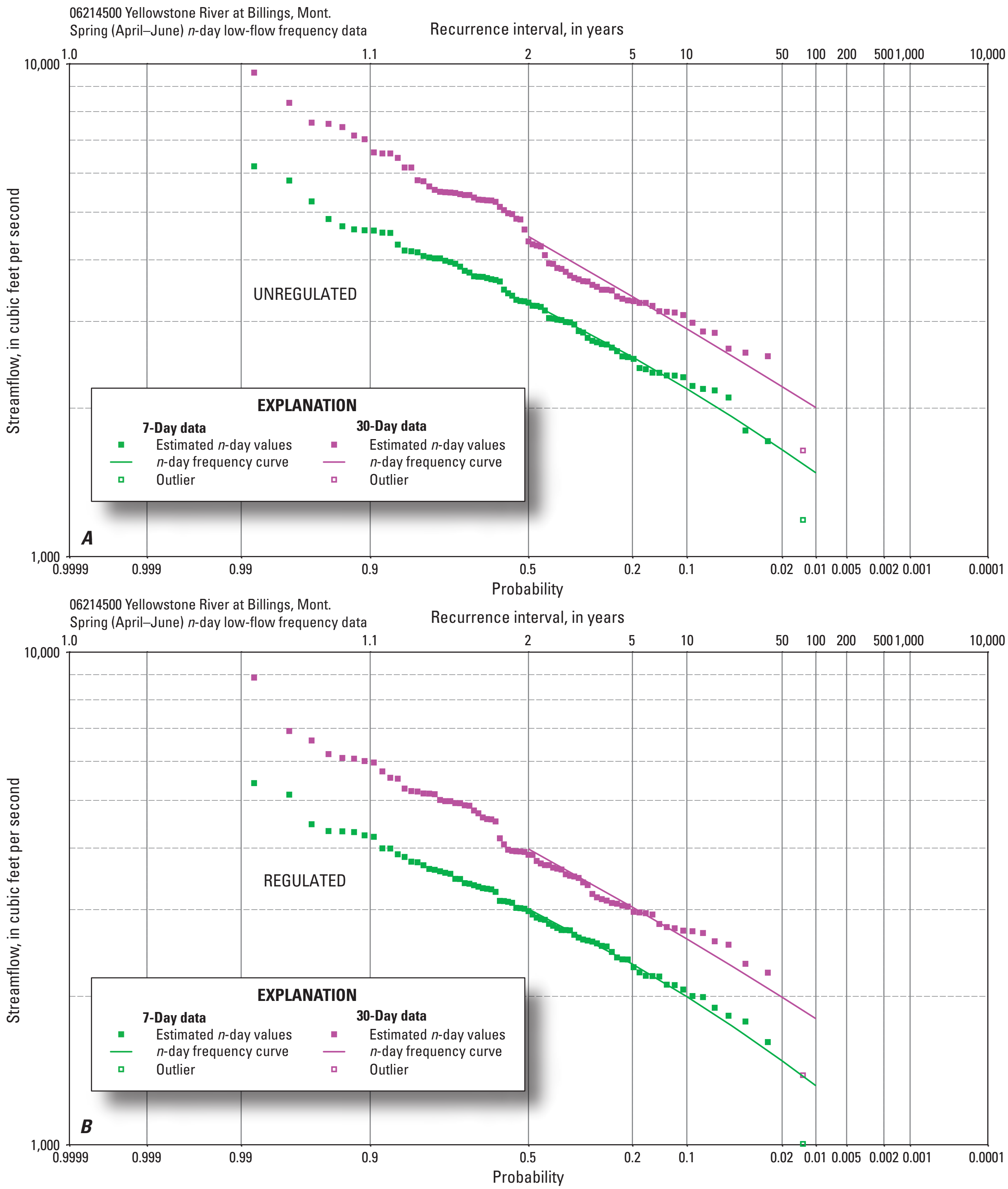


Figure 1–4–3. Spring (April–June) *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

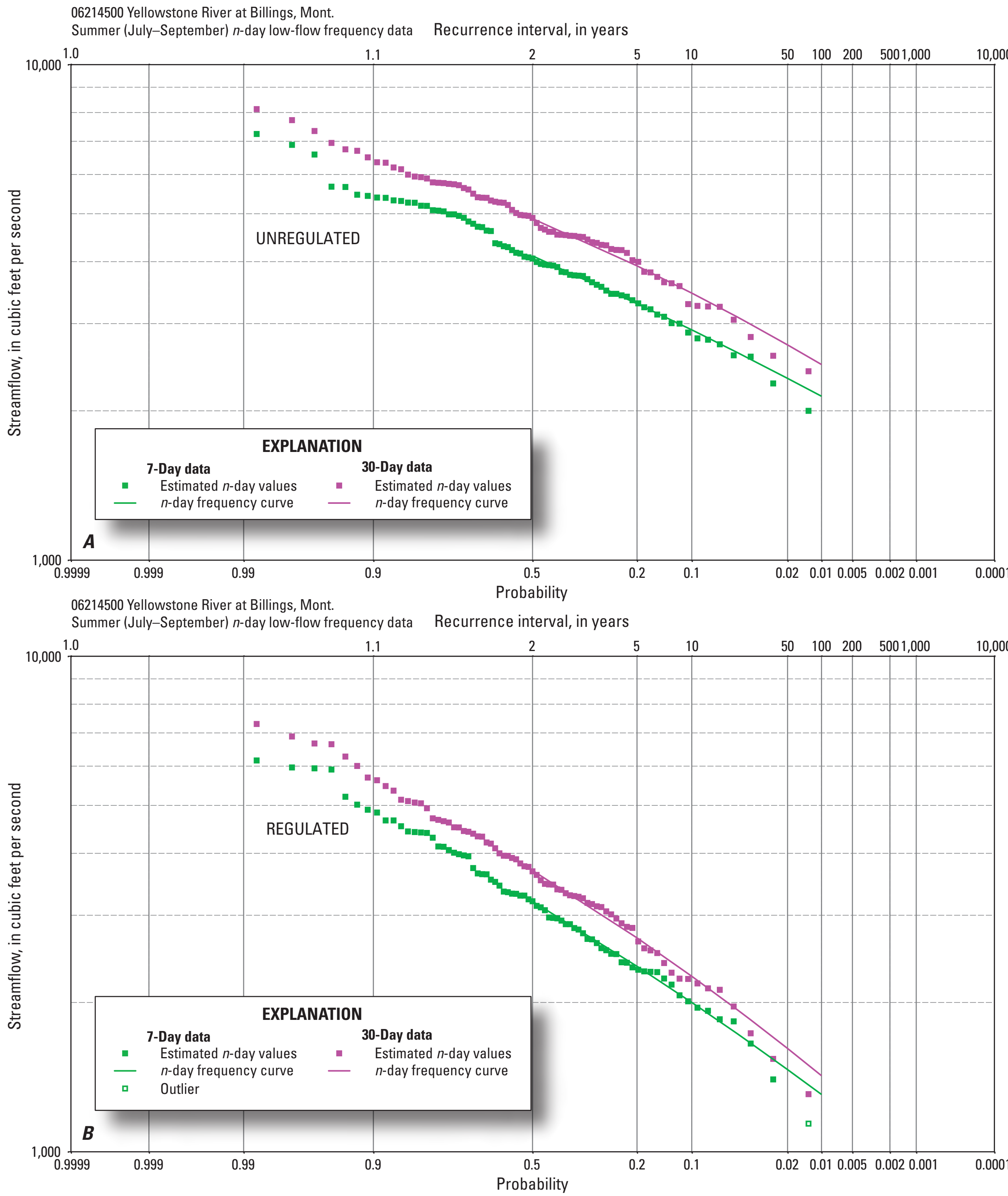
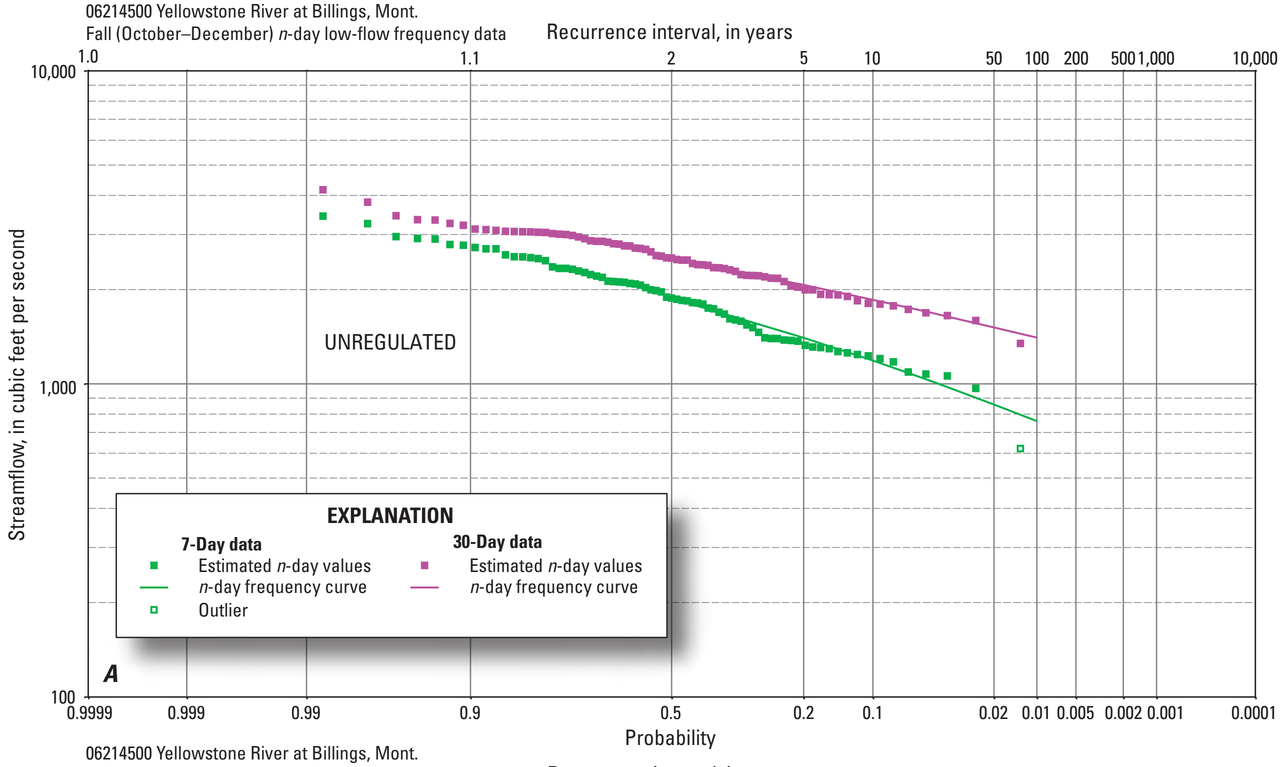


Figure 1–4–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



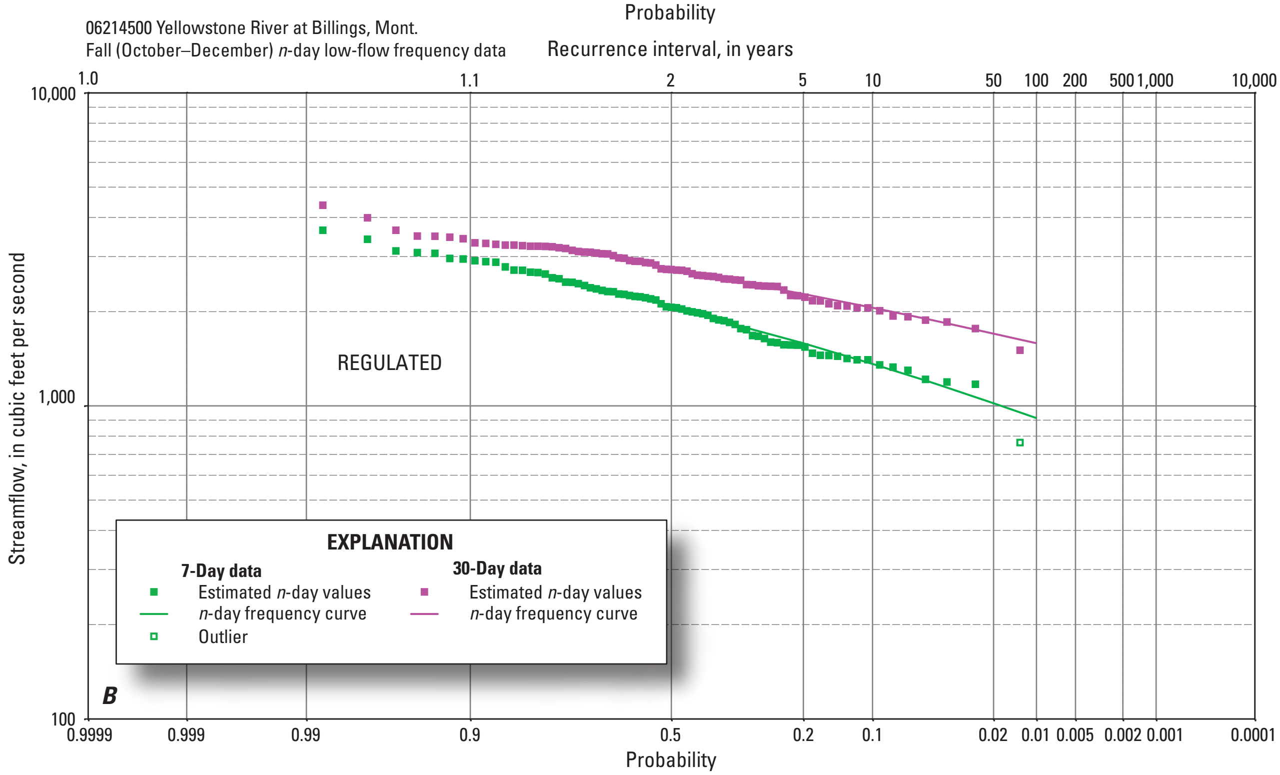
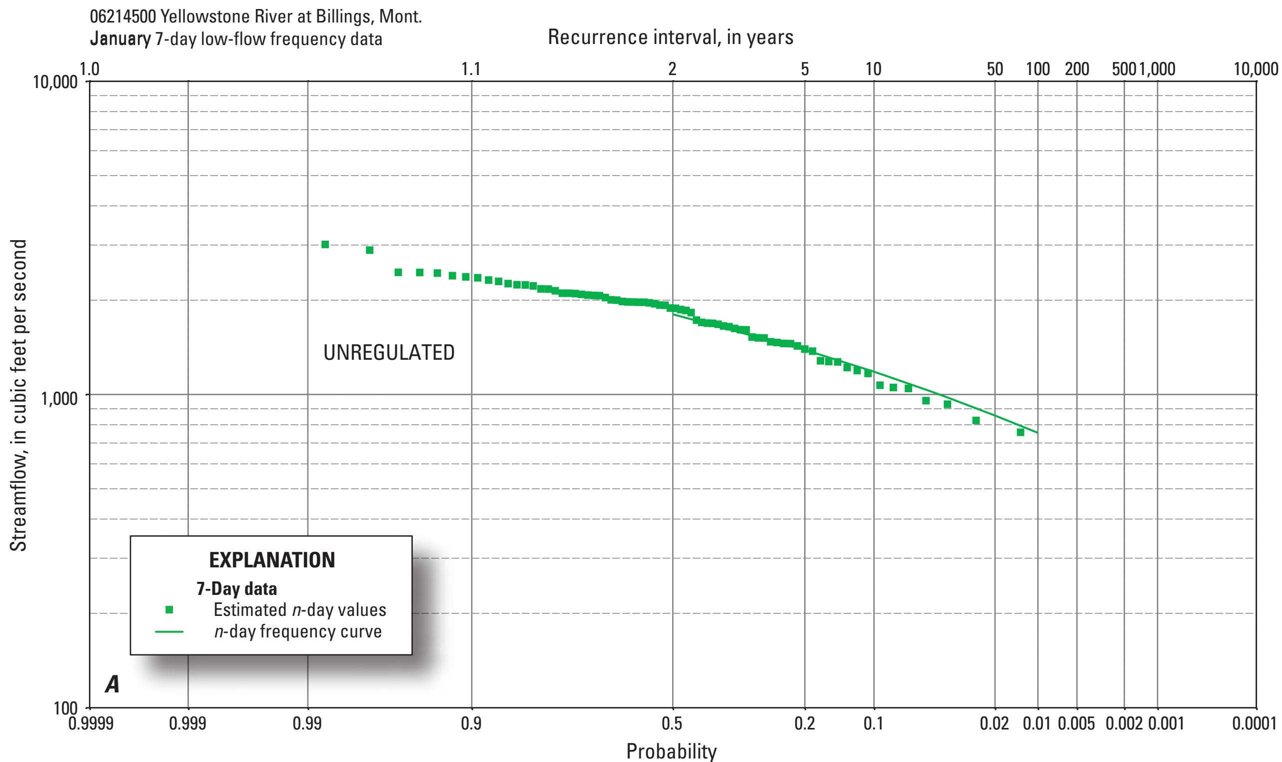


Figure 1–4–5. Fall (October–December) *n*-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



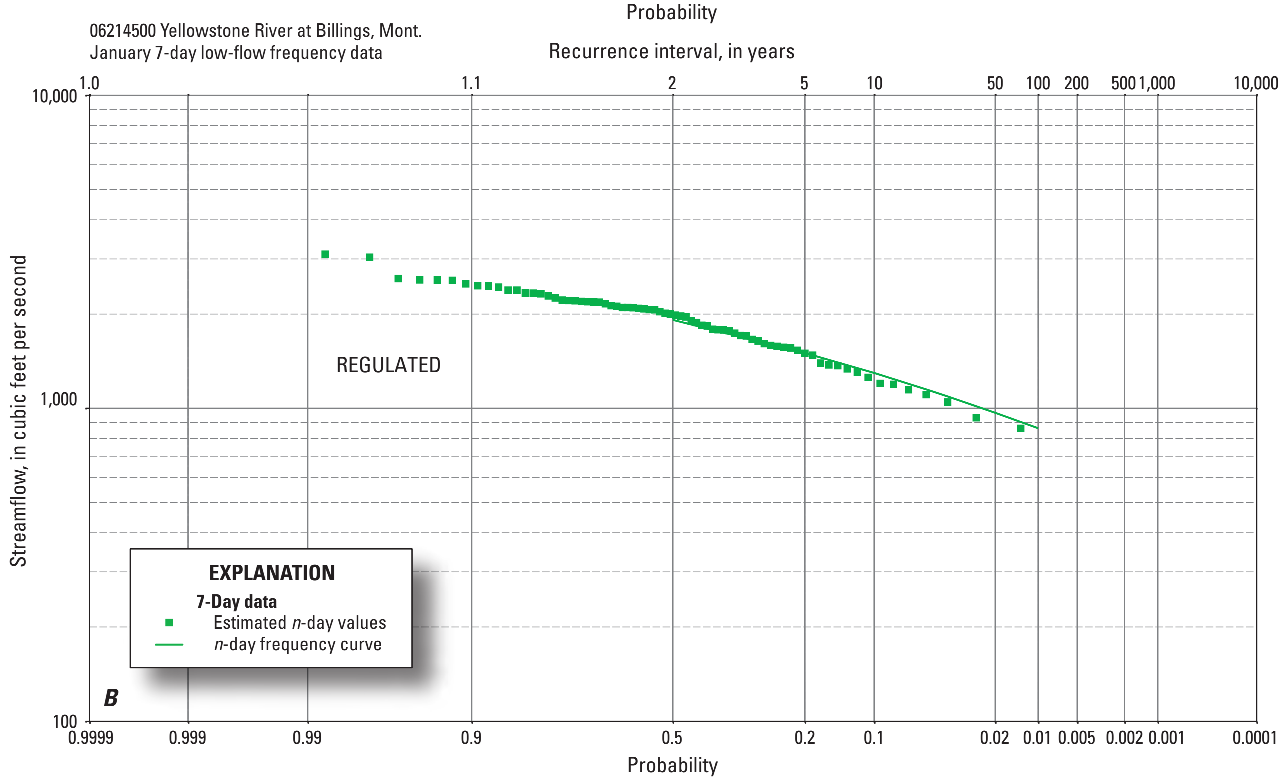
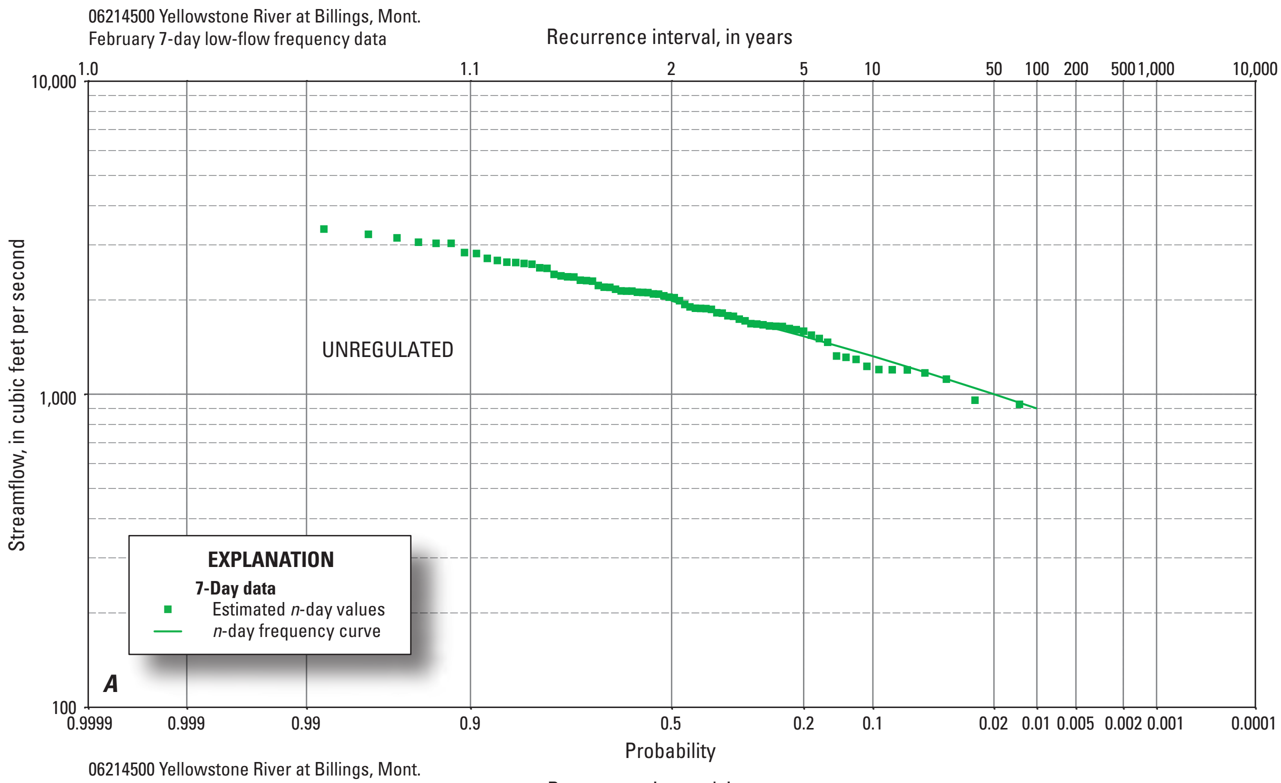


Figure 1–4–6. January 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



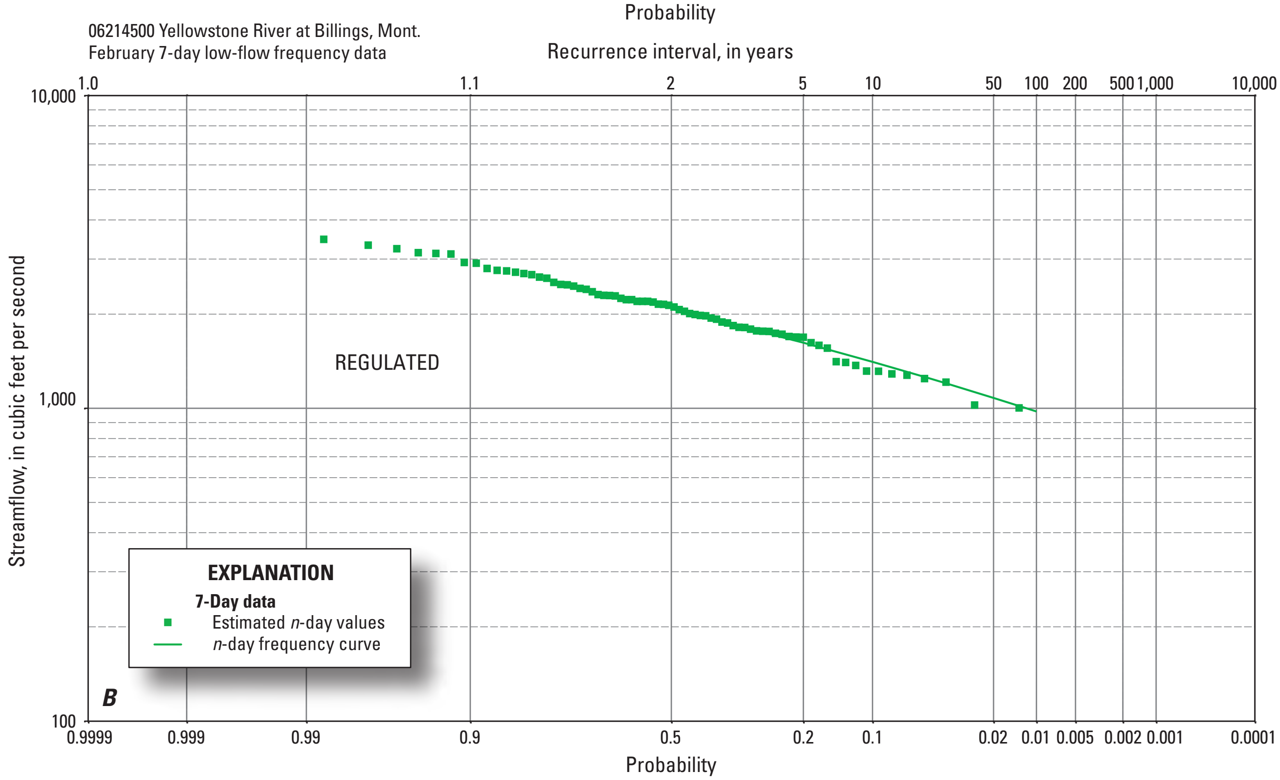
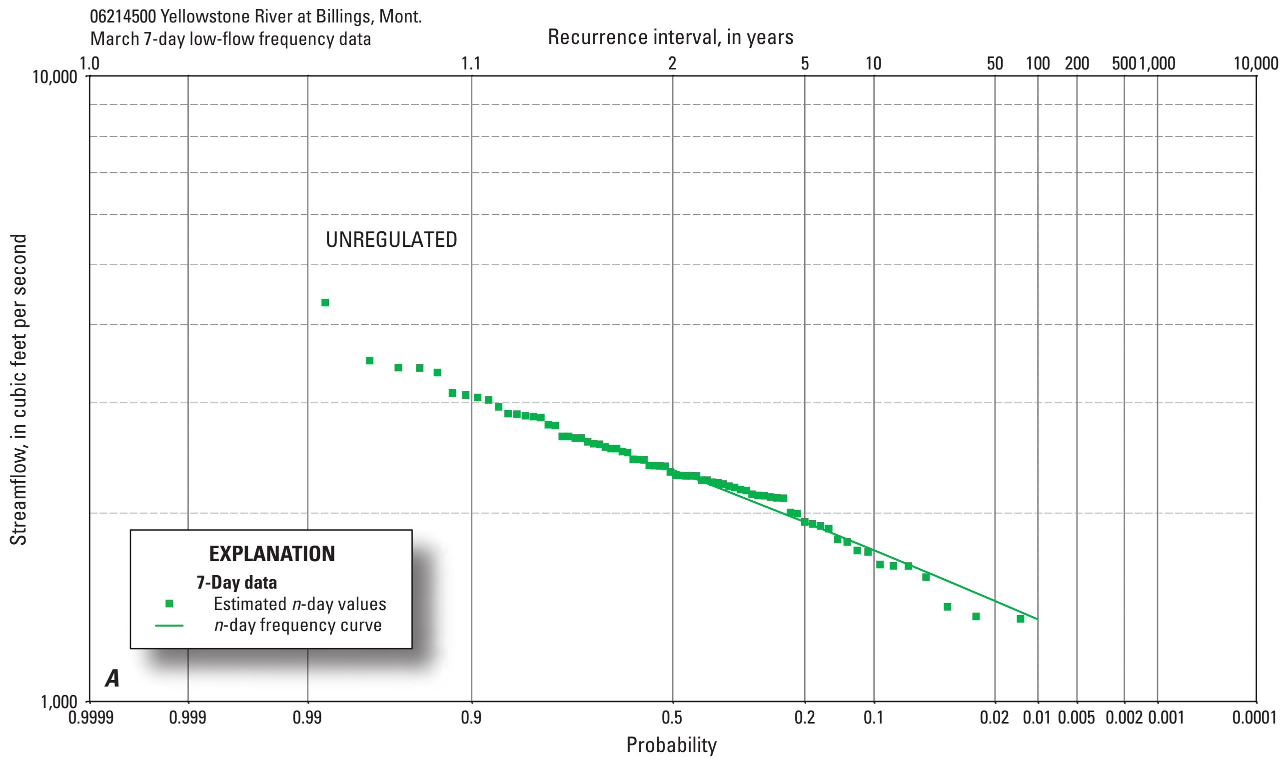


Figure 1–4–7. February 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



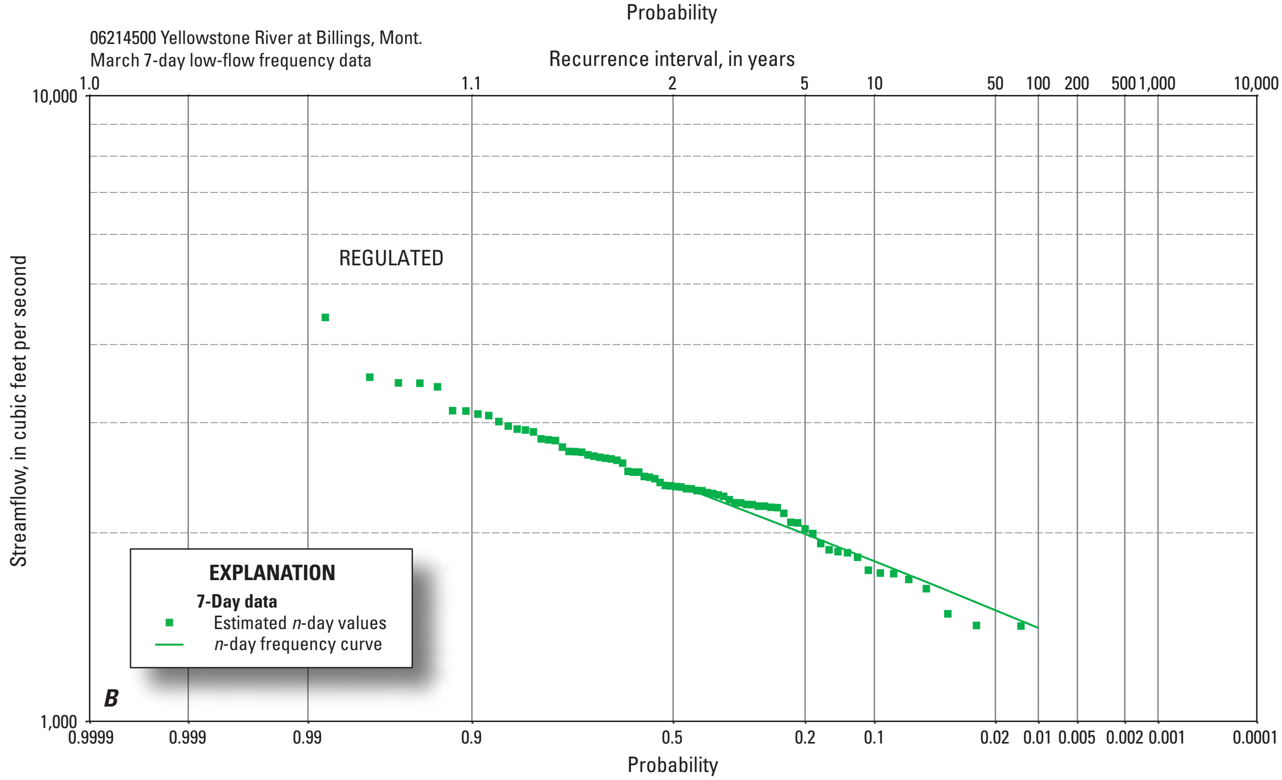
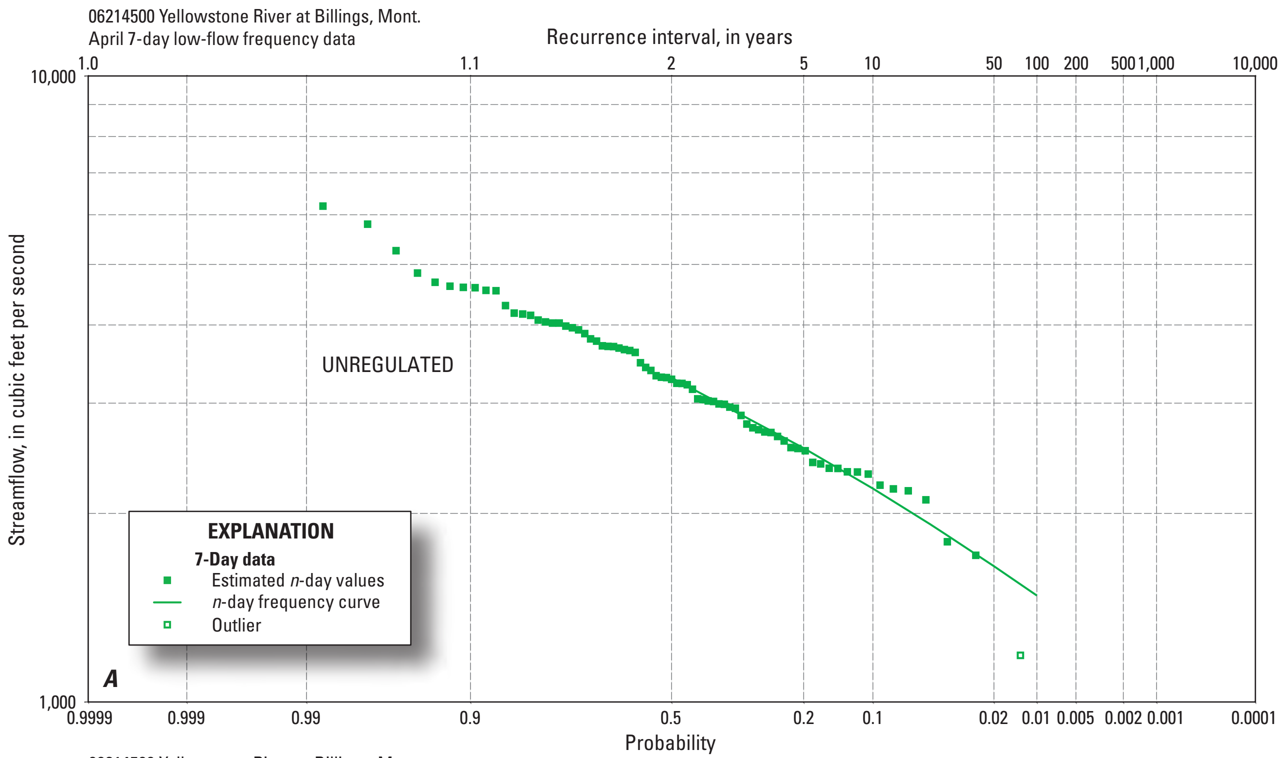


Figure 1–4–8. March 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



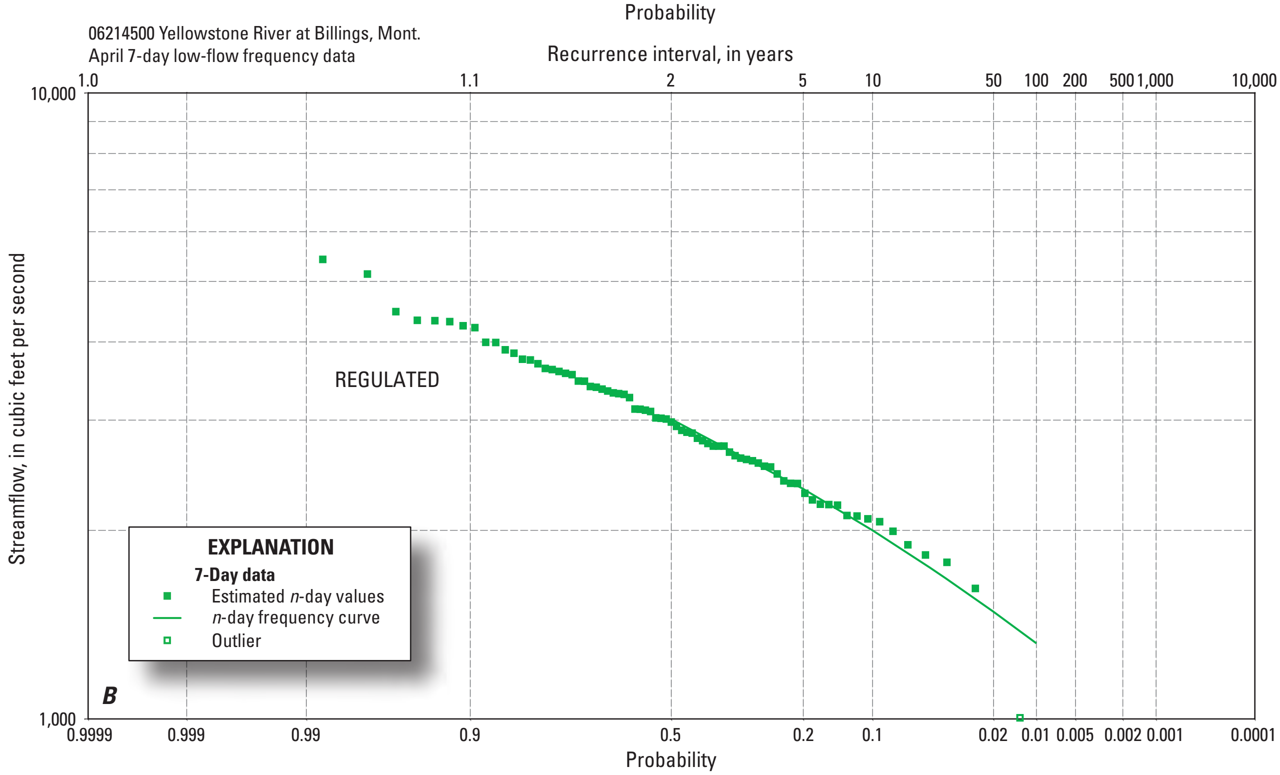
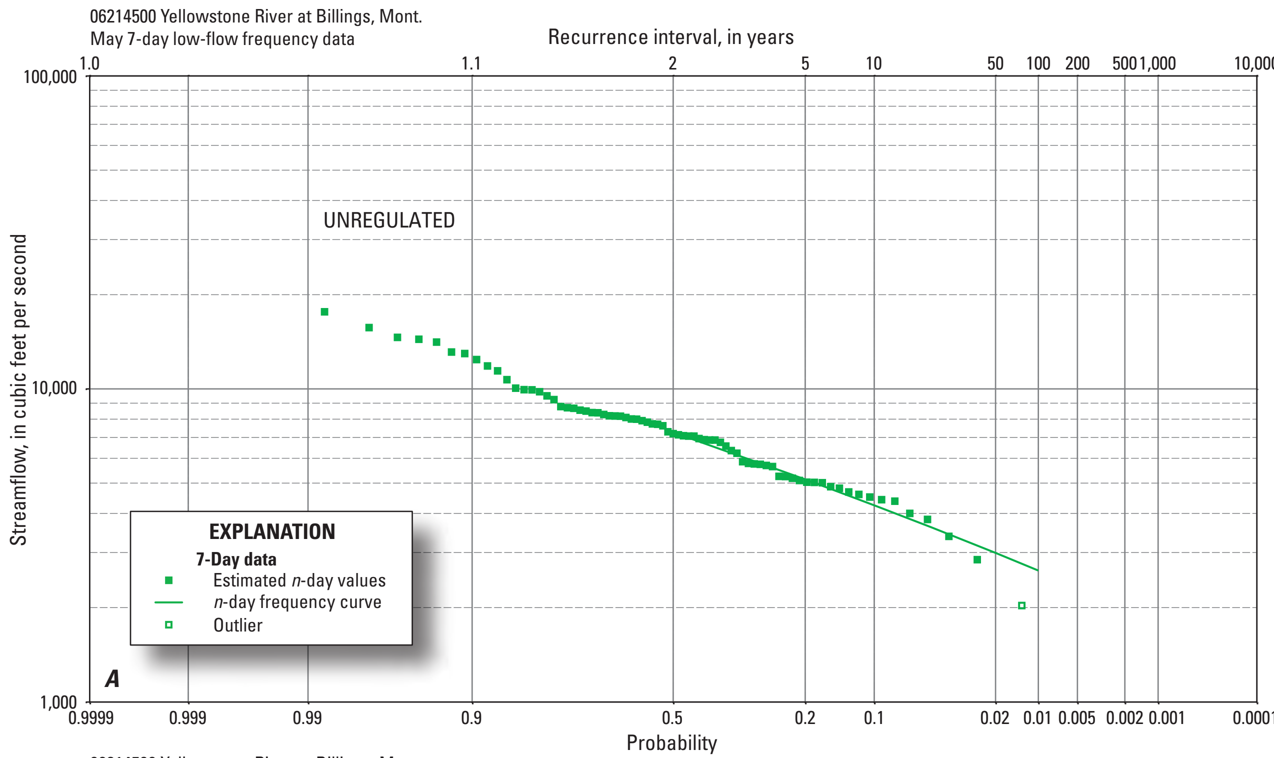


Figure 1–4–9. April 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



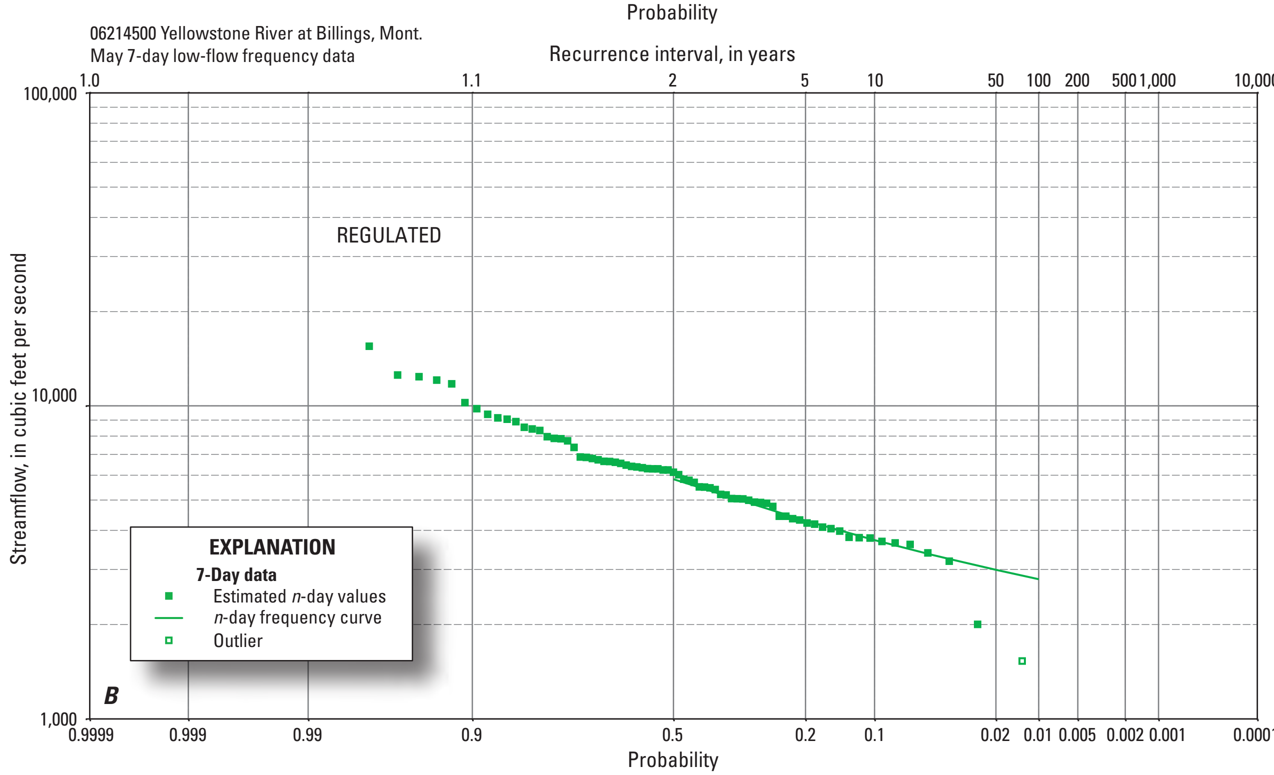


Figure 1–4–10. May 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

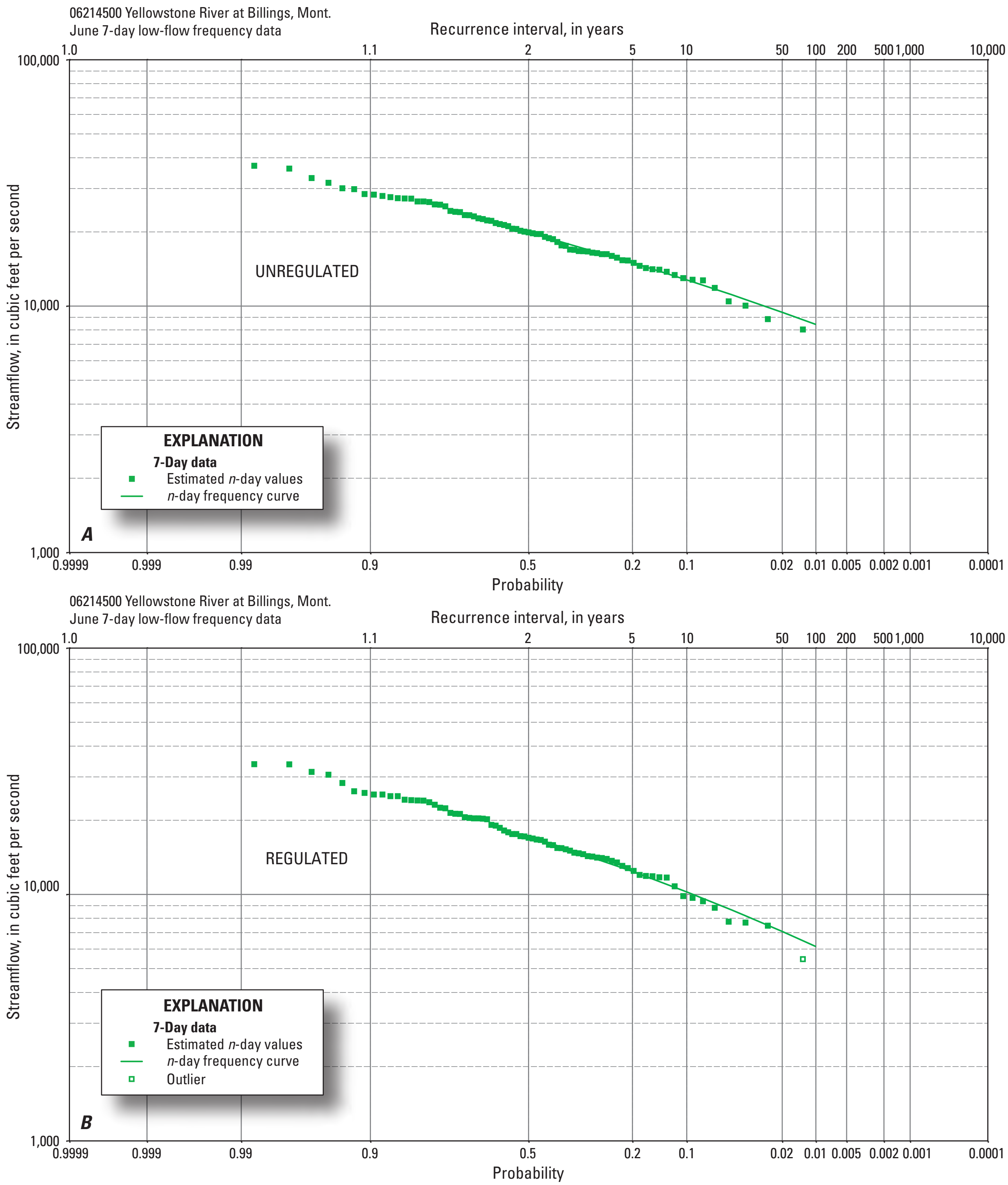


Figure 1–4–11. June 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

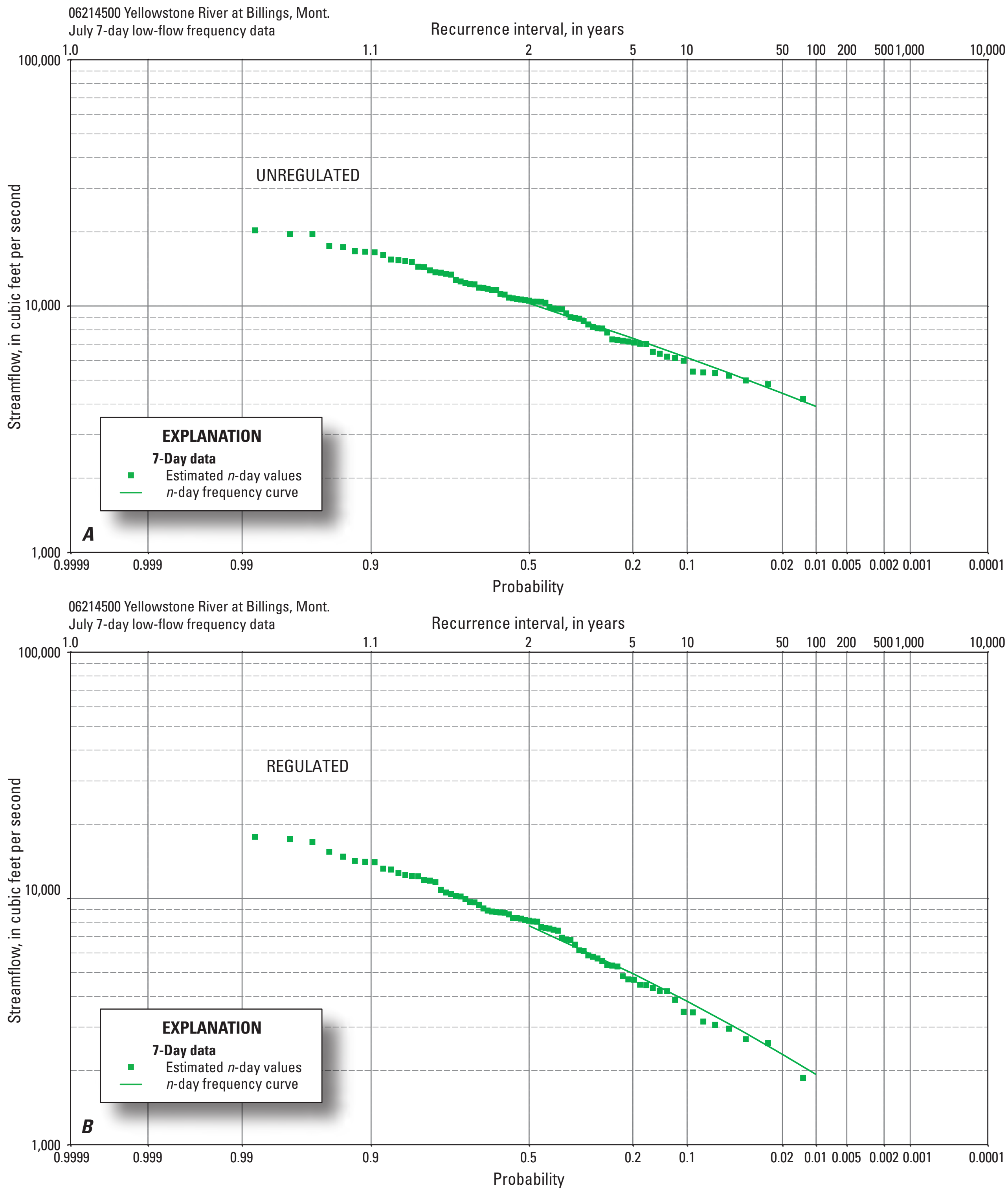
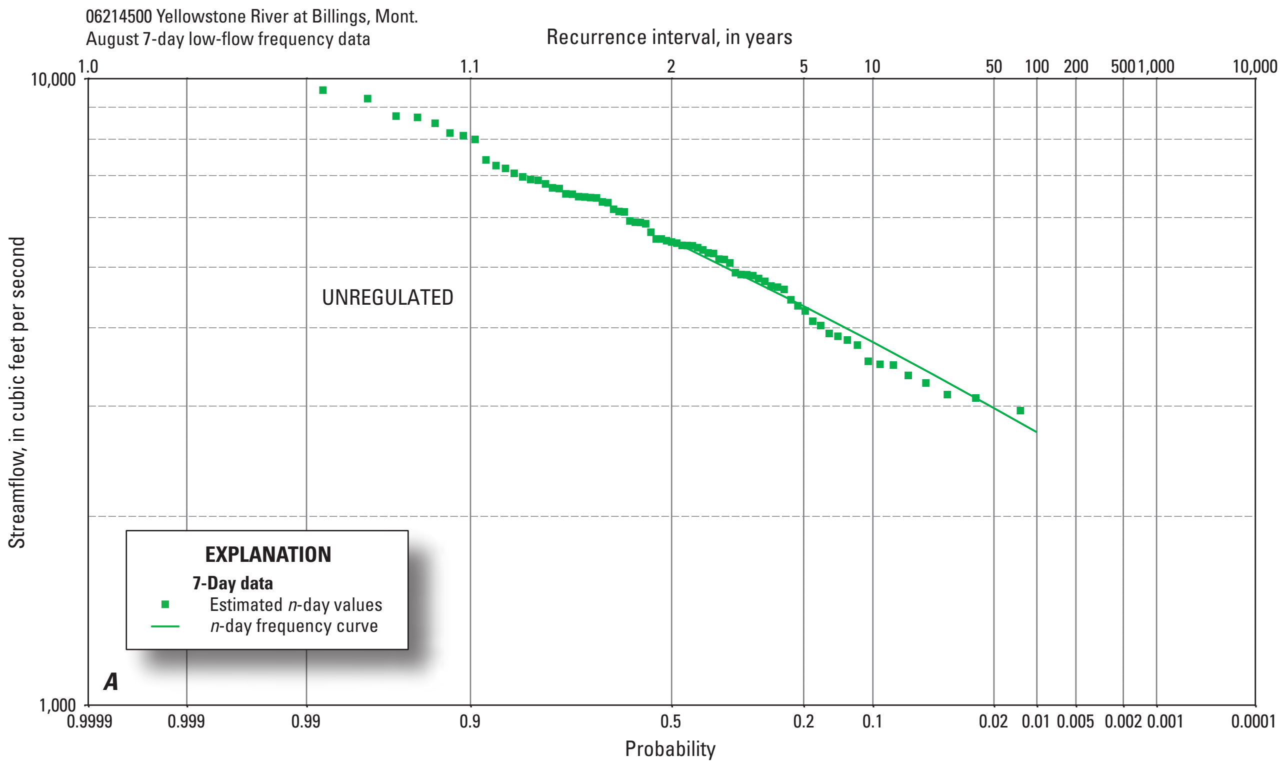


Figure 1–4–12. July 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



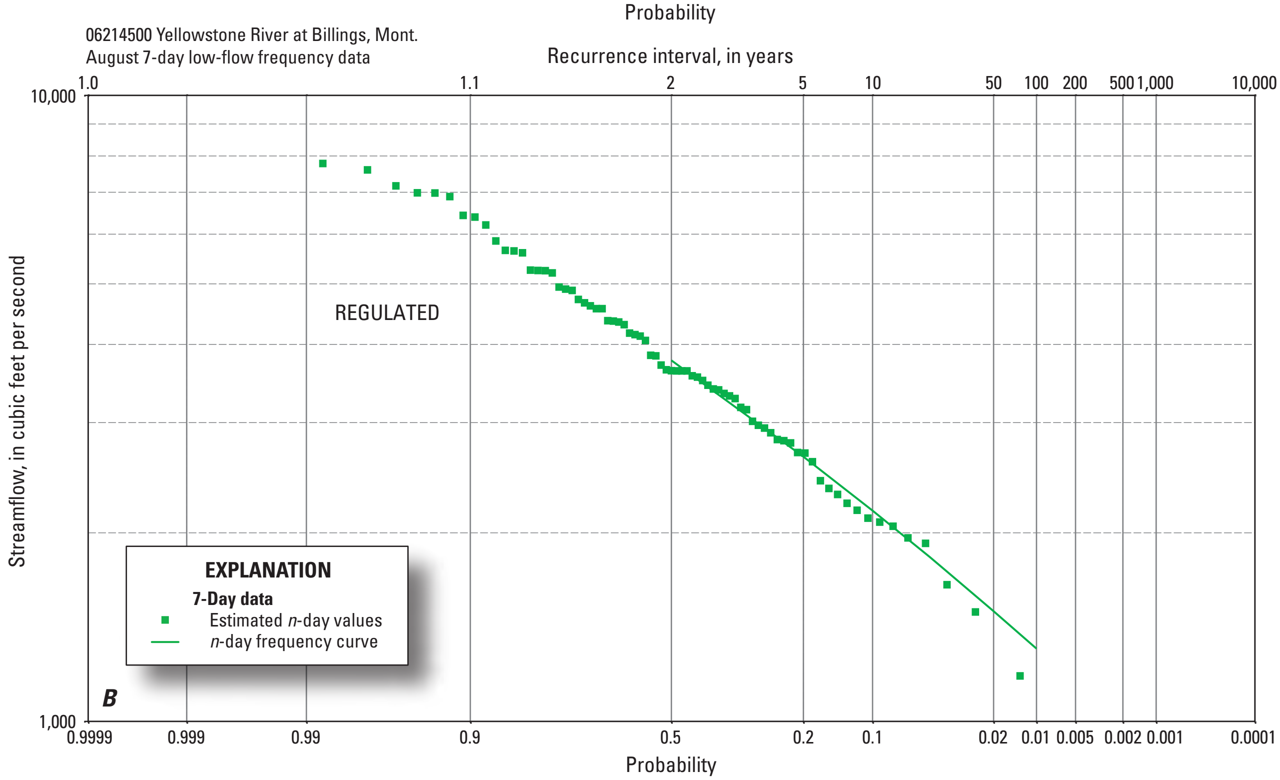


Figure 1–4–13. August 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

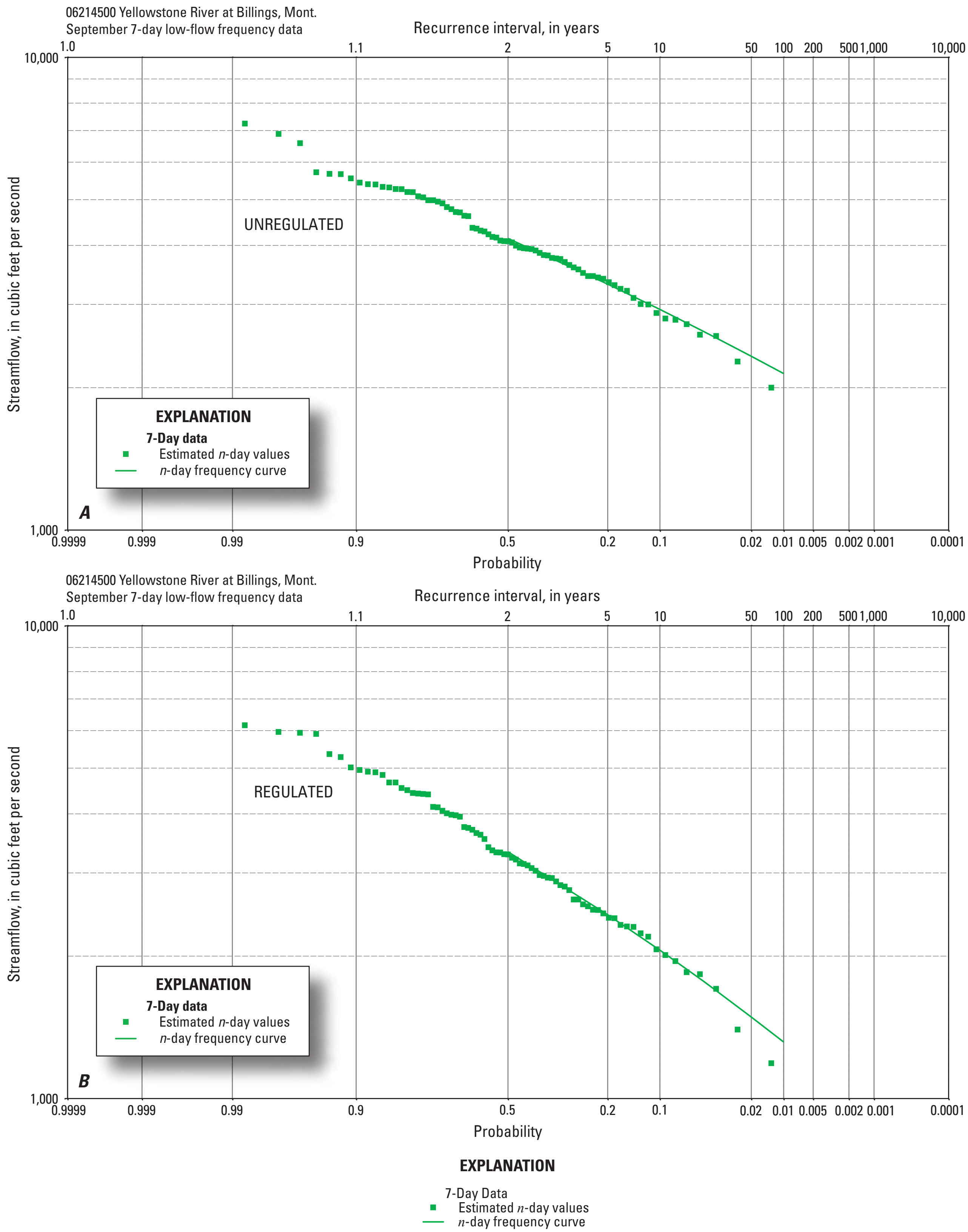
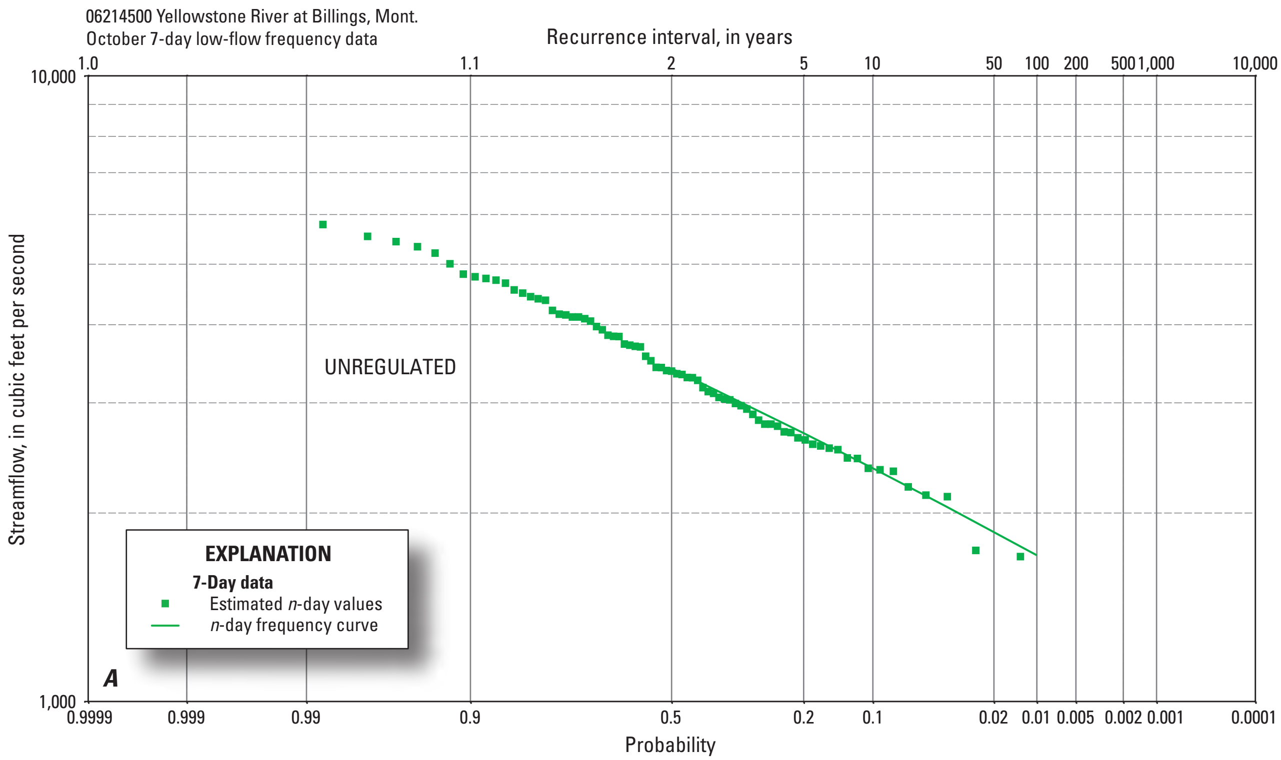


Figure 1–4–14. September 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



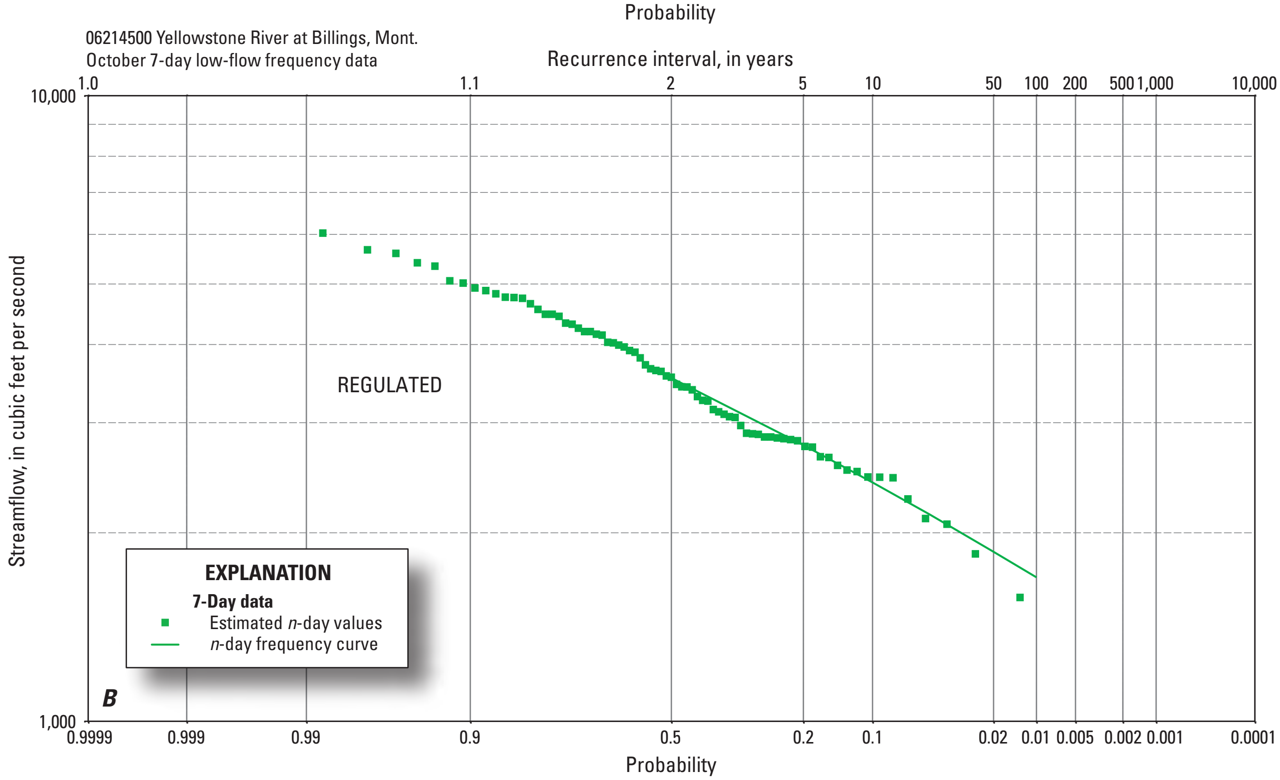


Figure 1–4–15. October 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

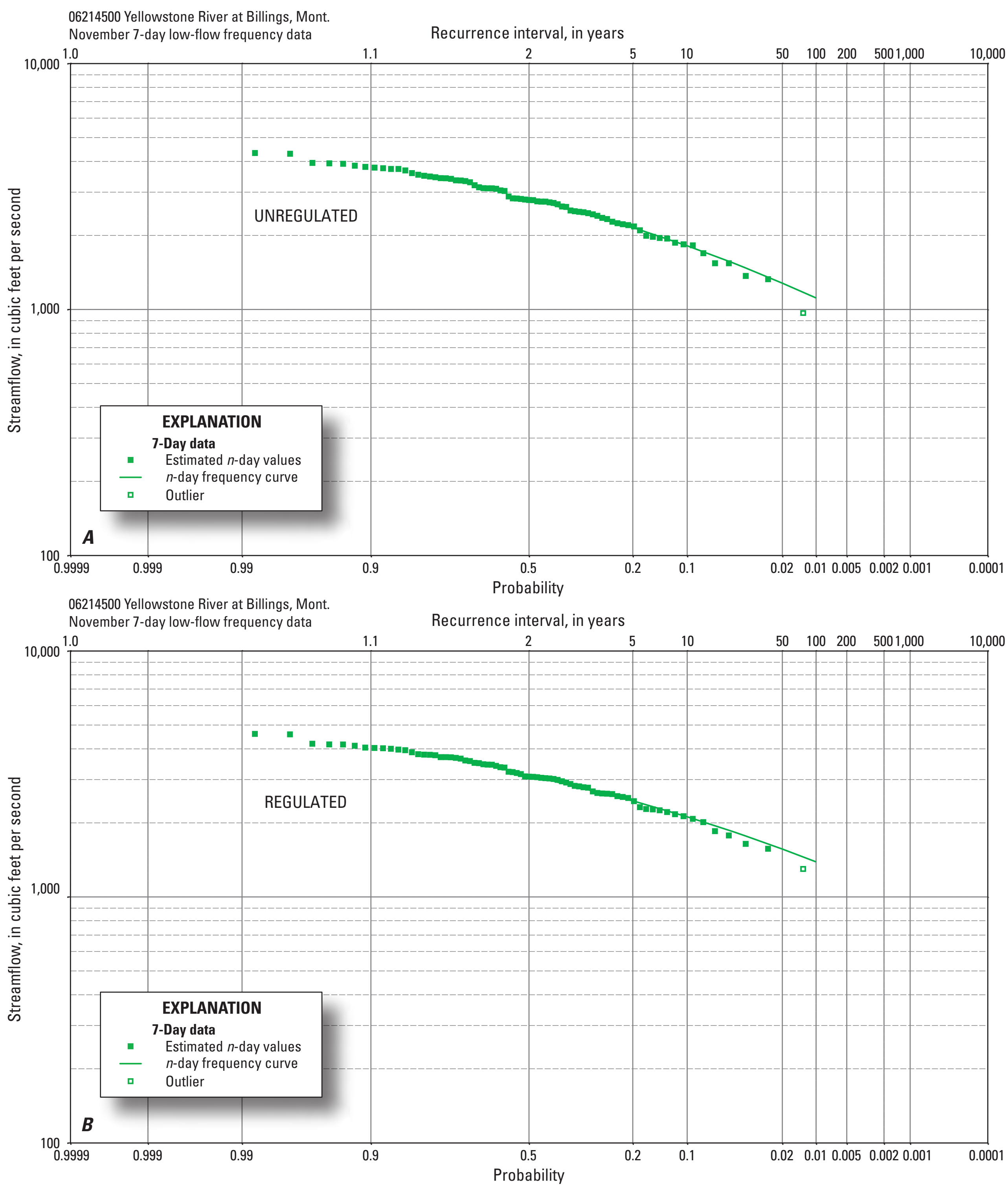


Figure 1–4–16. November 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

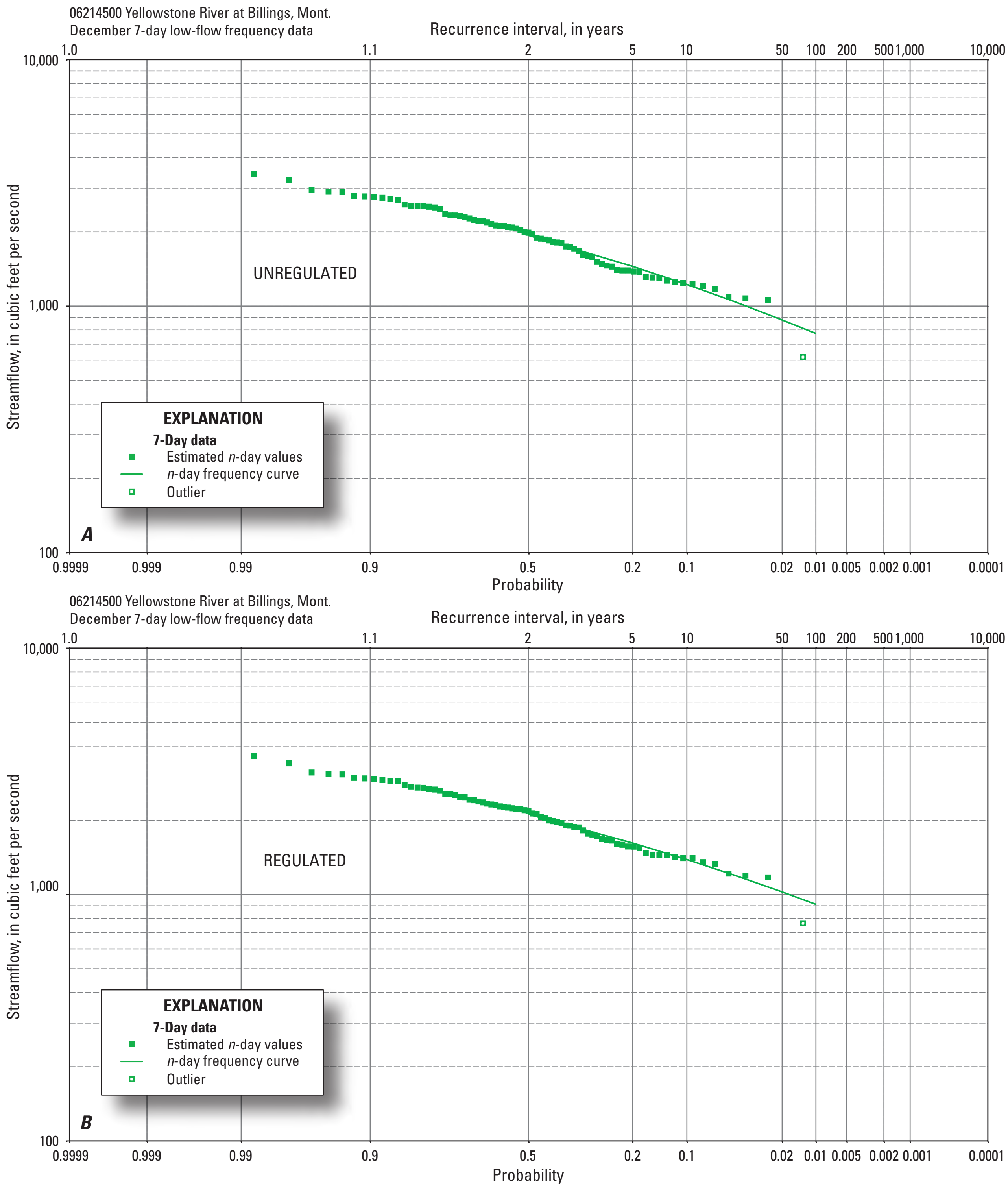


Figure 1–4–17. December 7-day low-flow frequency data for streamflow-gaging station 06214500 (Yellowstone River at Billings, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

Appendix 1–5. Statistics for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana)

Table 1–5–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Unregulated						
	Streamflow, in ft³/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	1,000	300	1	0	0	0	0
30	1,600	875	550	344	296	184	115
Winter (January–March)							
7	1,350	658	386	228	192	113	67
30	1,940	1,100	679	410	347	206	121
Spring (April–June)							
7	3,210	2,350	1,990	1,740	1,670	1,490	1,340
30	3,930	2,900	2,460	2,140	2,050	1,820	1,630
Summer (July–September)							
7	2,810	1,980	1,580	1,270	1,190	970	796
30	3,510	2,730	2,340	2,040	1,950	1,720	1,520
Fall (October–December)							
7	1,110	425	124	28	16	3	1
30	1,860	1,140	787	543	482	332	229
Monthly							
7 (January)	1,450	712	421	250	212	126	76
7 (February)	1,720	1,050	699	450	403	220	67
7 (March)	2,110	1,420	1,130	935	883	746	639
7 (April)	3,210	2,350	1,990	1,740	1,670	1,490	1,340
7 (May)	7,640	5,920	5,110	4,490	4,310	3,840	3,450
7 (June)	11,100	8,600	7,500	6,700	6,500	5,890	5,400
7 (July)	7,700	6,140	5,510	5,050	4,930	4,610	4,340
7 (August)	4,720	3,990	3,640	3,370	3,290	3,080	2,890
7 (September)	2,860	2,000	1,580	1,270	1,190	965	790
7 (October)	2,060	1,340	1,020	788	728	574	456
7 (November)	1,810	961	446	180	131	47	16
7 (December)	1,240	721	271	72	44	9	2

Table 1–5–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for unregulated and regulated streamflow conditions, 1928–2002.—Continued

[ft³/s, cubic feet per second; %, percent]

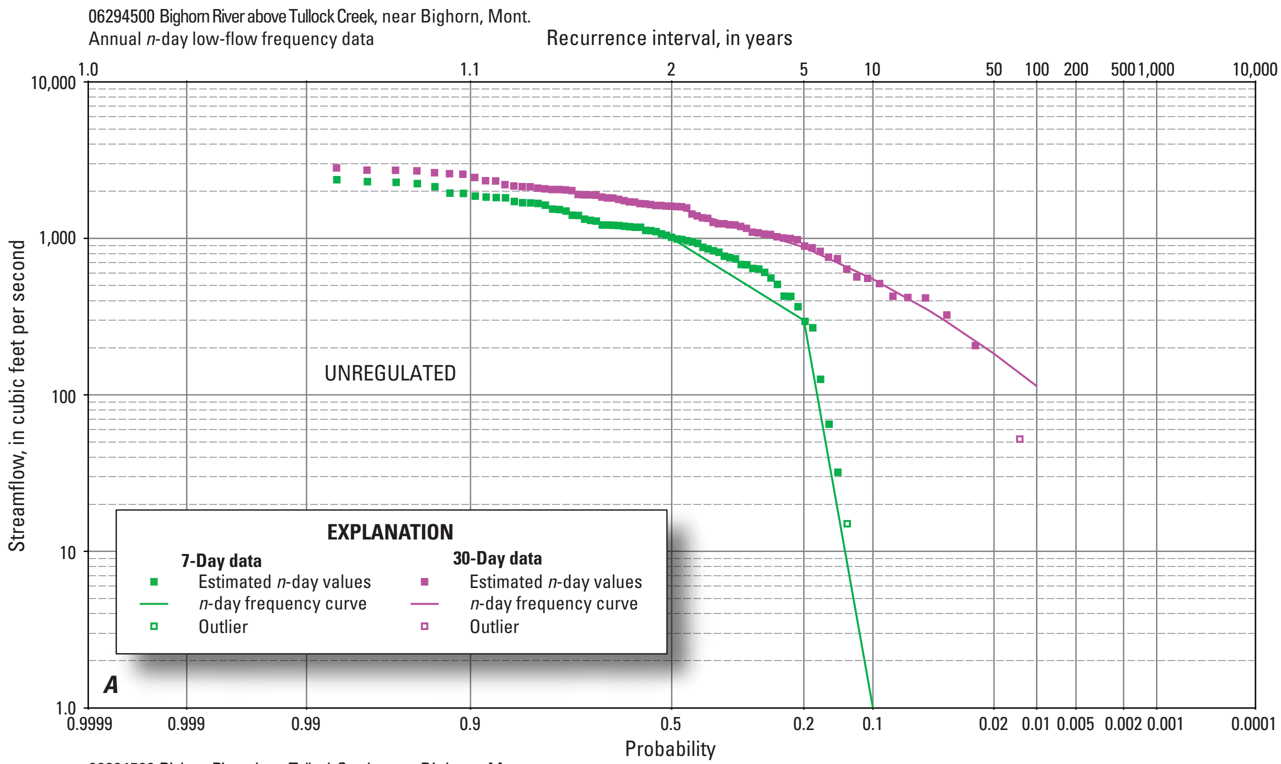
n, period of consecutive days (month, for monthly frequency data)	Regulated: Streamflow, in ft³/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
Annual							
7	1,200	300	90	30	20	7	2
30	1,580	802	504	323	281	183	120
Winter (January–March)							
7	2,400	1,620	1,240	970	897	708	563
30	2,840	2,080	1,690	1,380	1,290	1,060	879
Spring (April–June)							
7	1,430	496	110	30	26	7	2
30	2,190	1,070	664	422	366	238	156
Summer (July–September)							
7	1,480	590	294	146	117	58	29
30	2,080	1,120	728	483	425	286	194
Fall (October–December)							
7	2,160	1,420	1,110	886	828	679	562
30	2,790	2,030	1,660	1,380	1,310	1,110	940
Monthly							
7 (January)	2,560	1,790	1,430	1,170	1,100	907	756
7 (February)	2,780	2,050	1,640	1,290	1,190	888	612
7 (March)	3,050	2,040	1,550	1,190	1,100	852	665
7 (April)	2,120	1,100	670	407	347	211	128
7 (May)	1,770	616	231	80	56	18	6
7 (June)	4,100	1,900	1,200	723	623	398	257
7 (July)	2,810	969	433	193	149	67	30
7 (August)	1,920	1,000	659	446	395	273	191
7 (September)	2,300	1,420	1,040	767	698	525	397
7 (October)	2,770	1,980	1,620	1,350	1,280	1,090	930
7 (November)	2,810	1,820	1,390	1,080	1,000	796	638
7 (December)	2,590	1,750	1,380	1,100	1,030	839	689

Table 1–5–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second]

Unregulated						
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	3,510	1983	51	1937	1,970	740
February	5,050	1971	246	1936	2,340	1,020
March	9,670	1929	1,090	1931	3,330	1,440
April	7,790	1996	1,670	1935	4,090	1,370
May	15,500	1978	4,300	1935	9,620	2,280
June	28,700	1944	7,150	1985	14,600	4,610
July	22,700	1967	4,980	1934	10,950	4,260
August	11,000	1930	3,600	1966	5,610	1,280
September	5,720	1998	1,290	1934	3,510	895
October	4,740	1982	566	2002	2,500	922
November	3,960	1978	555	1960	2,200	837
December	3,440	1982	626	1936	2,030	709
Annual	7,340	1997	3,190	2002	5,240	1,035

Regulated						
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	5,260	1968	1,140	1937	3,120	790
February	5,350	1971	1,270	1936	3,260	970
March	10,590	1929	697	1966	3,970	1,483
April	7,920	1997	882	1934	2,830	1,550
May	8,900	1978	76	1934	3,300	1,950
June	20,200	1944	502	1961	6,600	3,800
July	18,600	1967	169	1931	5,500	4,310
August	7,780	1930	668	1934	2,830	1,570
September	6,170	1941	605	1940	2,820	1,076
October	5,750	1971	1,160	2002	3,340	1,083
November	5,700	1973	1,090	1960	3,300	1,086
December	4,900	1982	1,400	2002	3,200	823
Annual	5,850	1997	1,310	1966	3,680	1,130



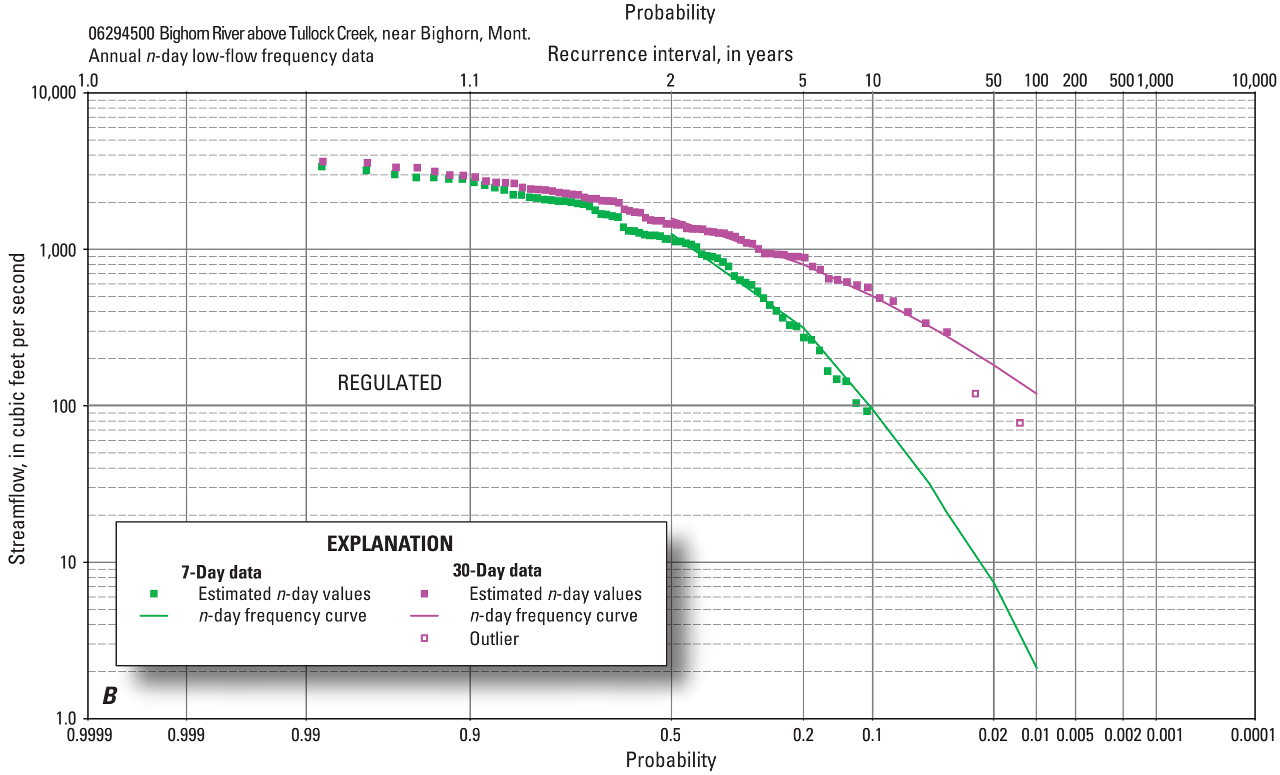
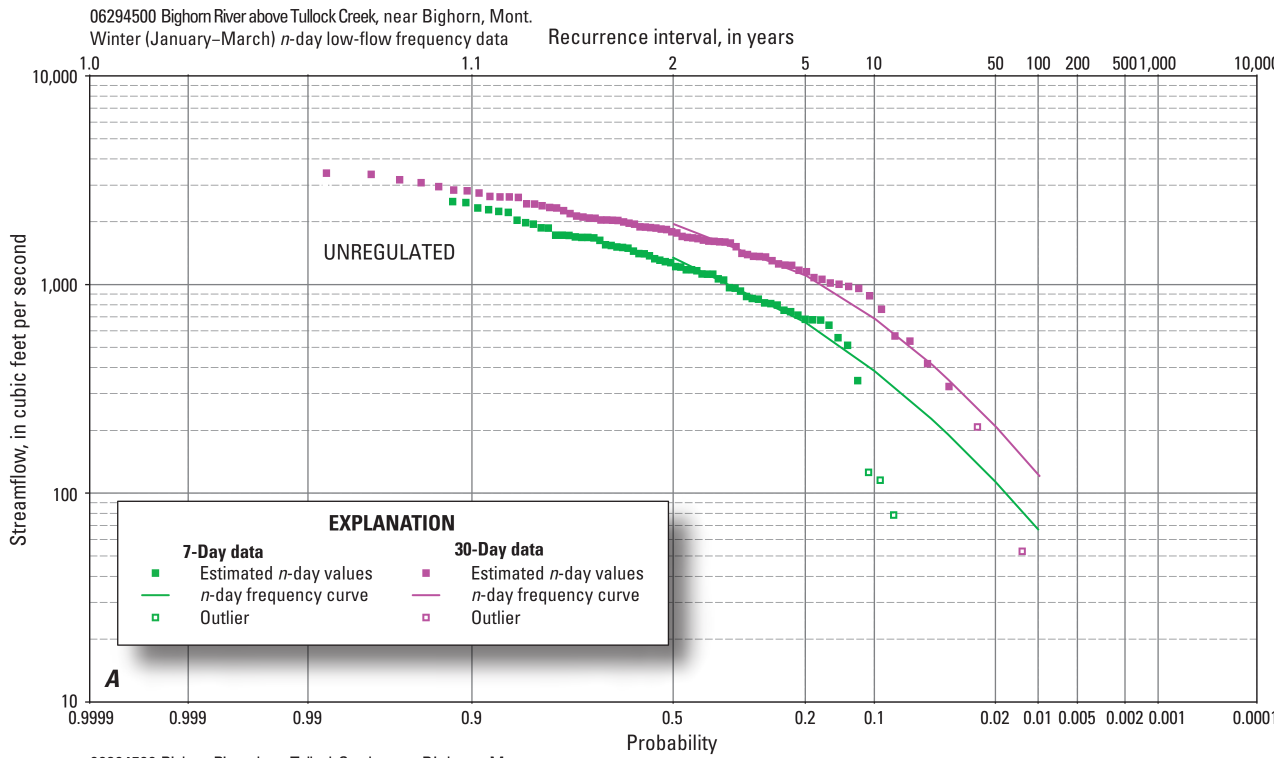


Figure 1–5–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002..



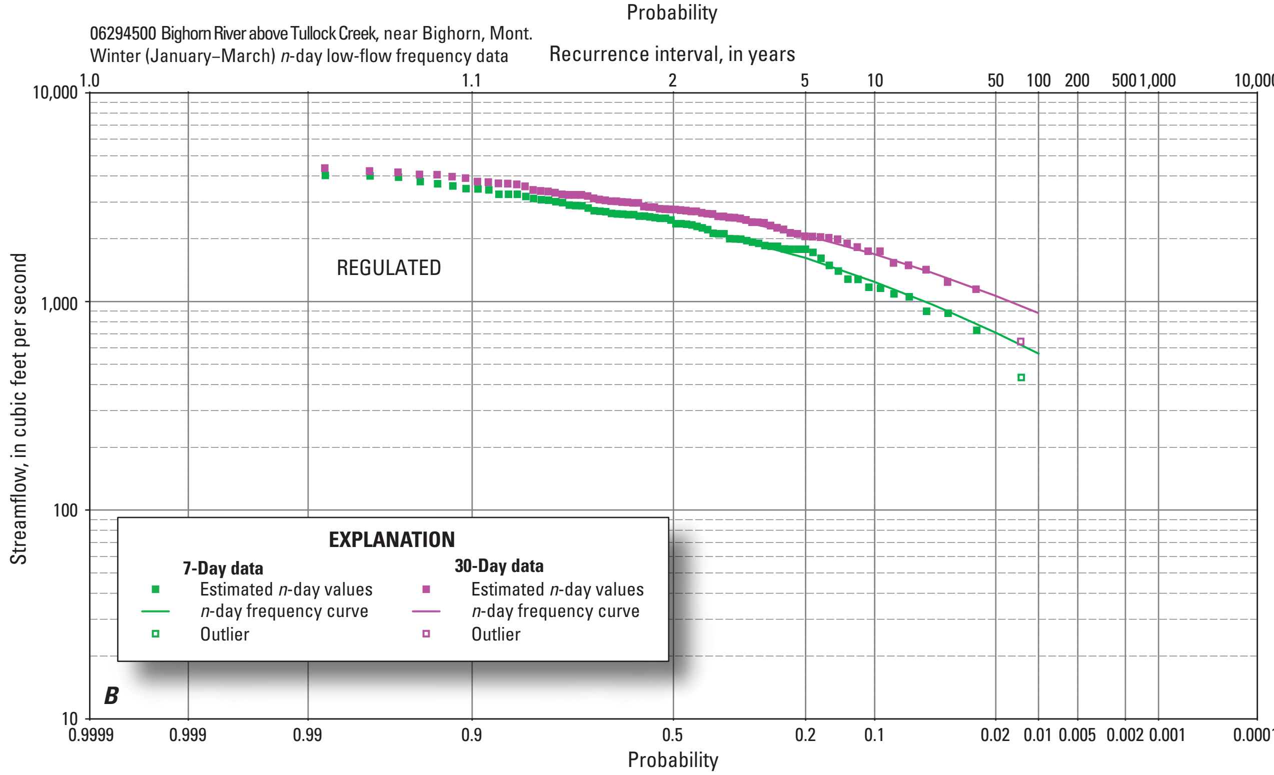


Figure 1–5–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

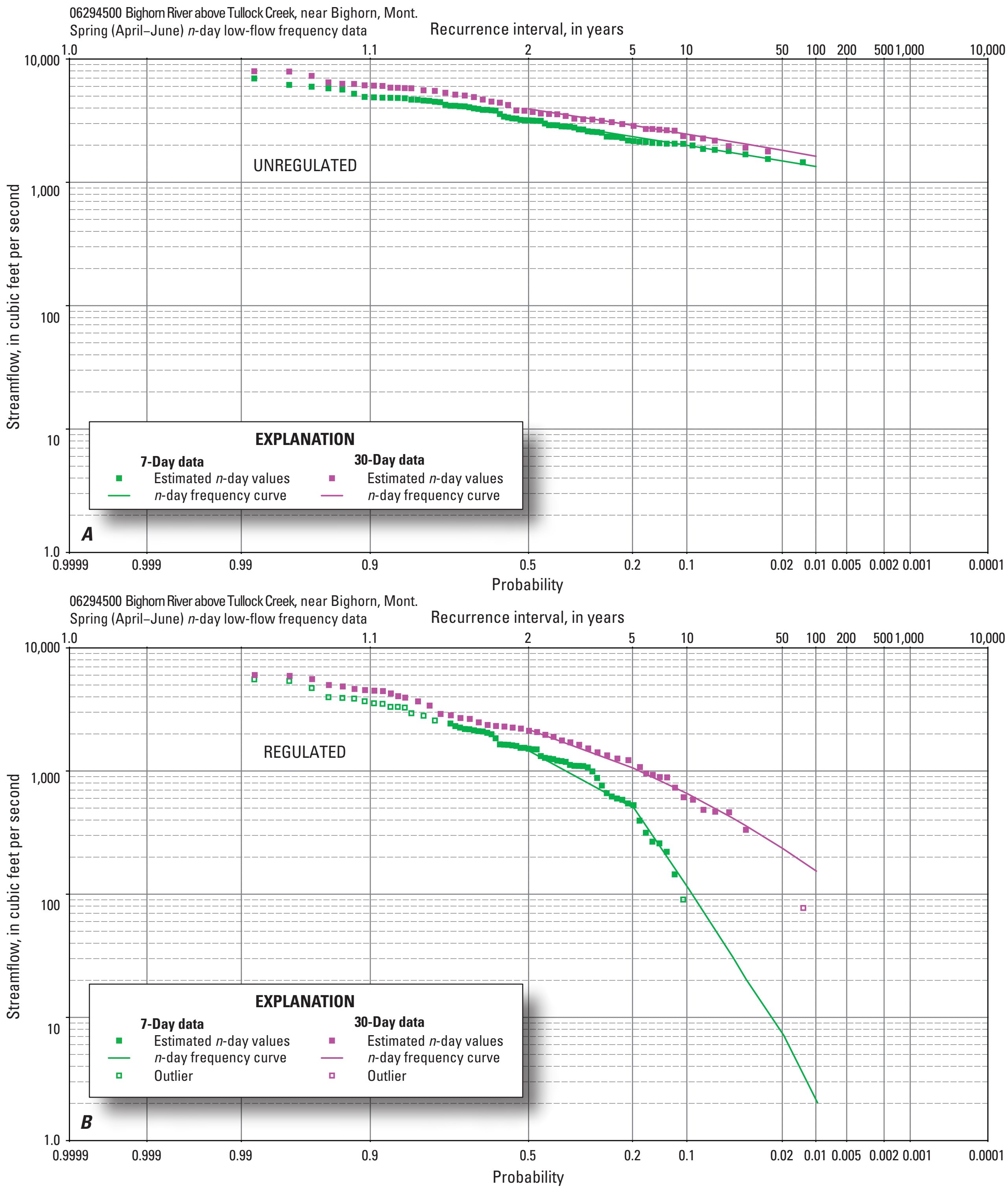


Figure 1–5–3. Spring (April–June) *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

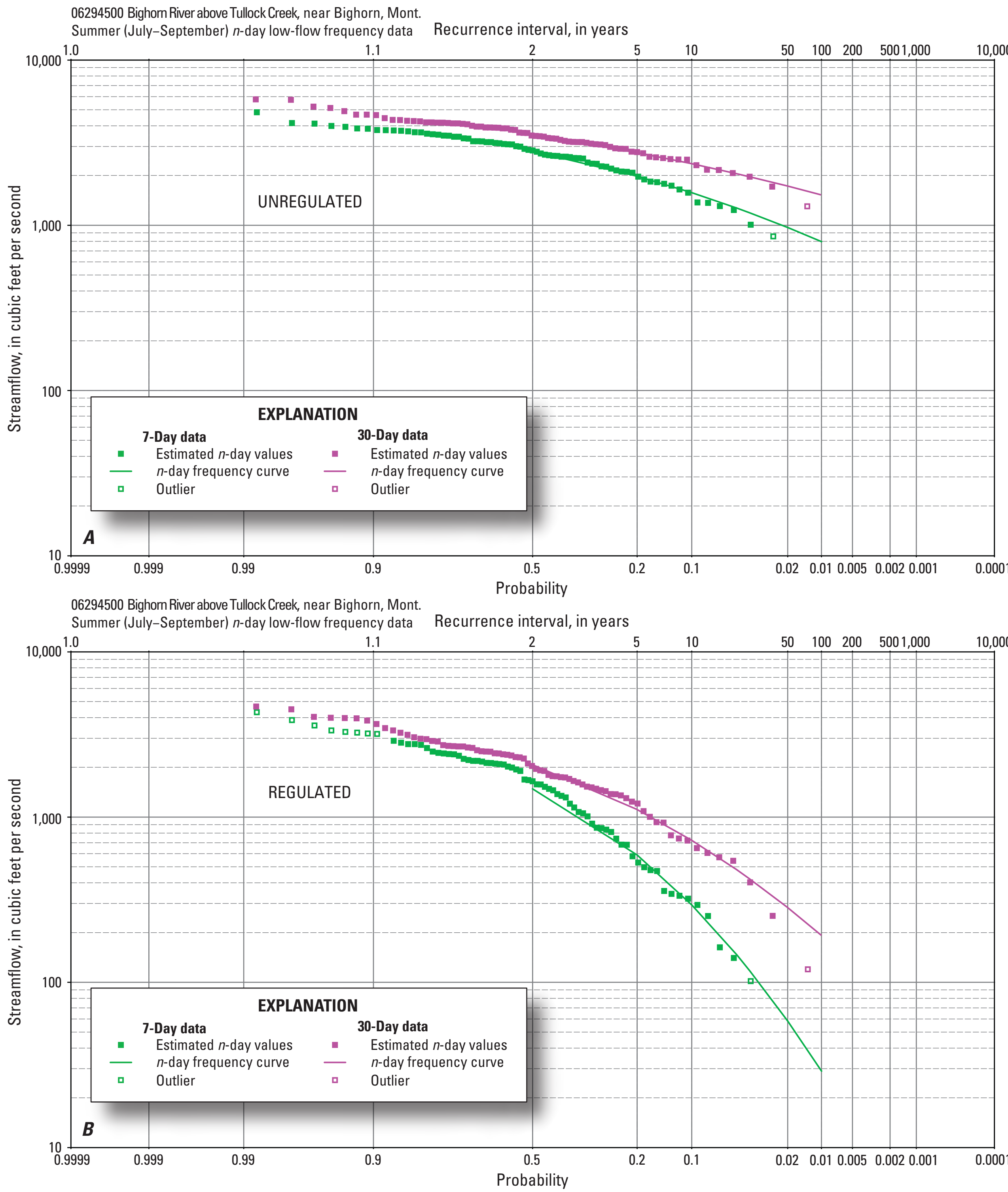


Figure 1–5–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

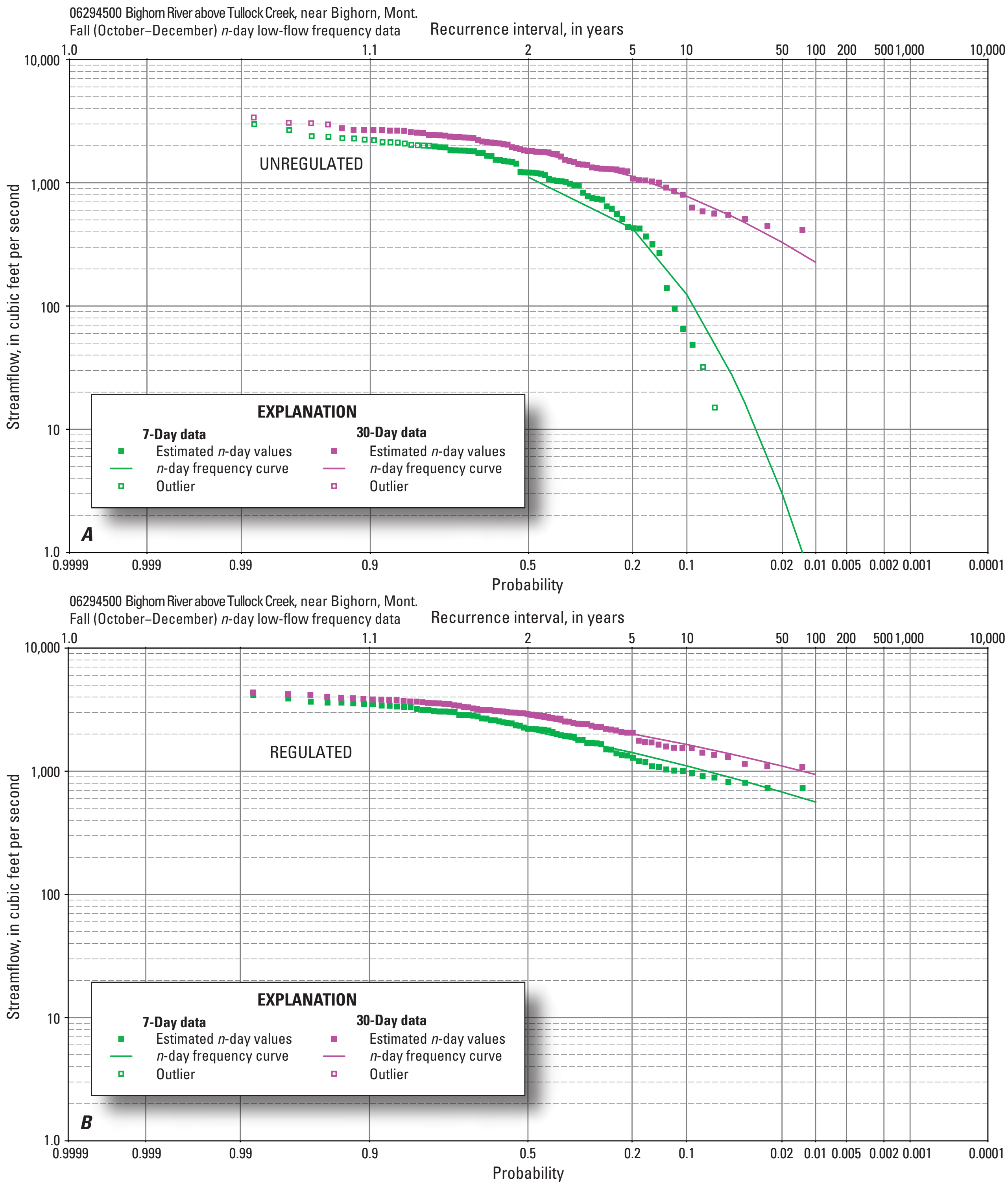


Figure 1–5–5. Fall (October–December) *n*-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

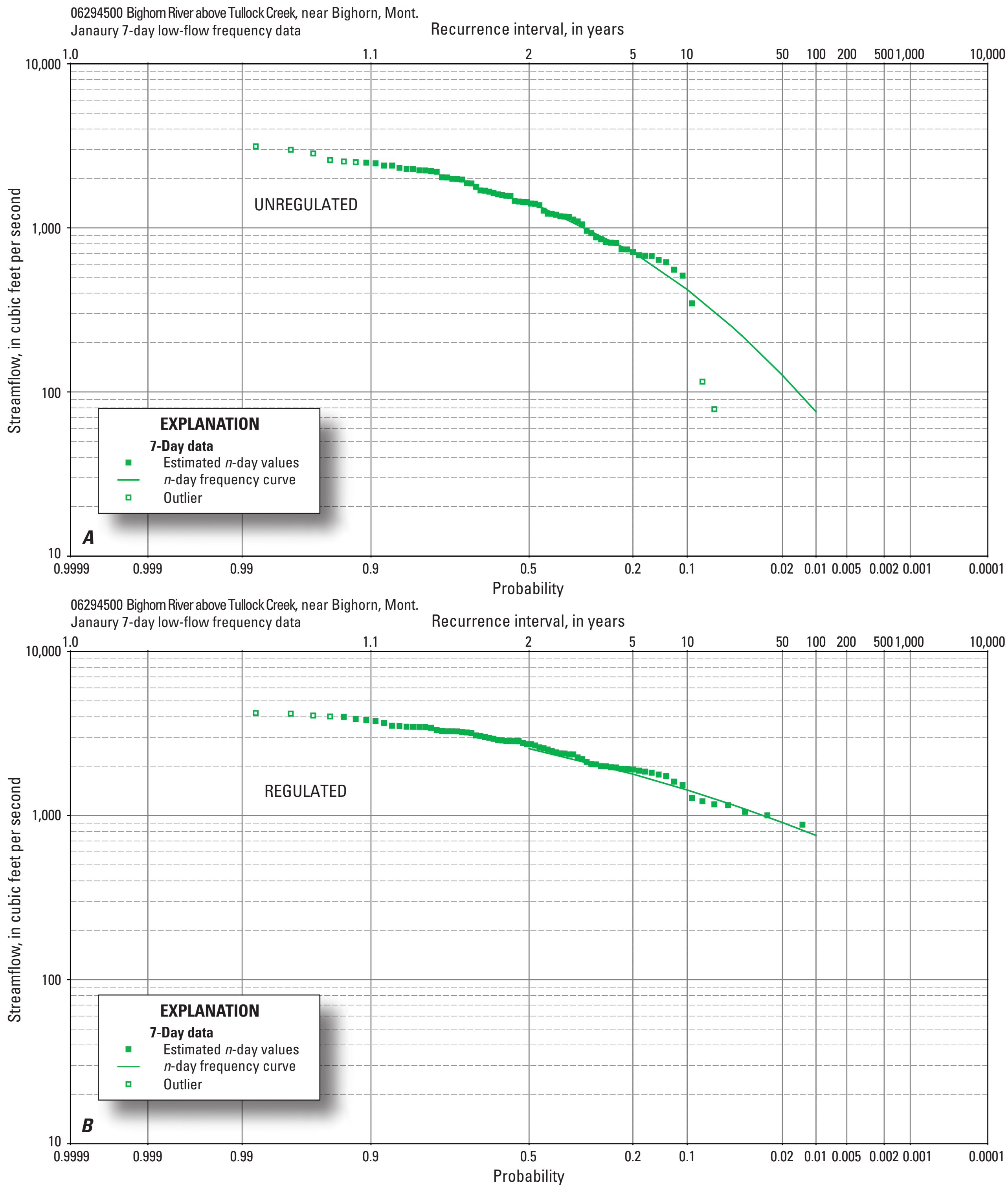


Figure 1–5–6. January 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

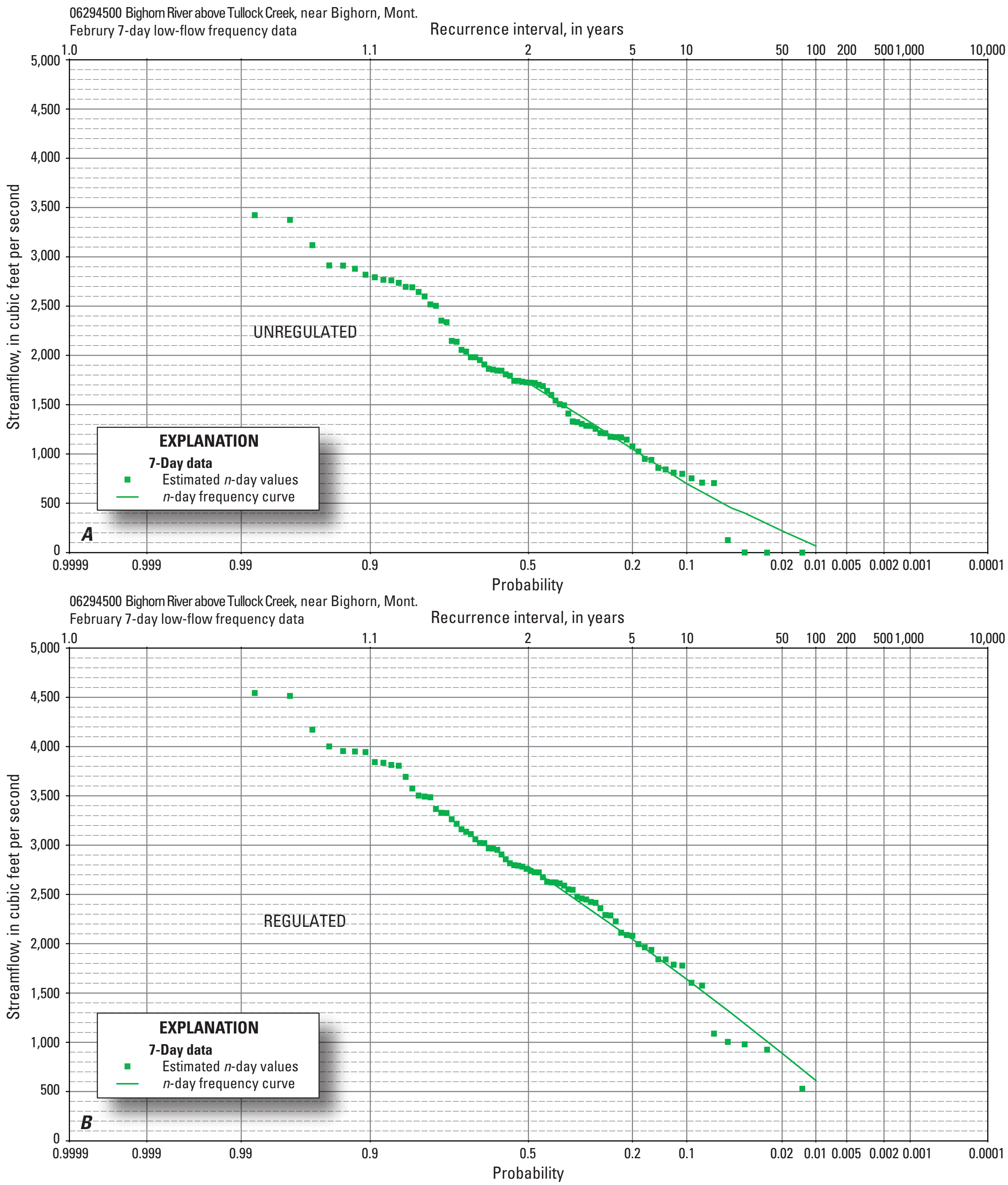


Figure 1–5–7. February 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

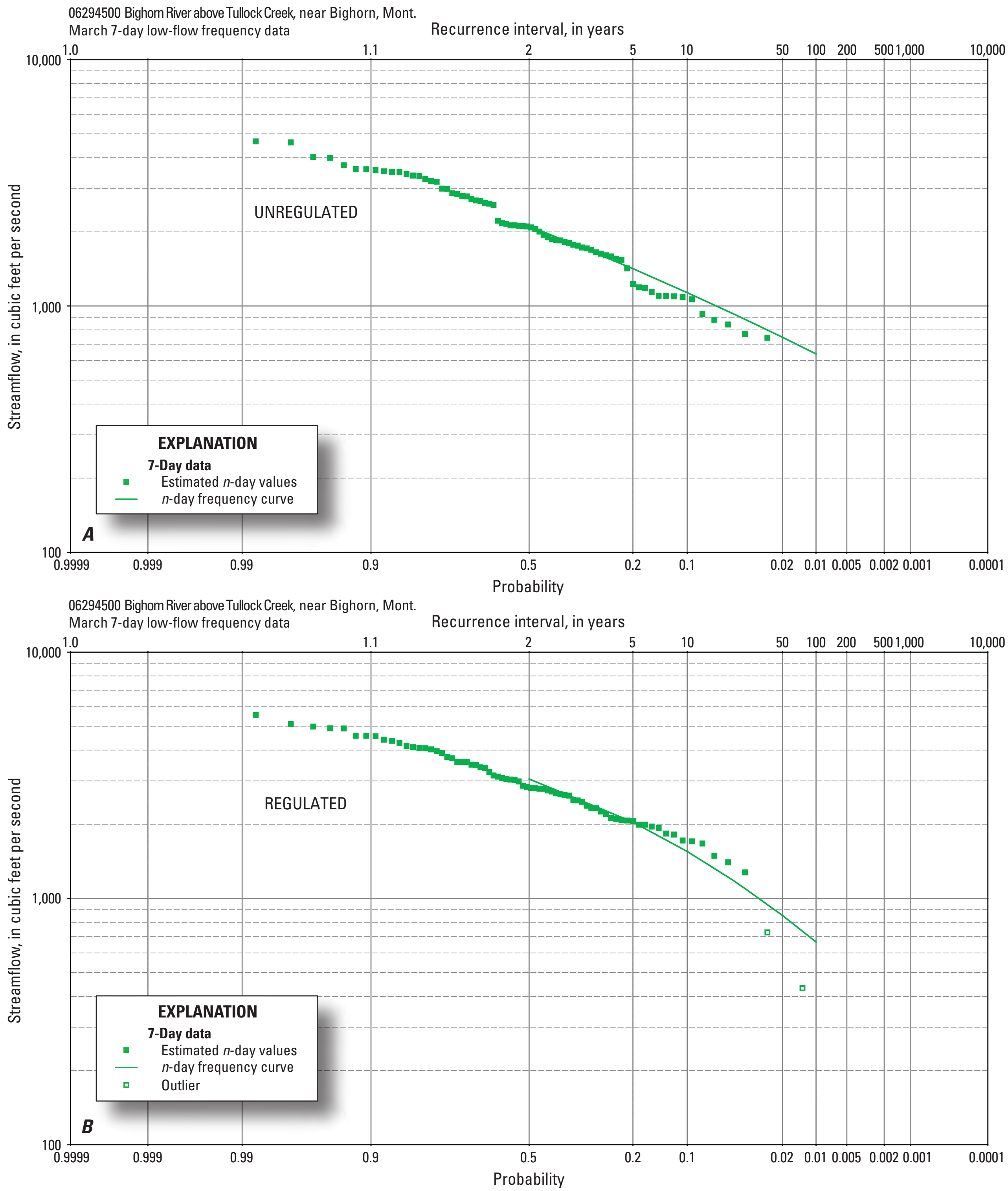


Figure 1–5–8. March 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

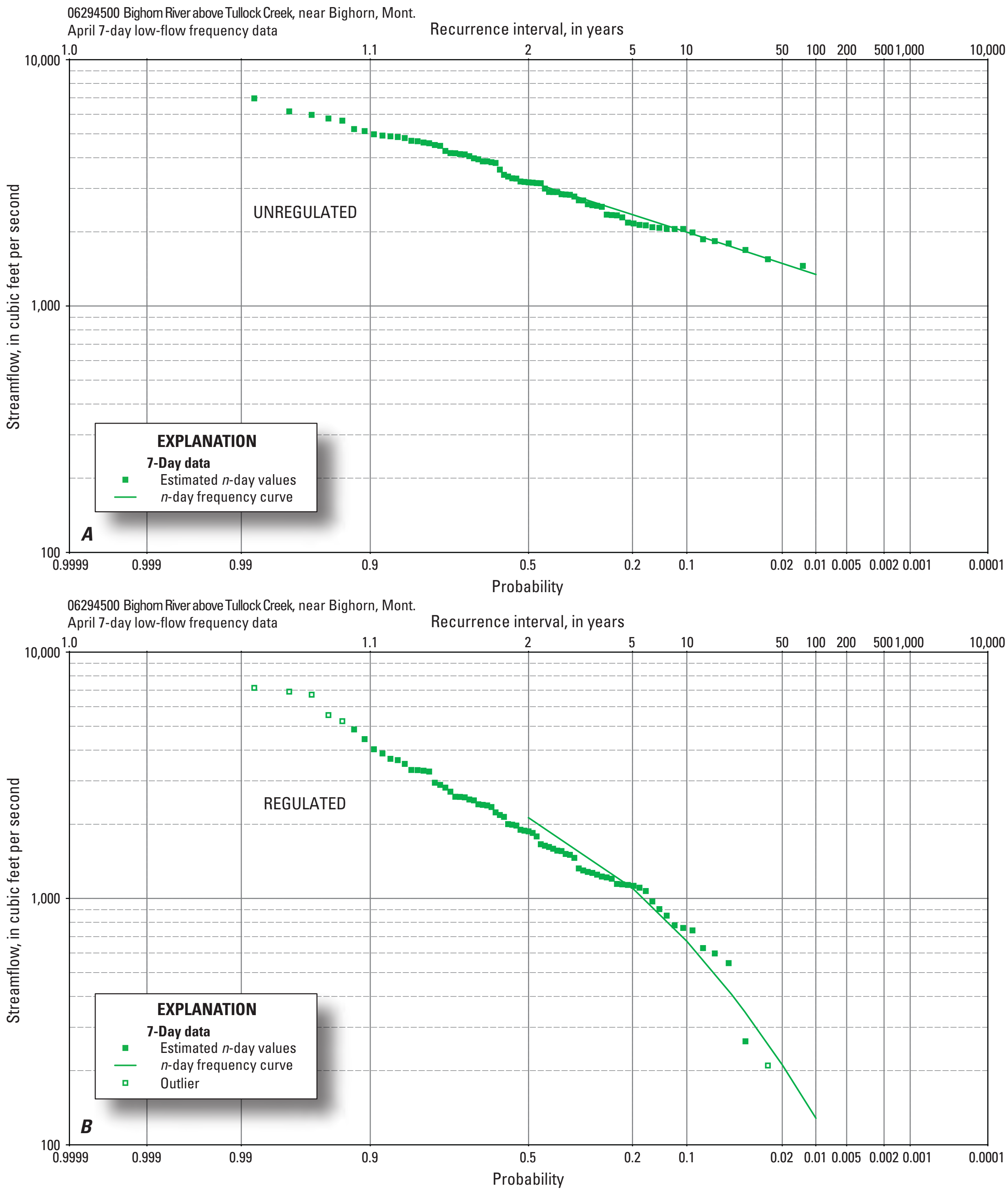


Figure 1–5–9. April 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

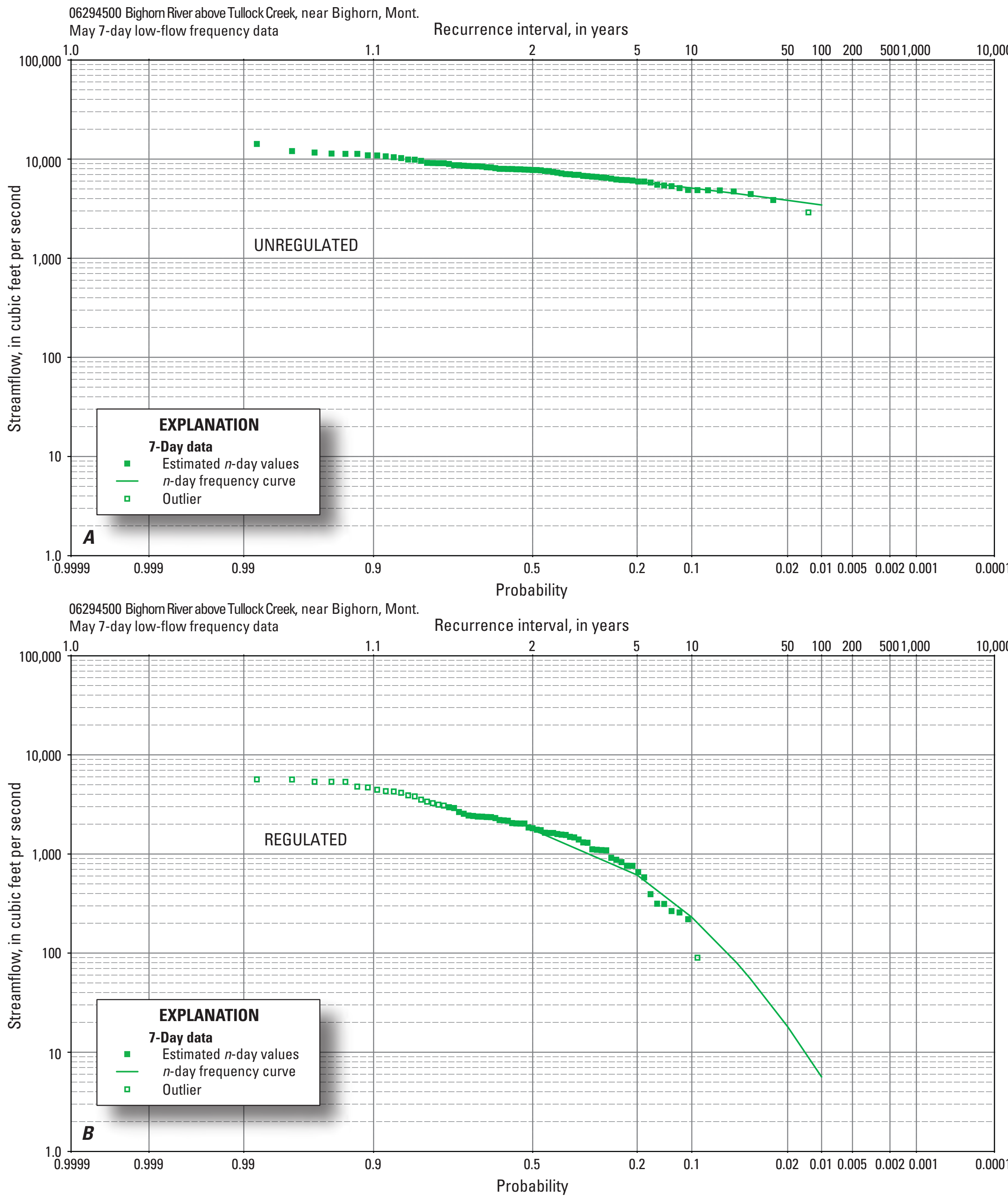


Figure 1–5–10. May 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

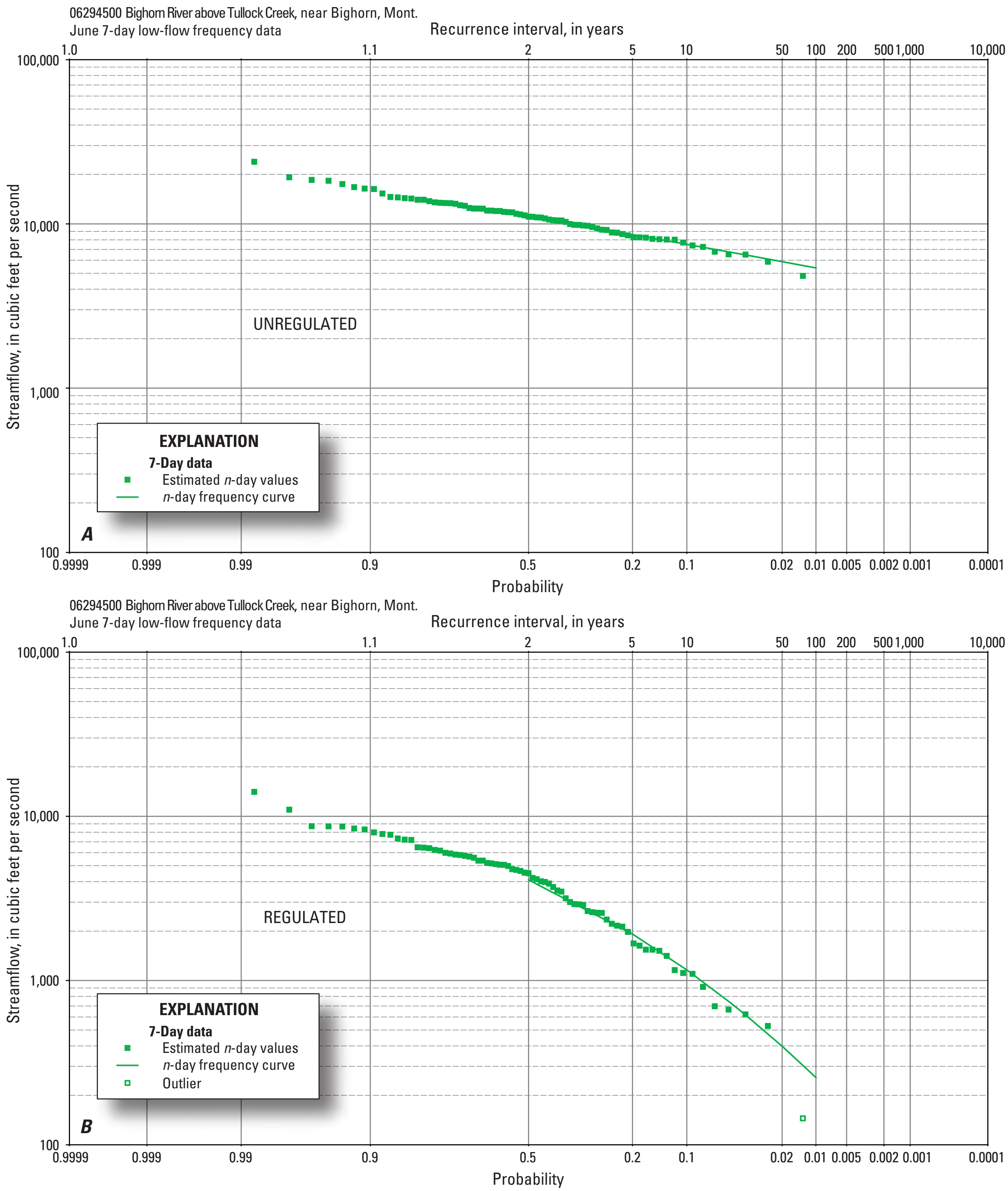


Figure 1–5–11. June 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

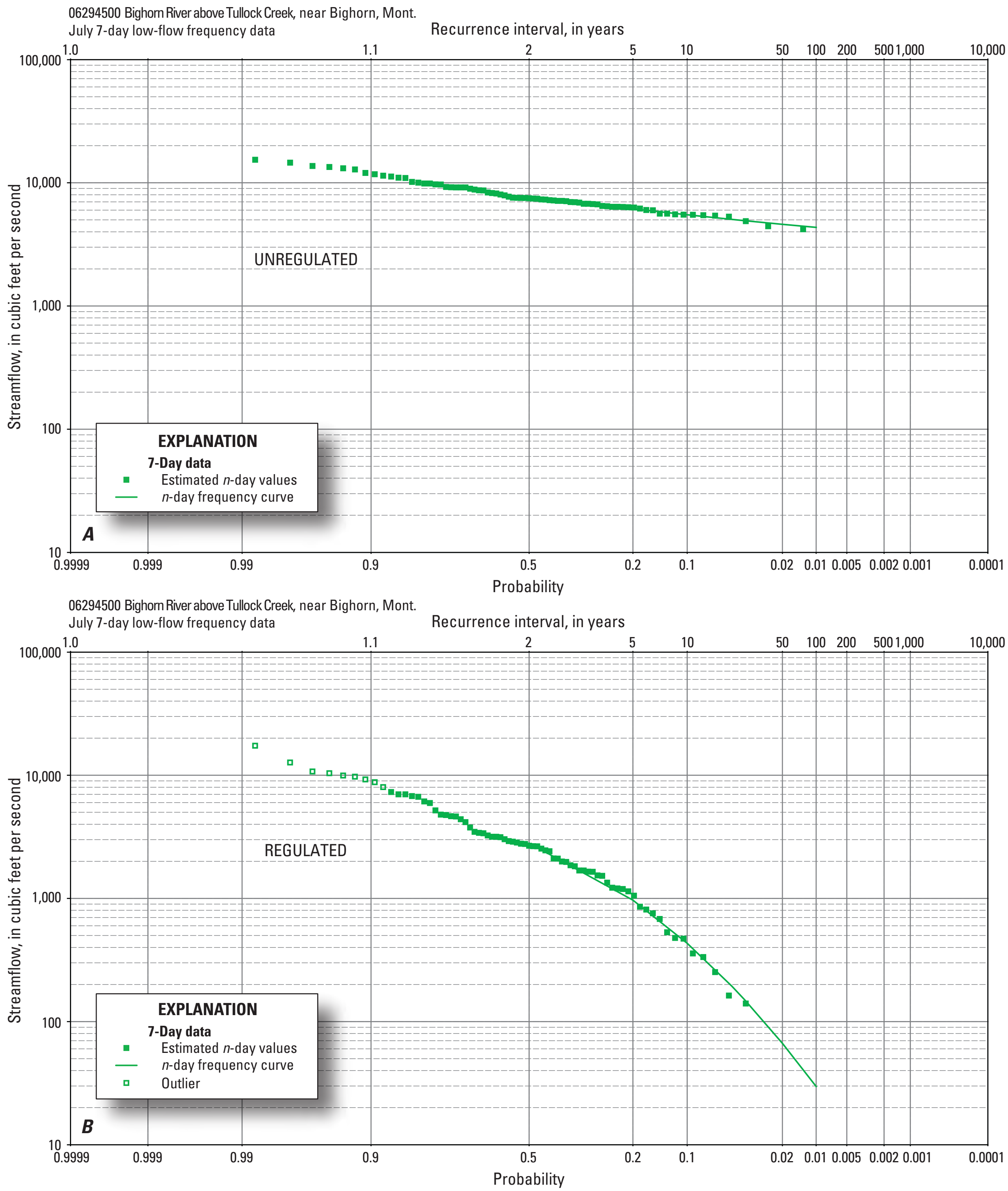


Figure 1–5–12. July 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

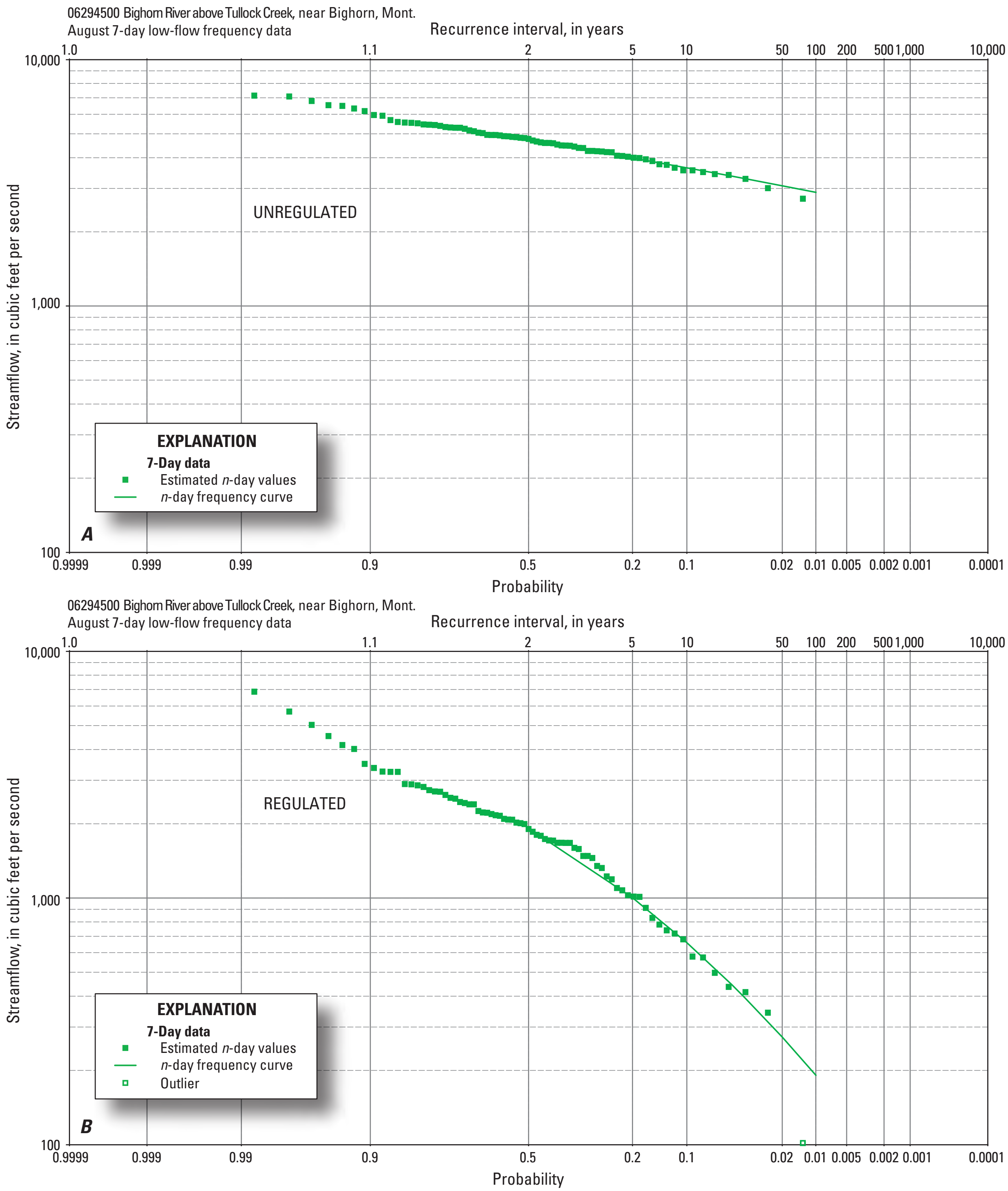
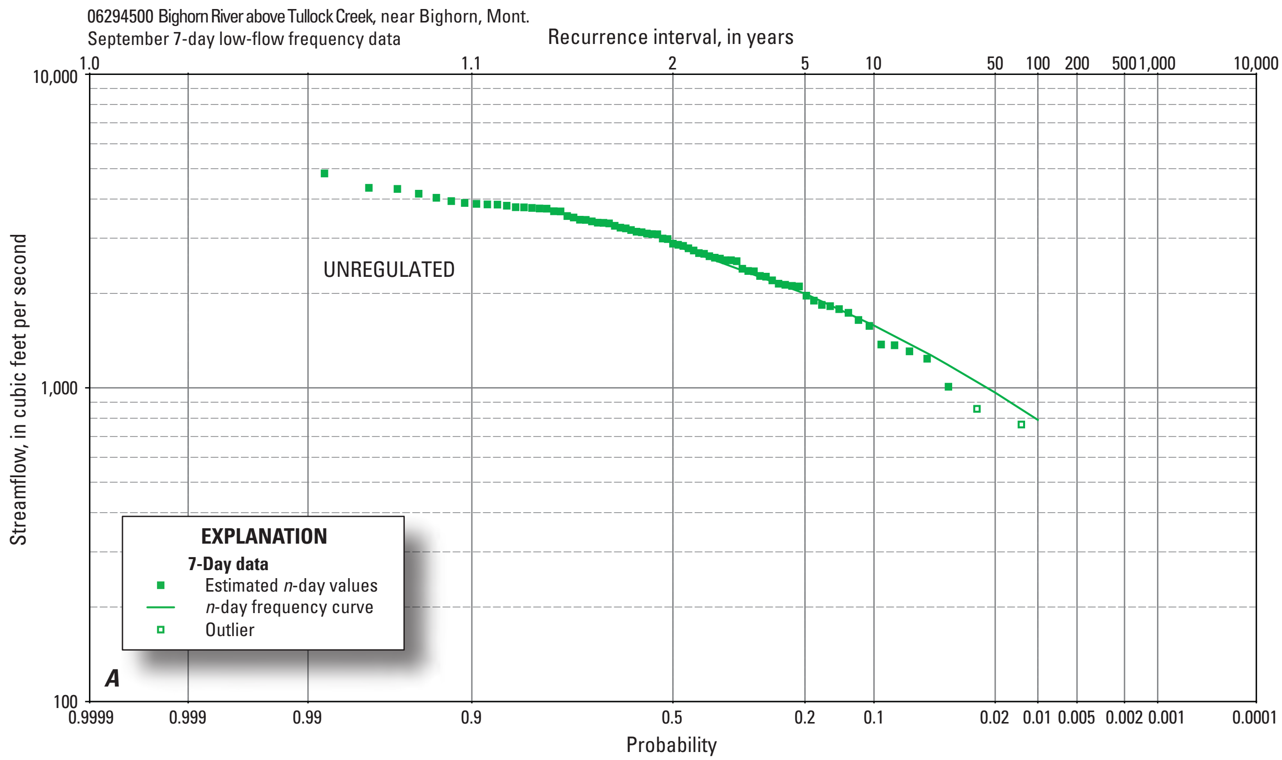


Figure 1–5–13. August 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



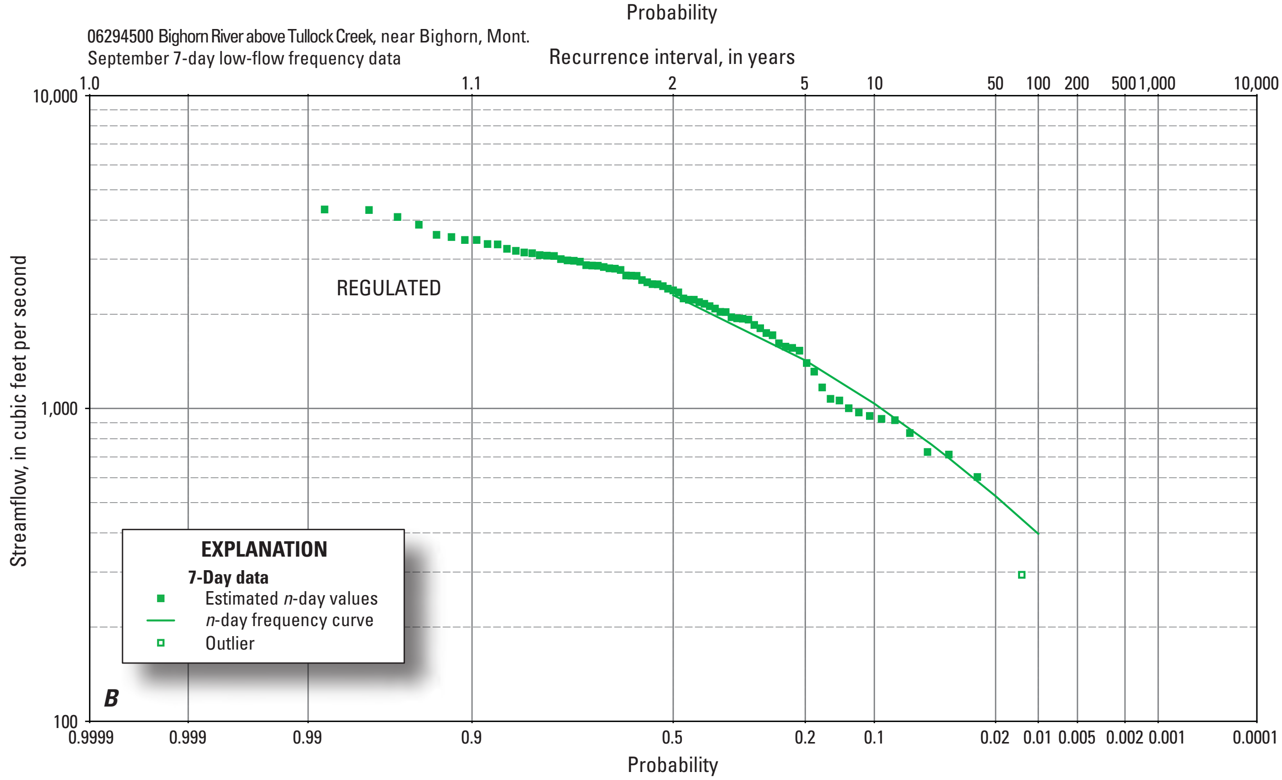


Figure 1–5–14. September 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

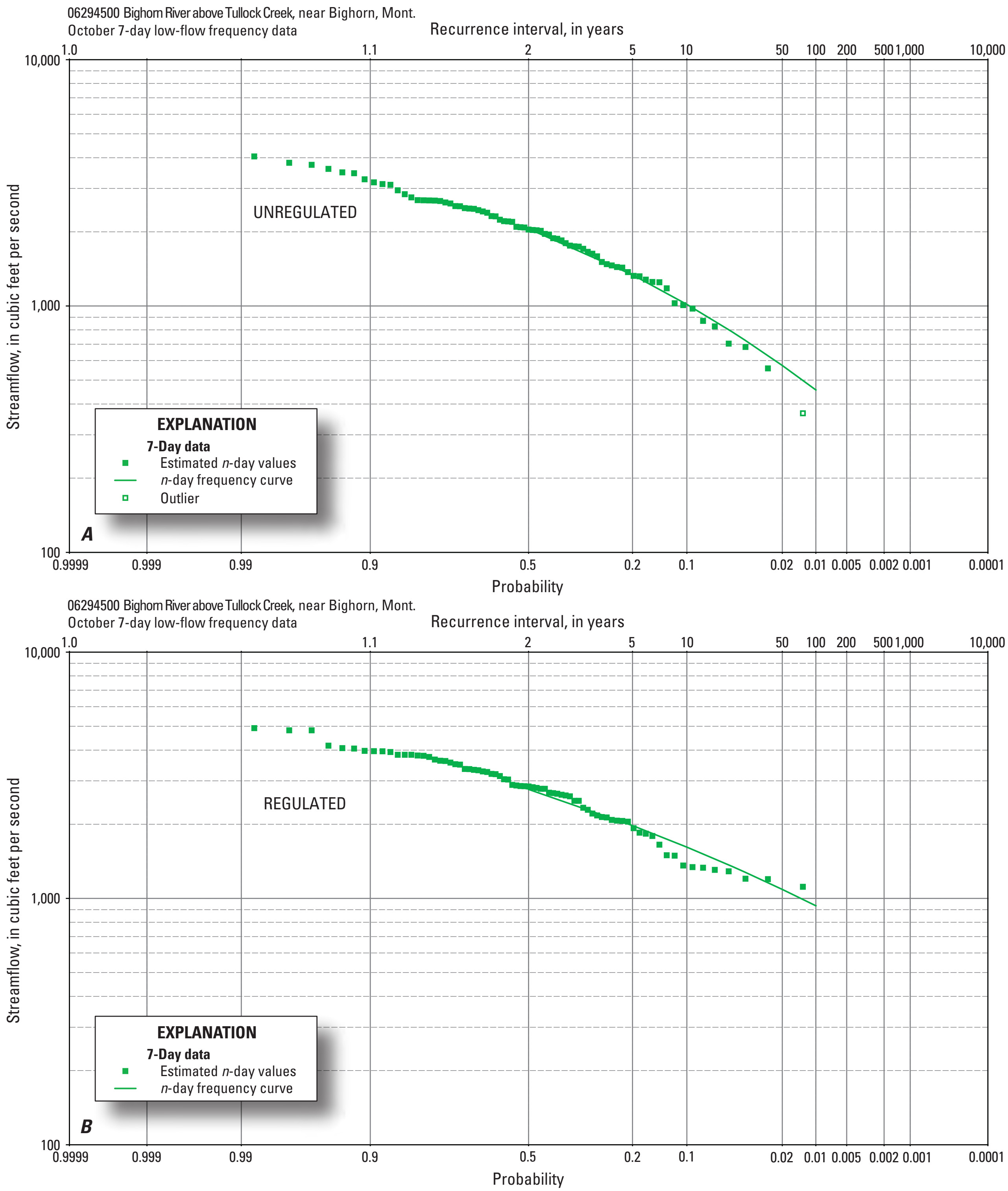


Figure 1–5–15. October 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

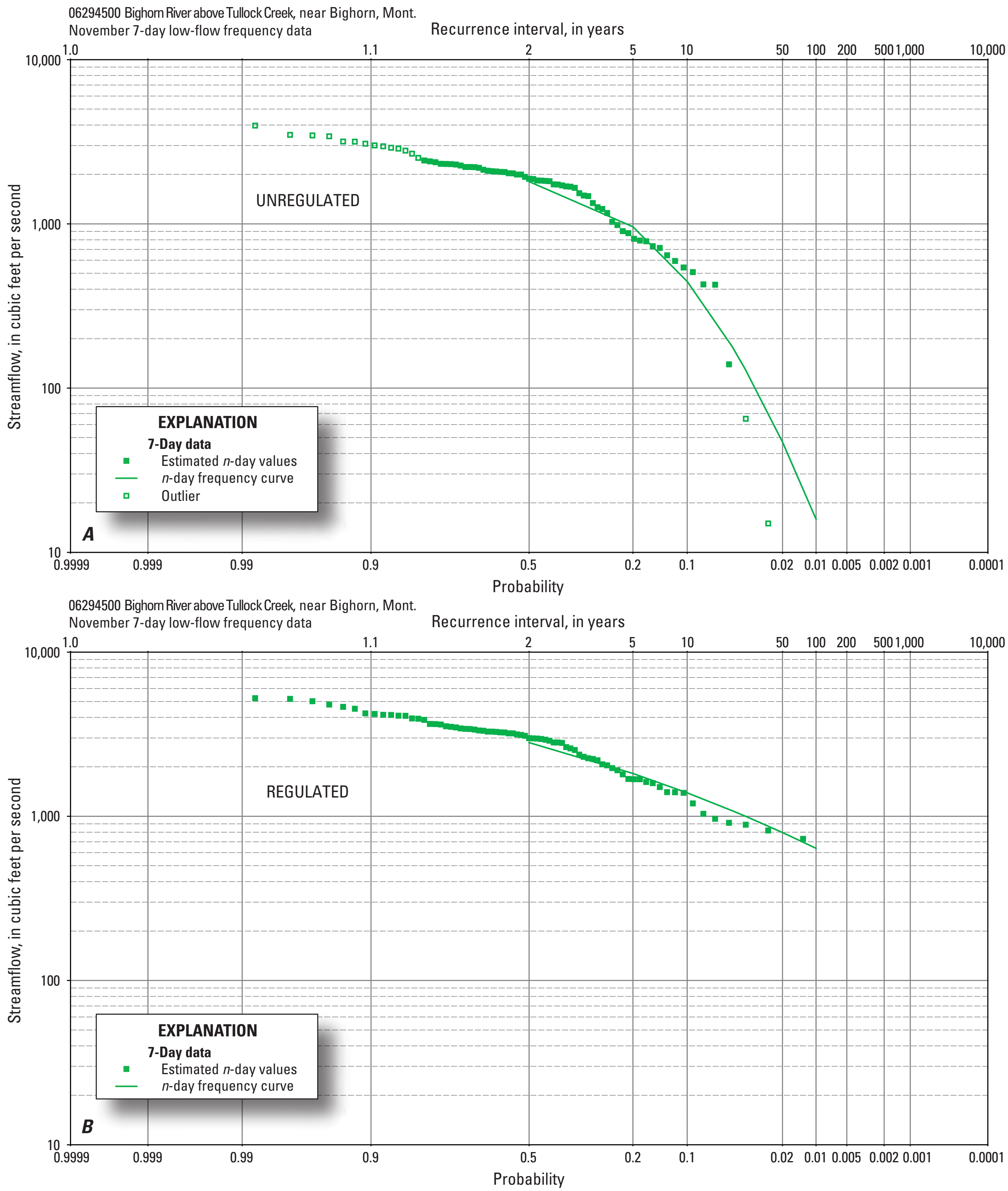
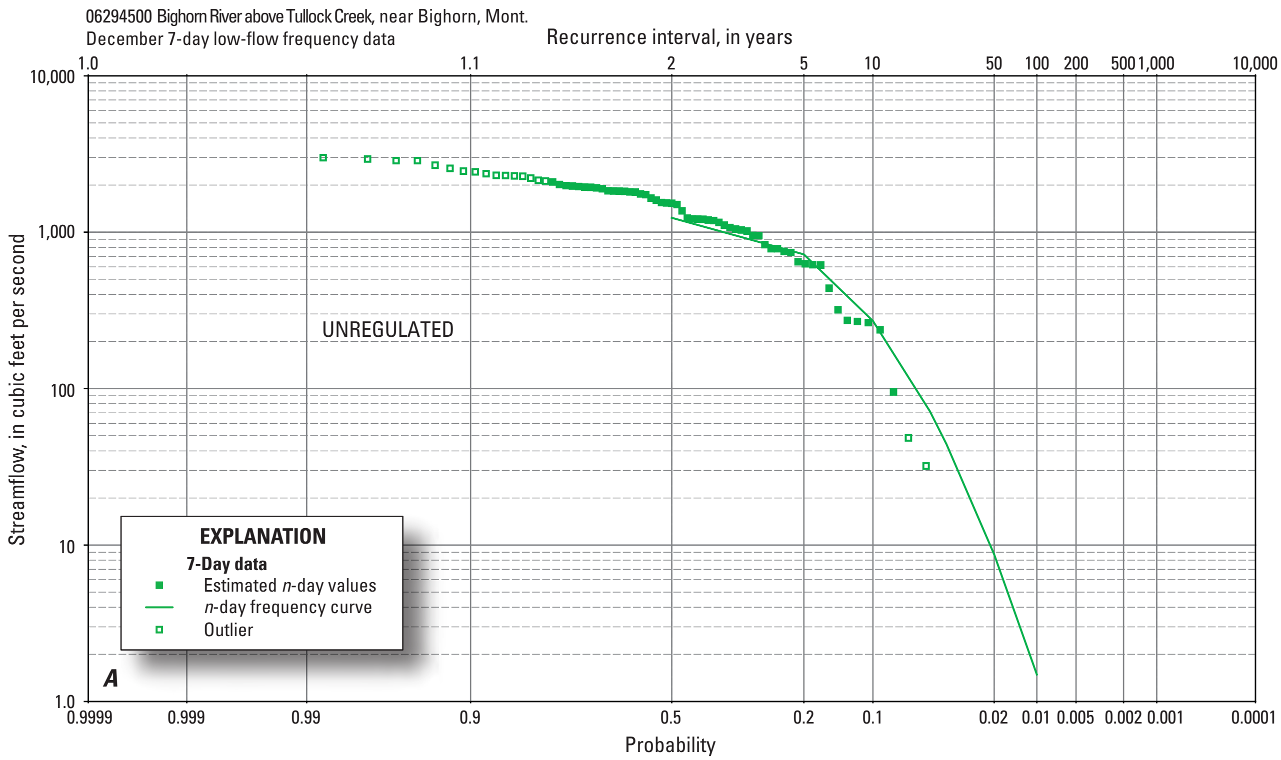


Figure 1–5–16. November 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



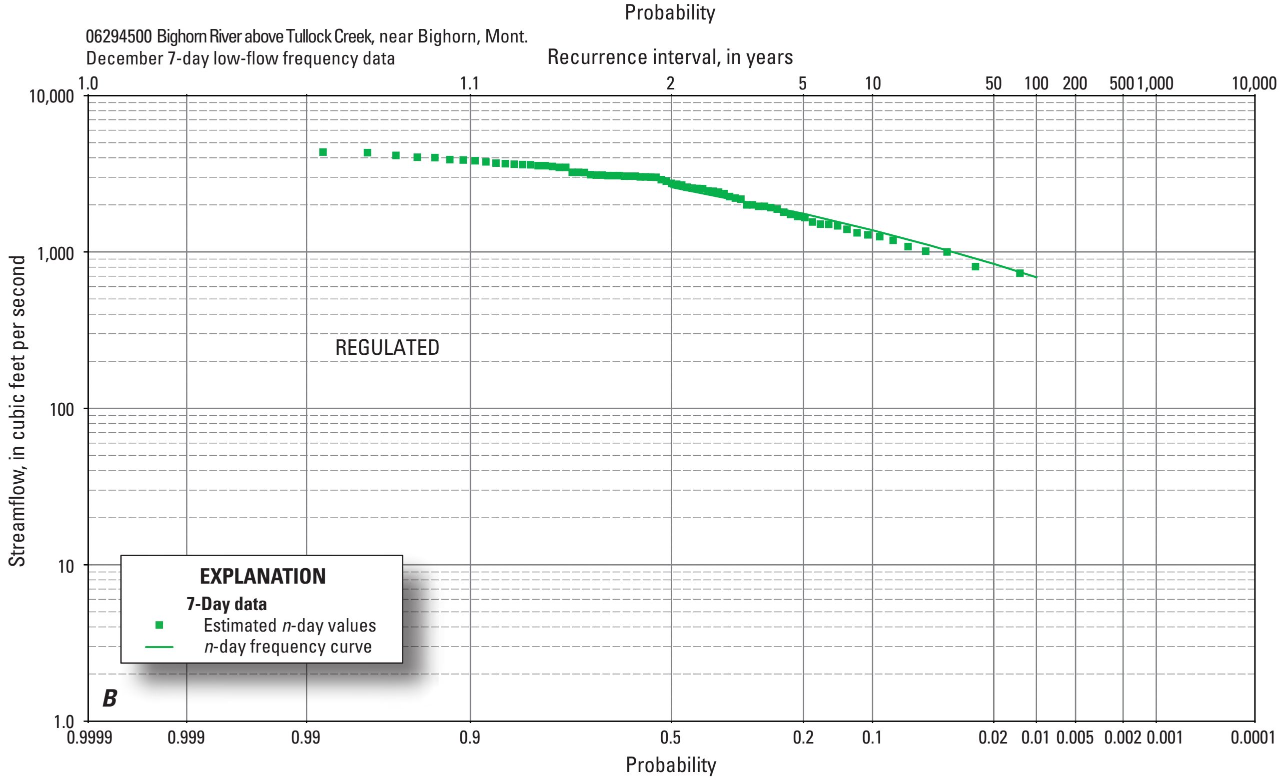


Figure 1–5–17. December 7-day low-flow frequency data for streamflow-gaging station 06294500 (Bighorn River above Tullock Creek, near Bighorn, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

Appendix 1–6. Statistics for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana)

Table 1–6–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Unregulated: Streamflow, in ft³/s, for indicated recurrence interval, in years, and exceedance probability, in percent: 2 (50%)	5 (20%)	10 (10%)	20 (5%)	25 (4%)	50 (2%)	100 (1%)
Annual							
7	1,920	1,210	927	732	681	551	452
30	3,410	2,620	2,250	1,960	1,880	1,660	1,480
Winter (January–March)							
7	2,560	1,690	1,320	1,060	994	815	676
30	3,820	2,840	2,380	2,040	1,950	1,700	1,490
Spring (April–June)							
7	7,280	5,510	4,700	4,100	3,940	3,500	3,130
30	8,620	6,610	5,720	5,060	4,880	4,400	3,990
Summer (July–September)							
7	7,600	5,710	4,730	3,960	3,750	3,170	2,690
30	8,750	7,010	6,140	5,450	5,260	4,720	4,260
Fall (October–December)							
7	2,490	1,470	1,080	826	760	596	474
30	4,190	3,260	2,830	2,500	2,400	2,150	1,940
Monthly							
7 (January)	2,840	1,830	1,400	1,100	1,020	820	664
7 (February)	3,650	2,570	2,100	1,760	1,670	1,430	1,240
7 (March)	4,770	3,520	2,990	2,600	2,490	2,210	1,980
7 (April)	7,280	5,510	4,700	4,100	3,940	3,500	3,130
7 (May)	17,500	14,100	12,500	11,300	10,900	10,000	9,220
7 (June)	33,100	26,000	22,700	20,400	19,700	17,900	16,400
7 (July)	20,000	15,700	13,900	12,500	12,100	11,100	10,200
7 (August)	11,400	9,630	8,820	8,210	8,040	7,570	7,170
7 (September)	7,600	5,710	4,730	3,960	3,750	3,170	2,690
7 (October)	5,700	4,230	3,550	3,040	2,900	2,530	2,220
7 (November)	4,820	3,110	2,270	1,670	1,520	1,120	835
7 (December)	2,750	1,650	1,210	914	838	648	508

Table 1–6–1. Annual, seasonal, and monthly *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for unregulated and regulated streamflow conditions, 1928–2002.—Continued

[ft^3/s, cubic feet per second; %, percent]

n, period of consecutive days (month, for monthly frequency data)	Regulated						
	Streamflow, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent						
	2 50%	5 20%	10 10%	20 5%	25 4%	50 2%	100 1%
				Annual			
7	3,350	2,650	2,340	2,110	2,050	1,880	1,740
30	4,480	3,550	3,090	2,730	2,630	2,360	2,130
				Winter (January–March)			
7	3,900	3,100	2,750	2,480	2,405	2,207	2,041
30	5,000	4,050	3,610	3,270	3,180	2,920	2,710
				Spring (April–June)			
7	5,400	4,040	3,460	3,040	2,920	2,620	2,370
30	6,620	4,980	4,280	3,770	3,640	3,270	2,970
				Summer (July–September)			
7	5,130	3,660	3,020	2,560	2,440	2,110	1,840
30	5,890	4,160	3,420	2,890	2,740	2,360	2,060
				Fall (October–December)			
7	4,050	3,040	2,630	2,330	2,250	2,036	1,863
30	5,550	4,490	3,970	3,570	3,460	3,140	2,880
				Monthly			
7 (January)	4,240	3,320	2,910	2,600	2,510	2,275	2,080
7 (February)	4,820	3,750	3,270	2,900	2,800	2,530	2,300
7 (March)	5,630	4,370	3,820	3,410	3,310	3,010	2,760
7 (April)	5,410	4,050	3,470	3,050	2,930	2,630	2,380
7 (May)	8,730	6,260	5,200	4,440	4,230	3,690	3,240
7 (June)	22,700	15,900	13,000	10,900	10,400	8,900	7,730
7 (July)	10,700	6,550	4,980	3,950	3,680	3,010	2,500
7 (August)	5,500	3,790	3,110	2,630	2,510	2,180	1,920
7 (September)	5,570	4,000	3,320	2,820	2,690	2,340	2,050
7 (October)	6,780	5,220	4,480	3,910	3,750	3,320	2,960
7 (November)	6,180	4,580	3,790	3,190	3,020	2,570	2,200
7 (December)	4,270	3,230	2,780	2,450	2,360	2,130	1,930

Table 1–6–2. Monthly and annual streamflow characteristics for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for unregulated and regulated streamflow conditions, 1928–2002.

[ft³/s, cubic feet per second]

Unregulated						
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	7,090	1983	1,570	1937	4,210	1,206
February	15,100	1971	1,850	1932	5,180	2,098
March	17,600	1929	2,850	2002	7,270	2,853
April	16,400	1943	3,410	1961	8,970	2,687
May	44,300	1928	13,660	1953	25,580	5,807
June	78,100	1997	20,389	1934	43,760	11,650
July	55,900	1975	12,101	1934	29,010	10,040
August	22,100	1997	8,120	1934	13,631	3,137
September	13,500	1968	4,010	1934	8,760	2,007
October	11,500	1941	2,860	2001	6,570	2,000
November	8,520	1982	2,900	1931	5,510	1,400
December	7,310	1982	2,240	1932	4,440	1,151
Annual	20,800	1997	8,750	2001	13,500	2,549
Regulated						
	Streamflow, in ft³/s, or year, for indicated streamflow characteristic					
Period	Maximum monthly mean and maximum annual mean streamflow	Year of maximum monthly mean and maximum annual mean streamflow	Minimum monthly mean and minimum annual mean streamflow	Year of minimum monthly mean and minimum annual mean streamflow	Mean monthly and mean annual streamflow	Standard deviation of mean monthly and mean annual streamflow
January	8,340	1968	2,800	1937	5,520	1,210
February	15,600	1971	3,040	1932	6,220	2,020
March	18,600	1929	3,220	2002	8,010	2,820
April	13,300	1997	2,450	1961	7,070	2,360
May	35,300	1928	7,040	1961	16,300	4,970
June	64,100	1997	11,700	1934	32,200	10,600
July	43,700	1967	3,820	1934	19,400	9,720
August	17,800	1997	2,540	1934	7,910	3,450
September	13,400	1941	2,740	2001	6,960	2,380
October	12,800	1941	3,570	2001	7,620	2,050
November	10,600	1982	4,030	1934	7,020	1,610
December	8,970	1982	3,430	1934	5,850	1,220
Annual	18,200	1997	5,680	1934	10,800	2,720

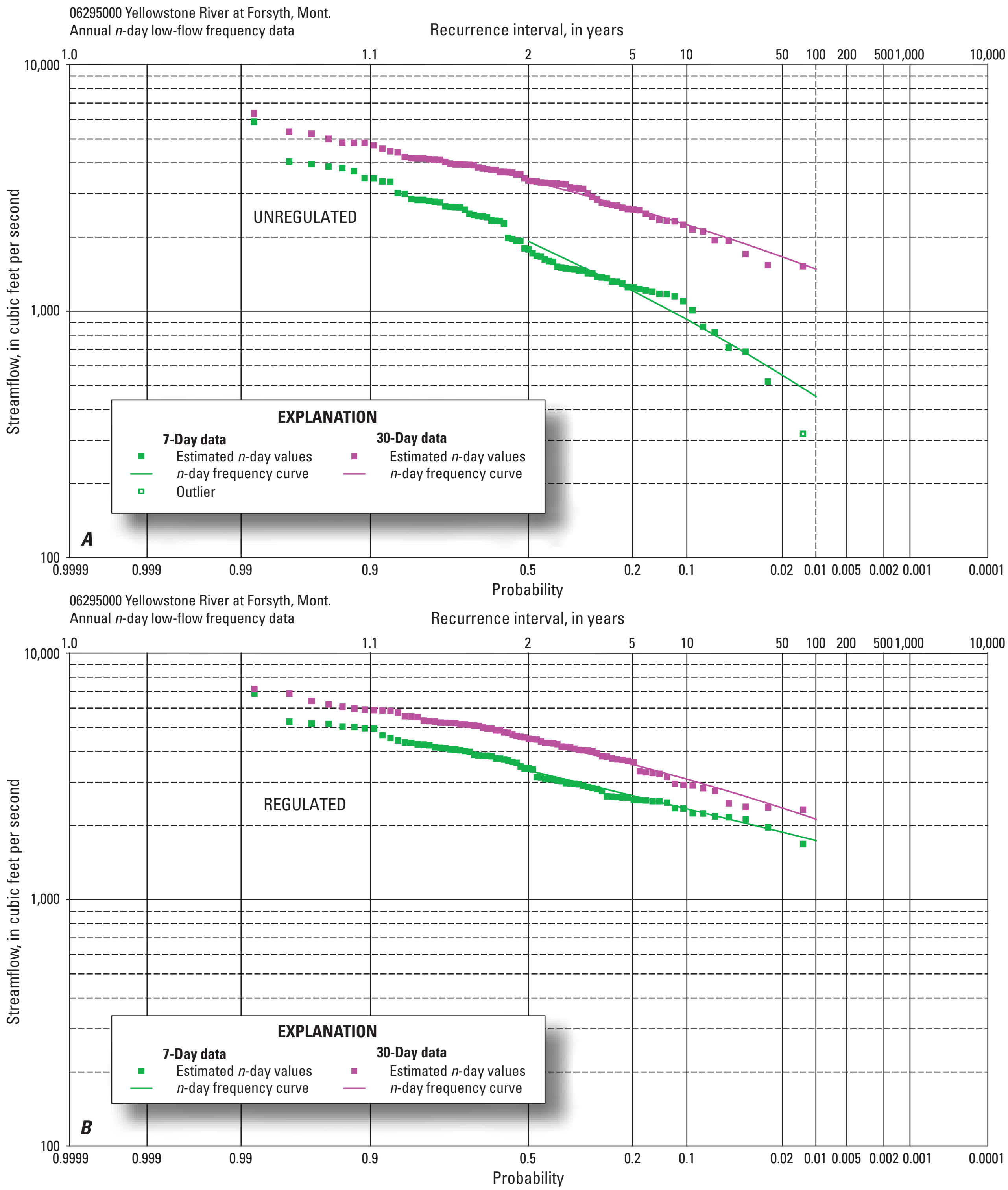


Figure 1–6–1. Annual *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

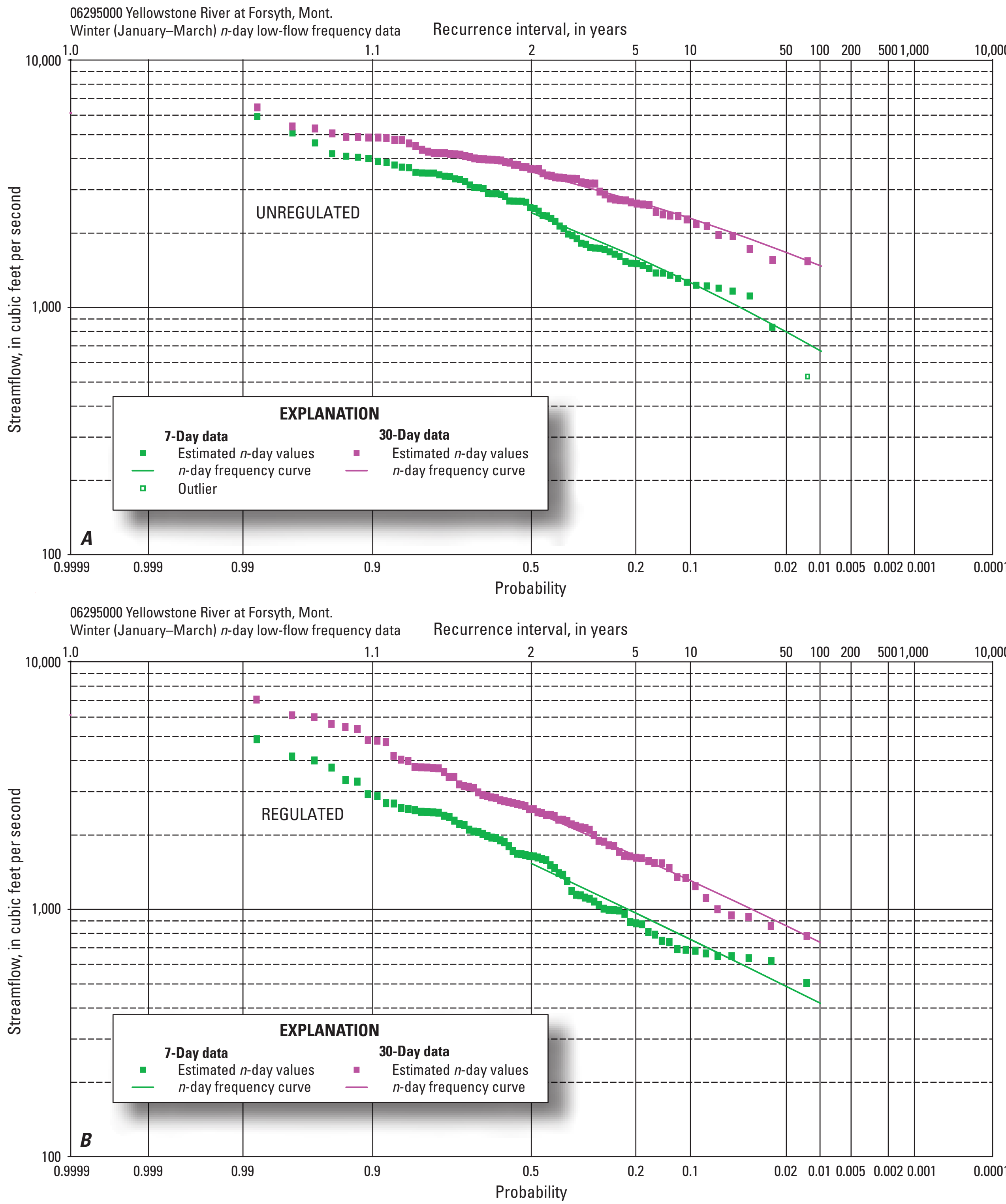
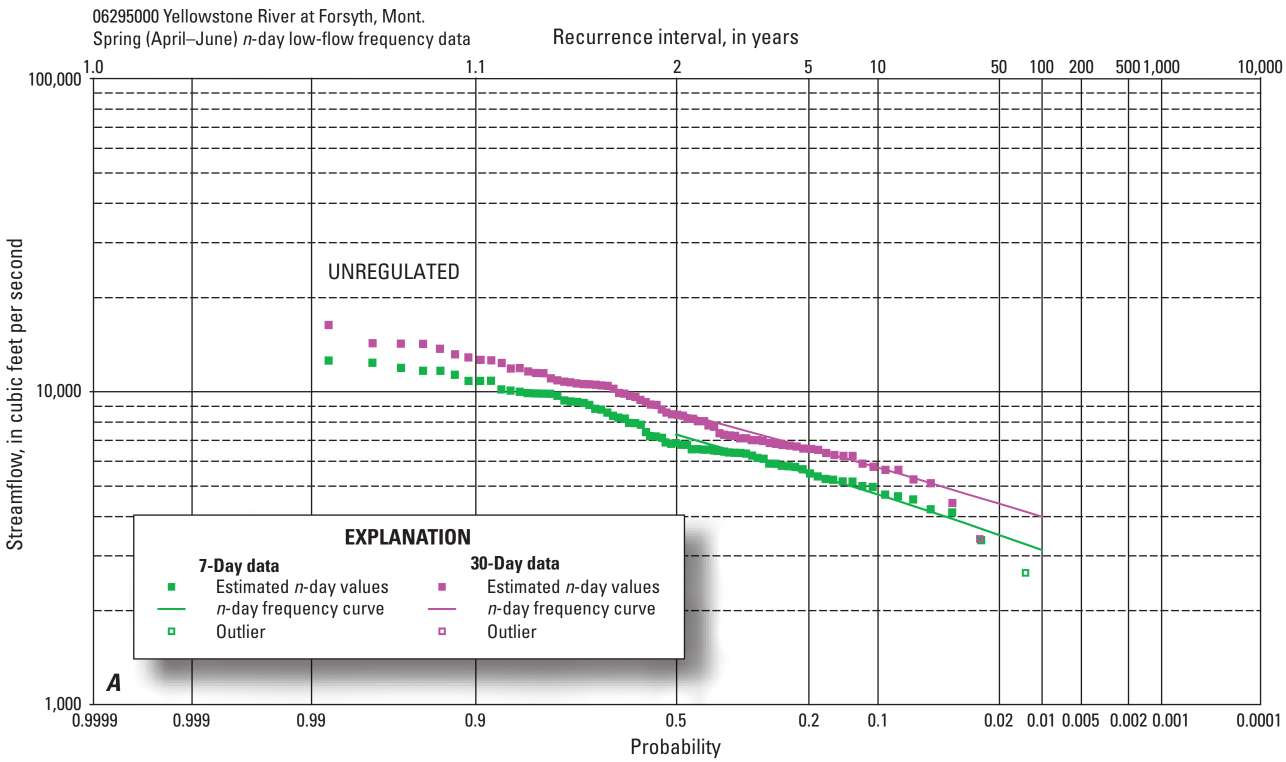


Figure 1–6–2. Winter (January–March) *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



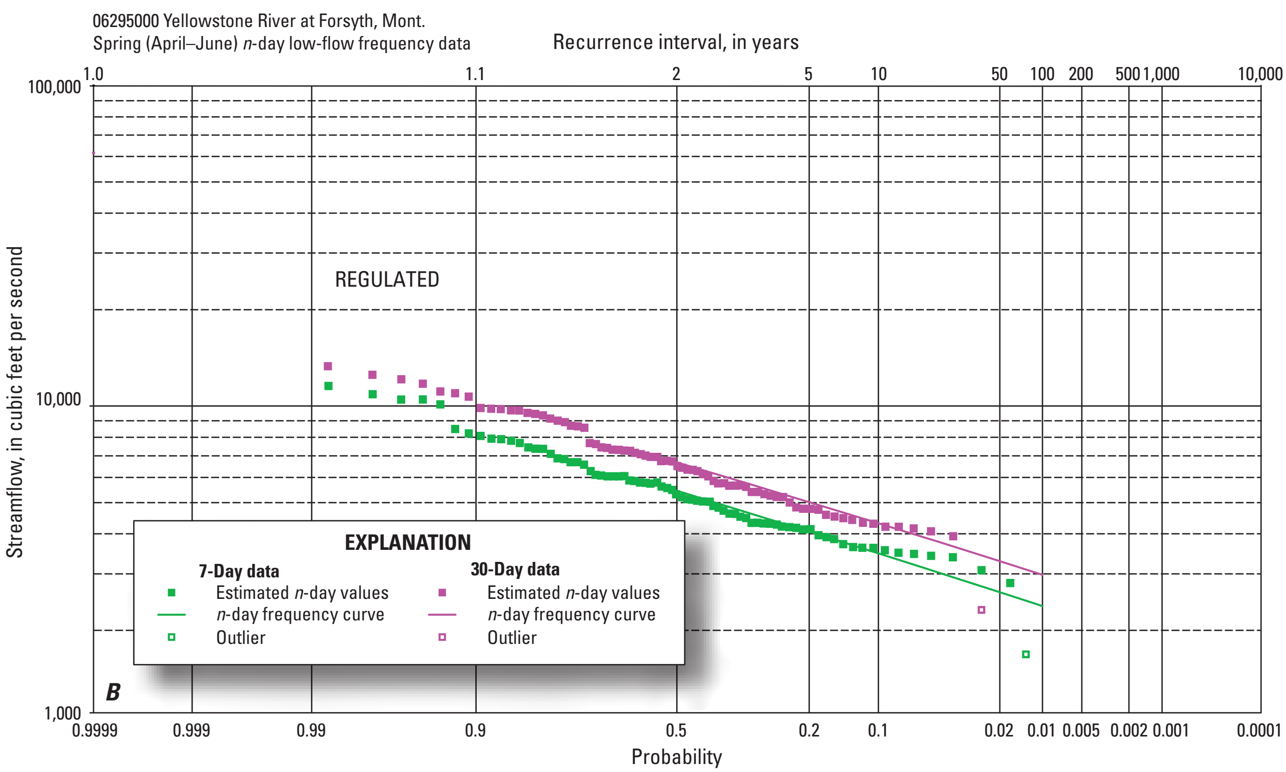
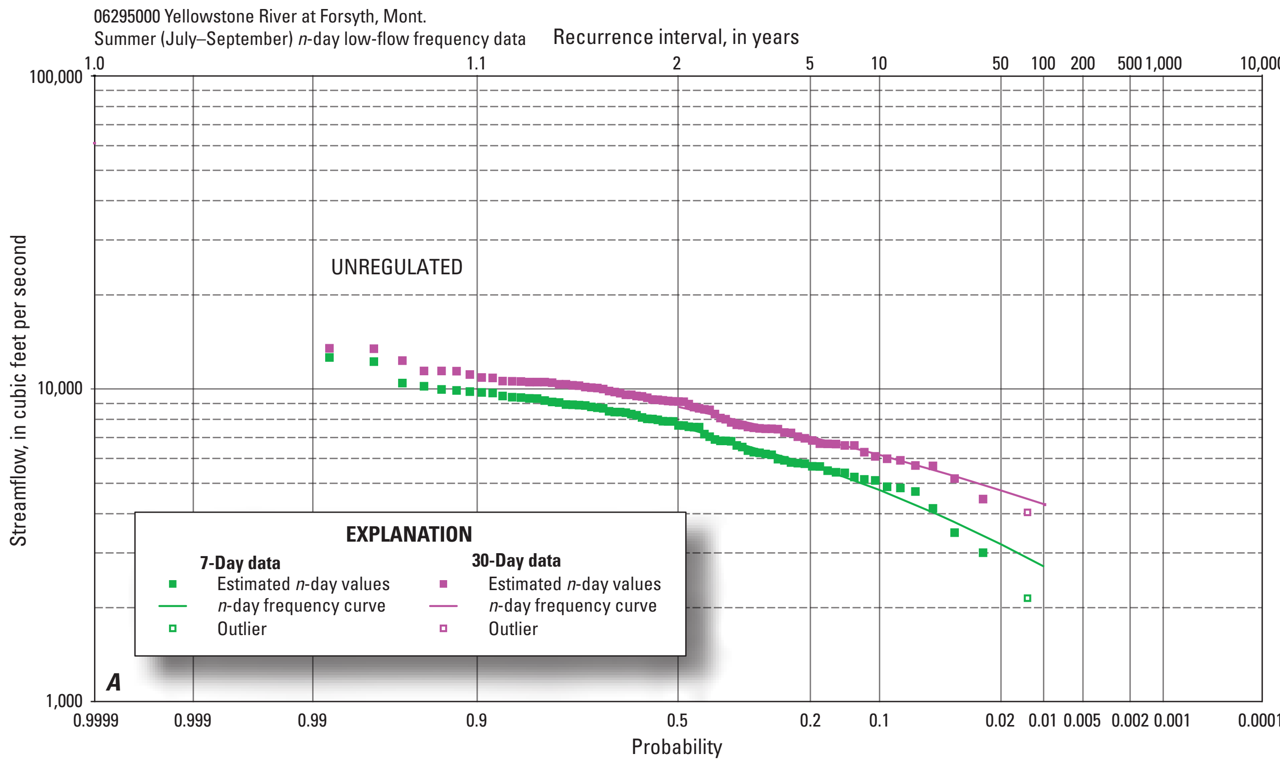


Figure 1–6–3. Spring (April–June) *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



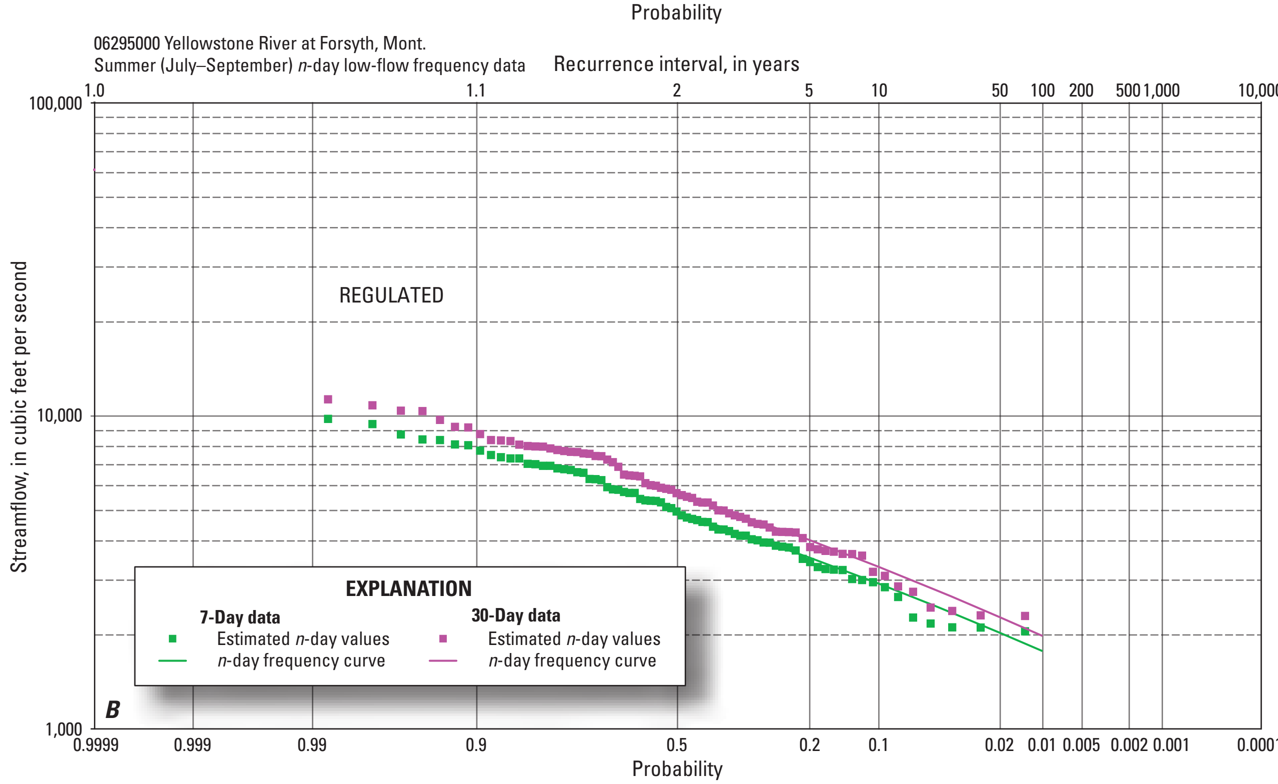
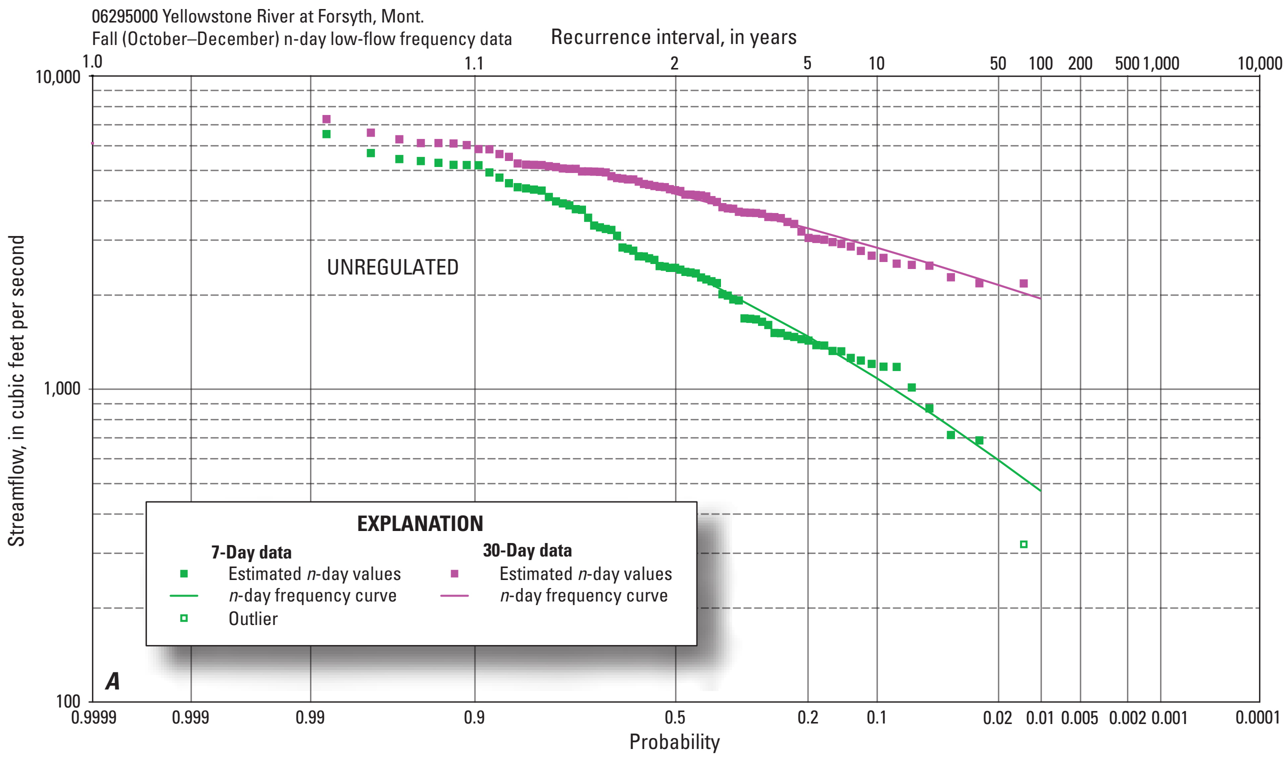


Figure 1–6–4. Summer (July–September) *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



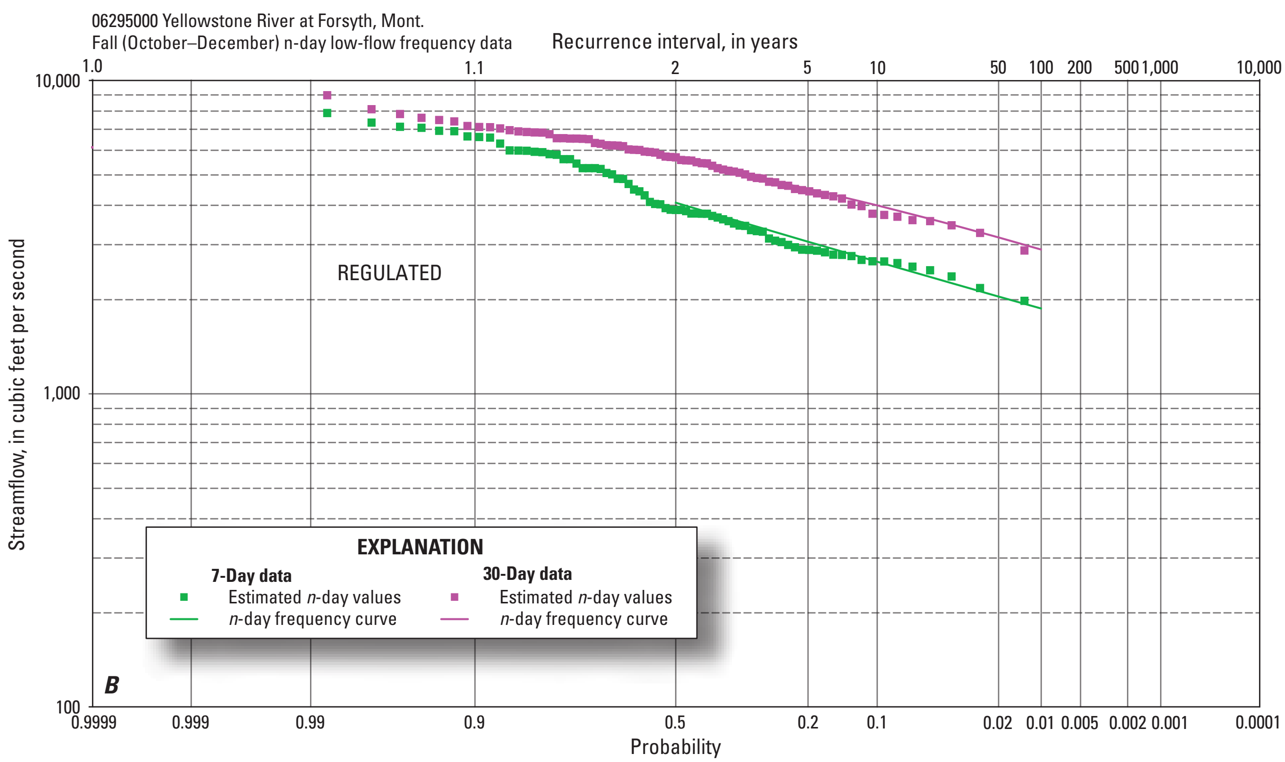
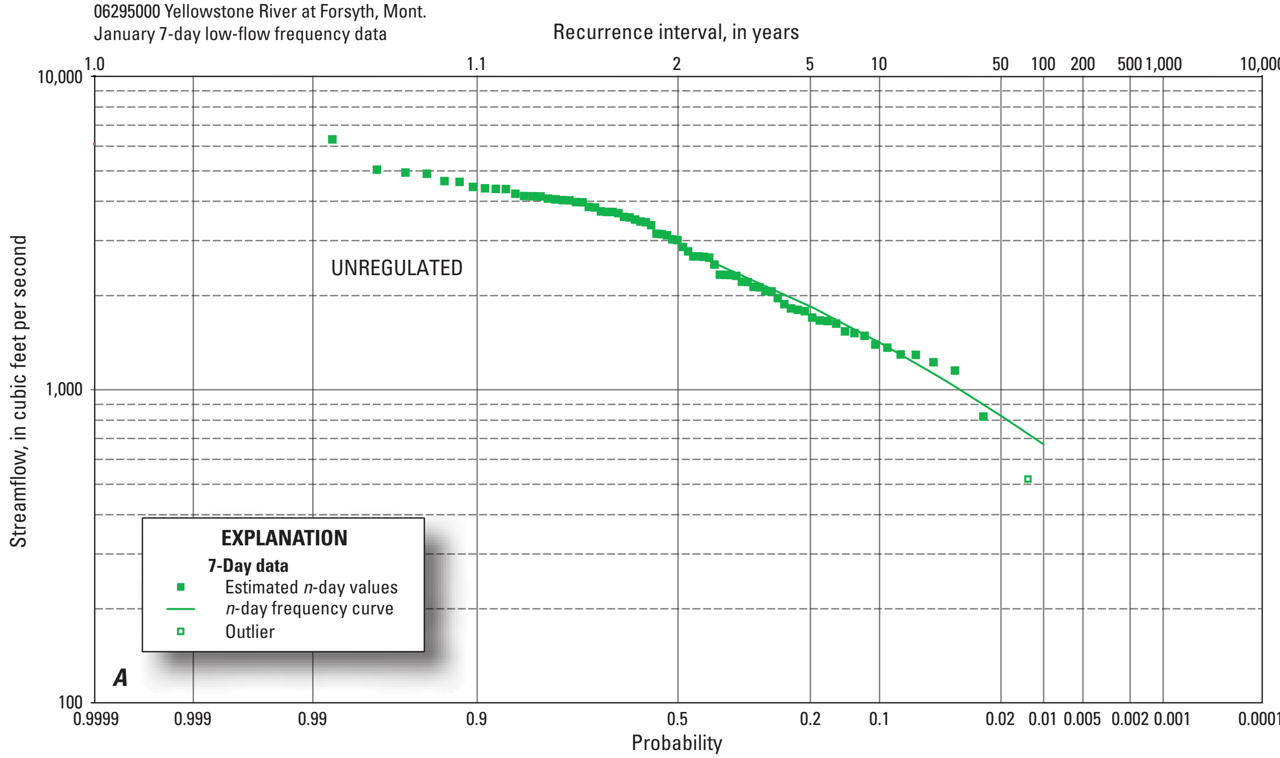


Figure 1–6–5. Fall (October–December) *n*-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



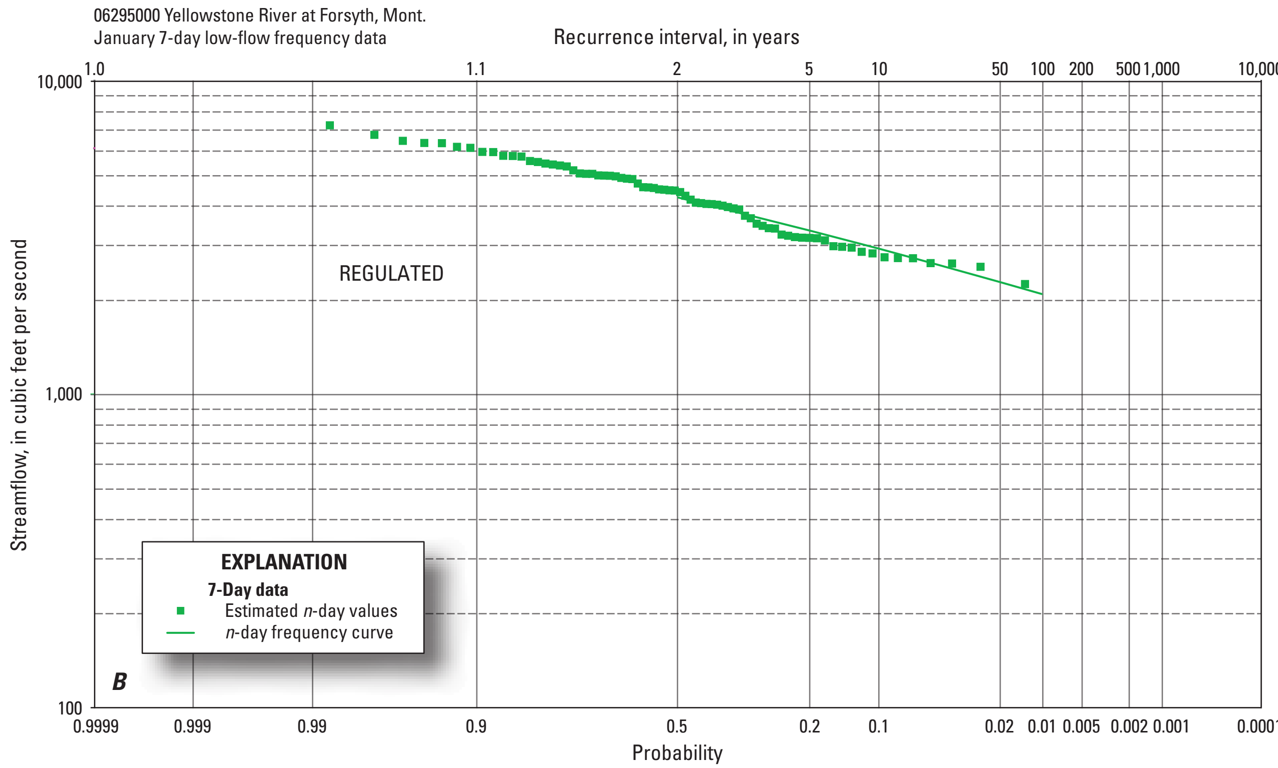
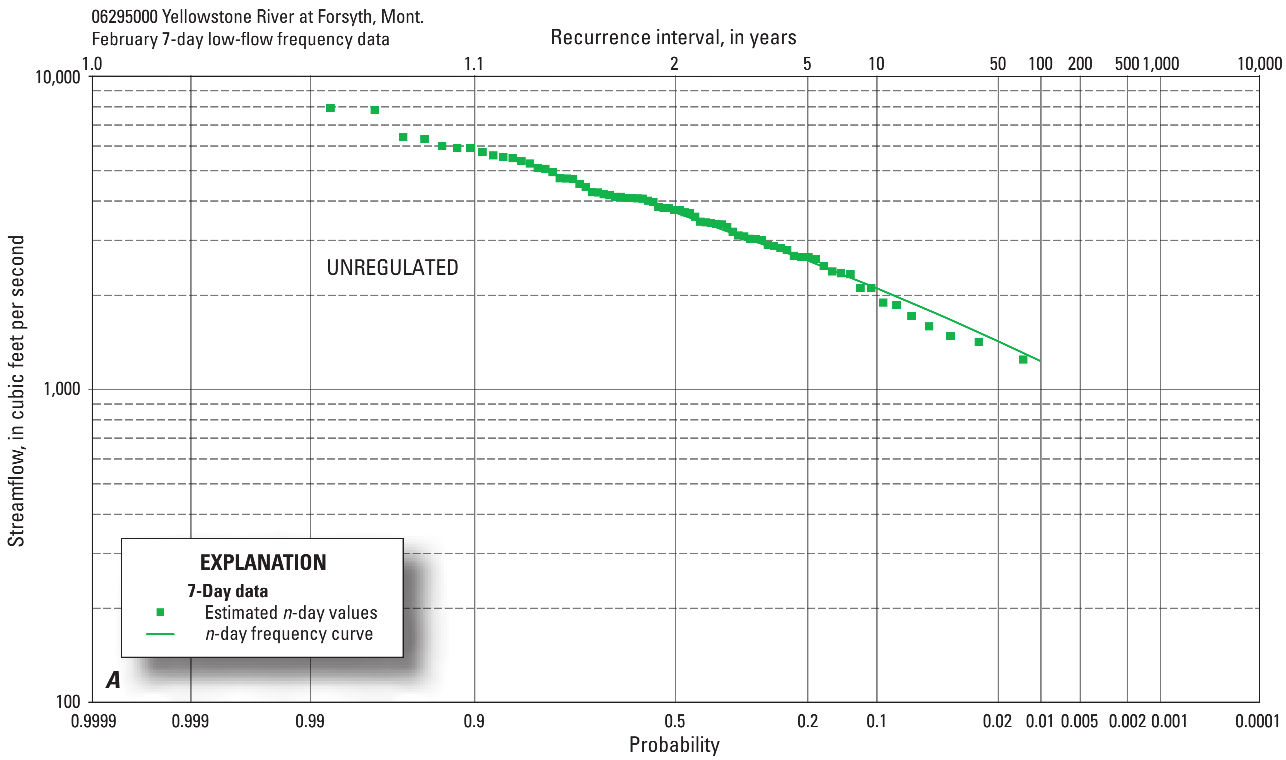


Figure 1–6–6. January 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



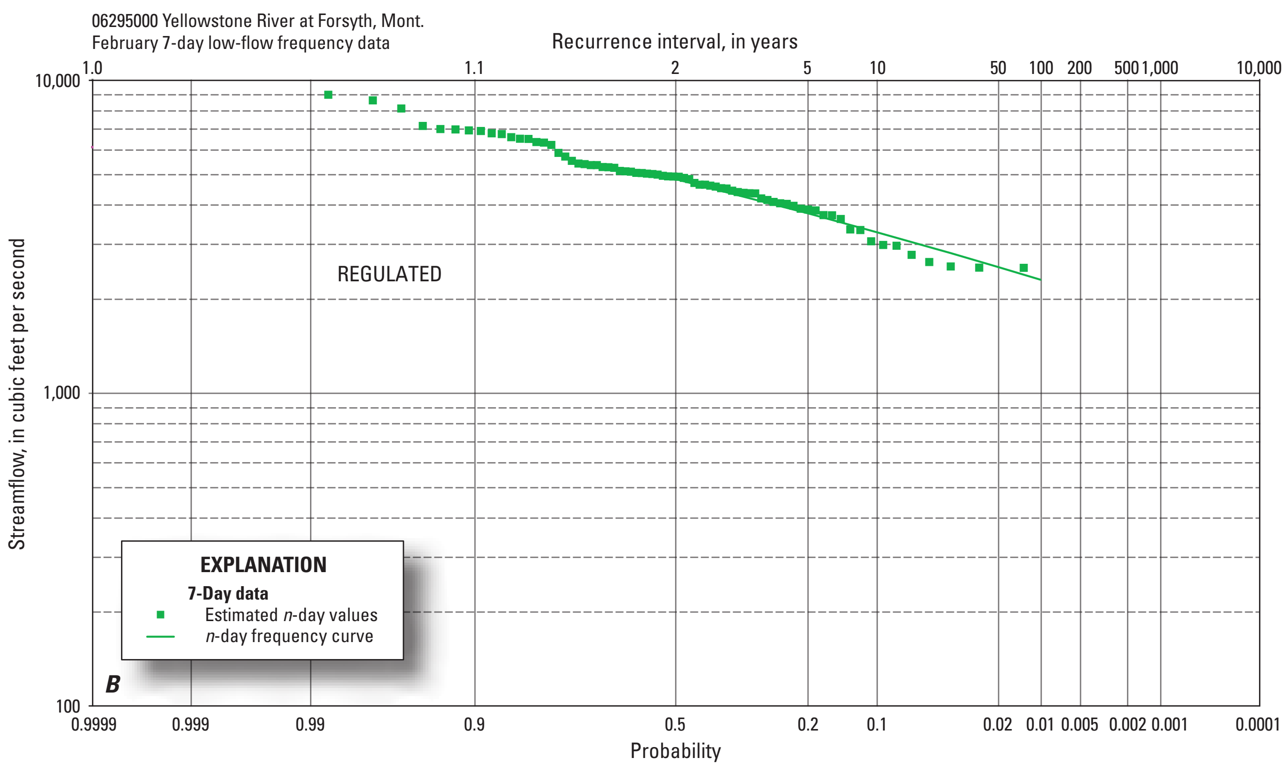
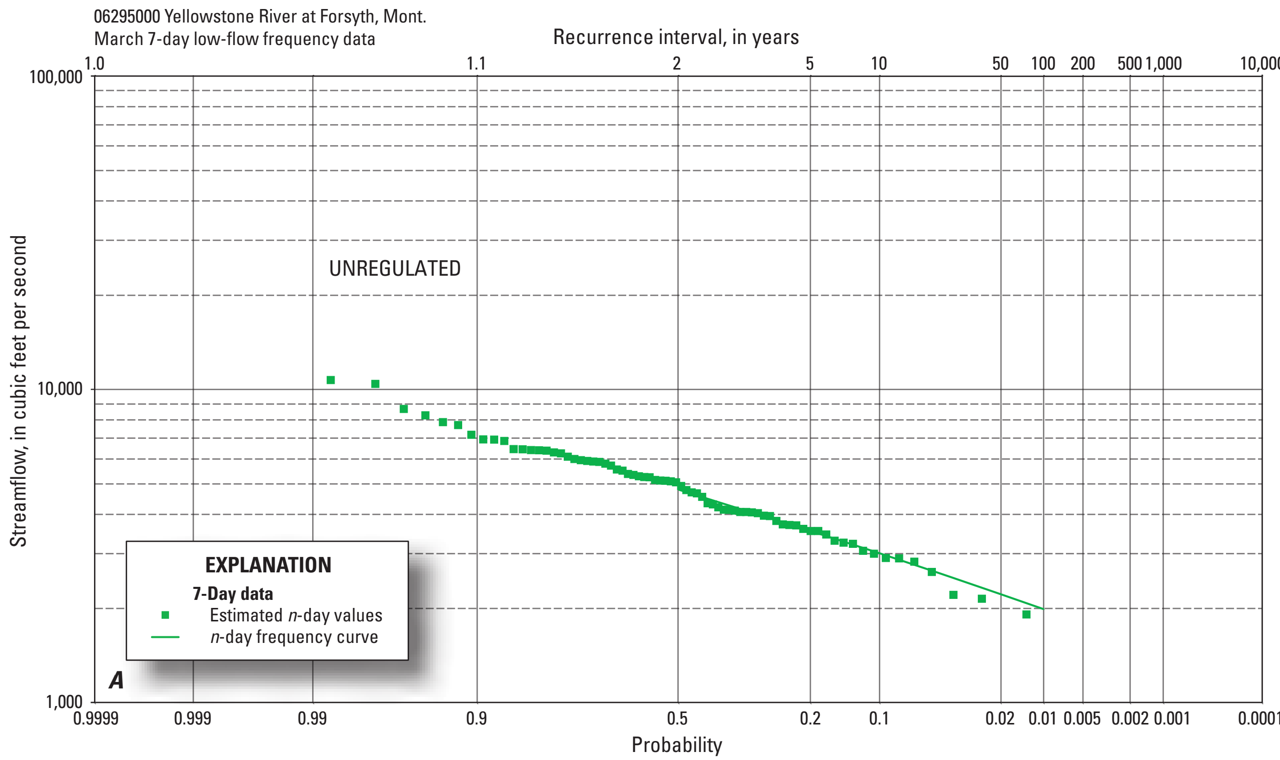


Figure 1–6–7. February 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



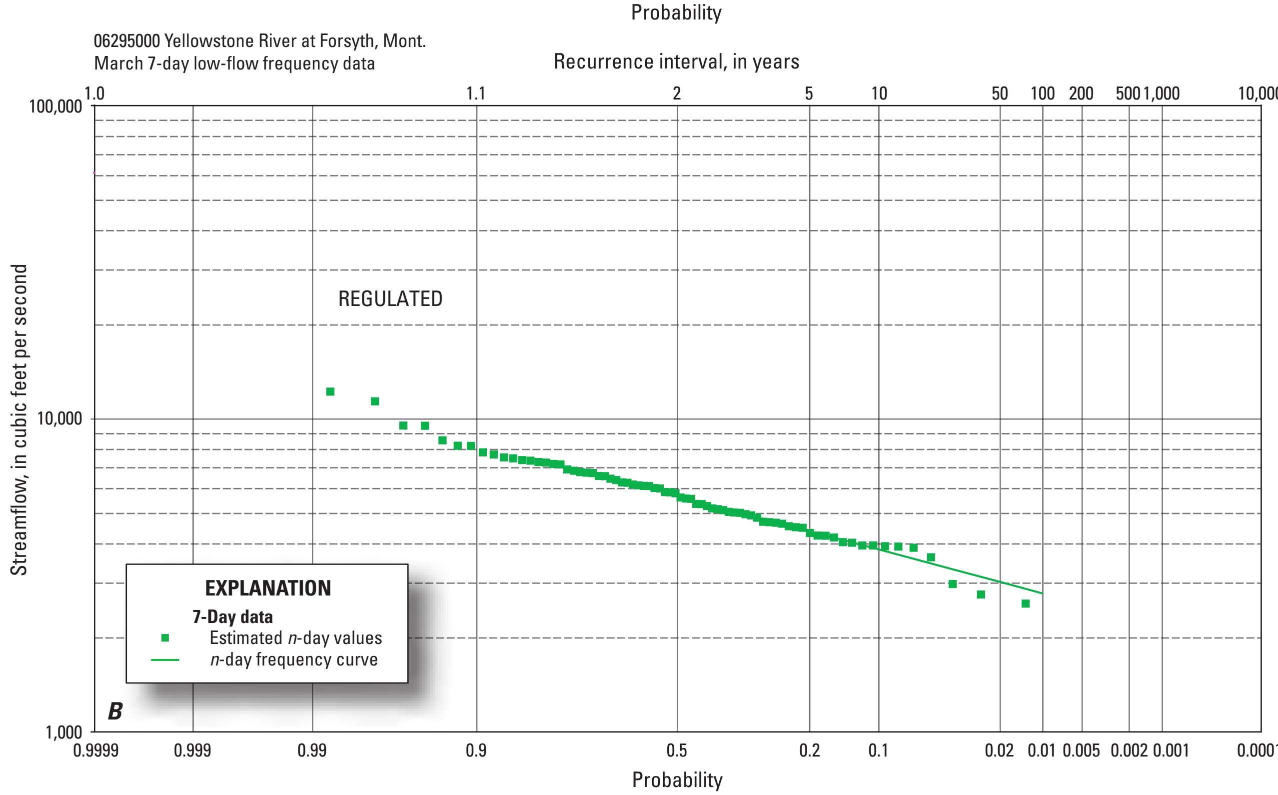


Figure 1–6–8. March 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

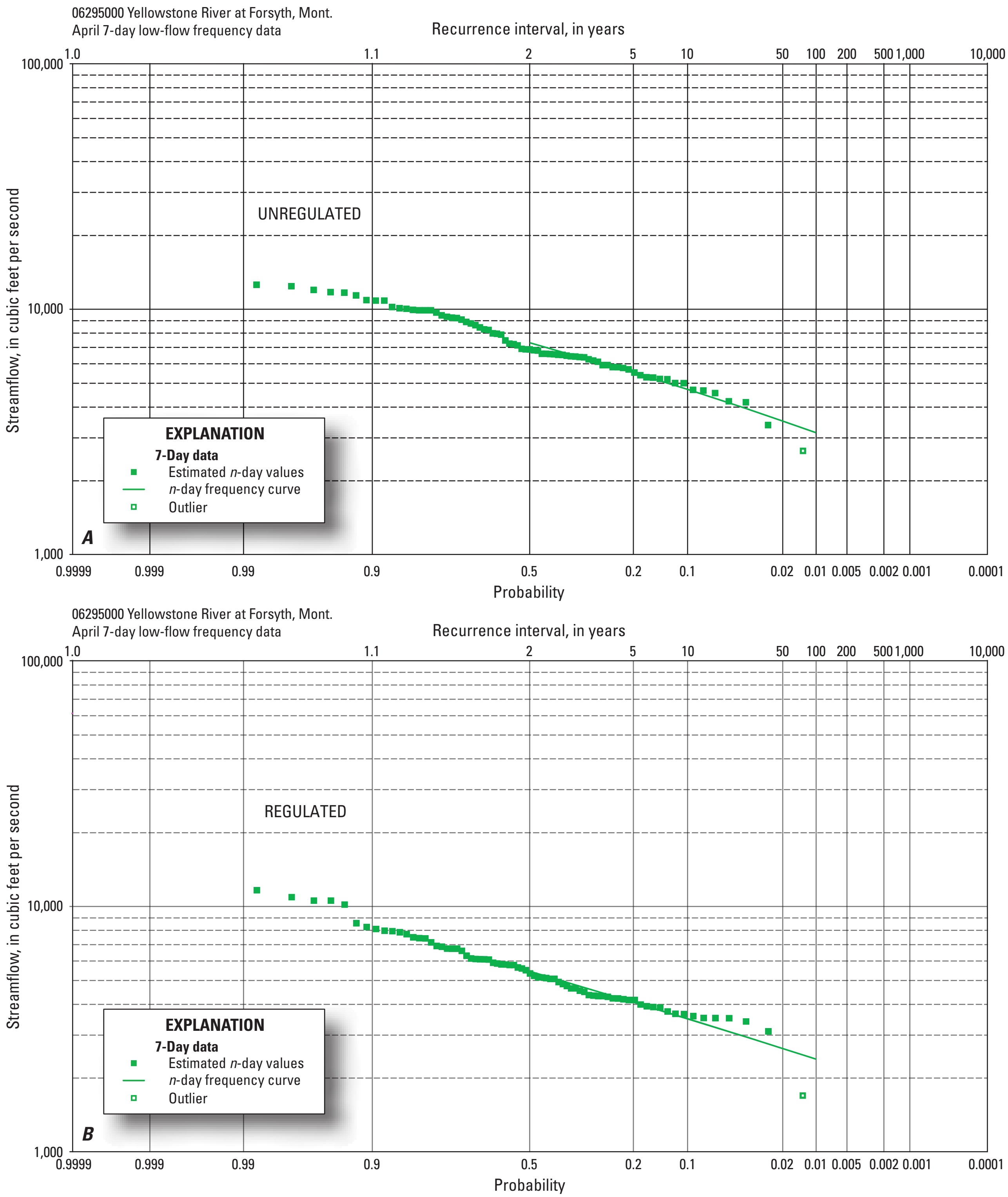
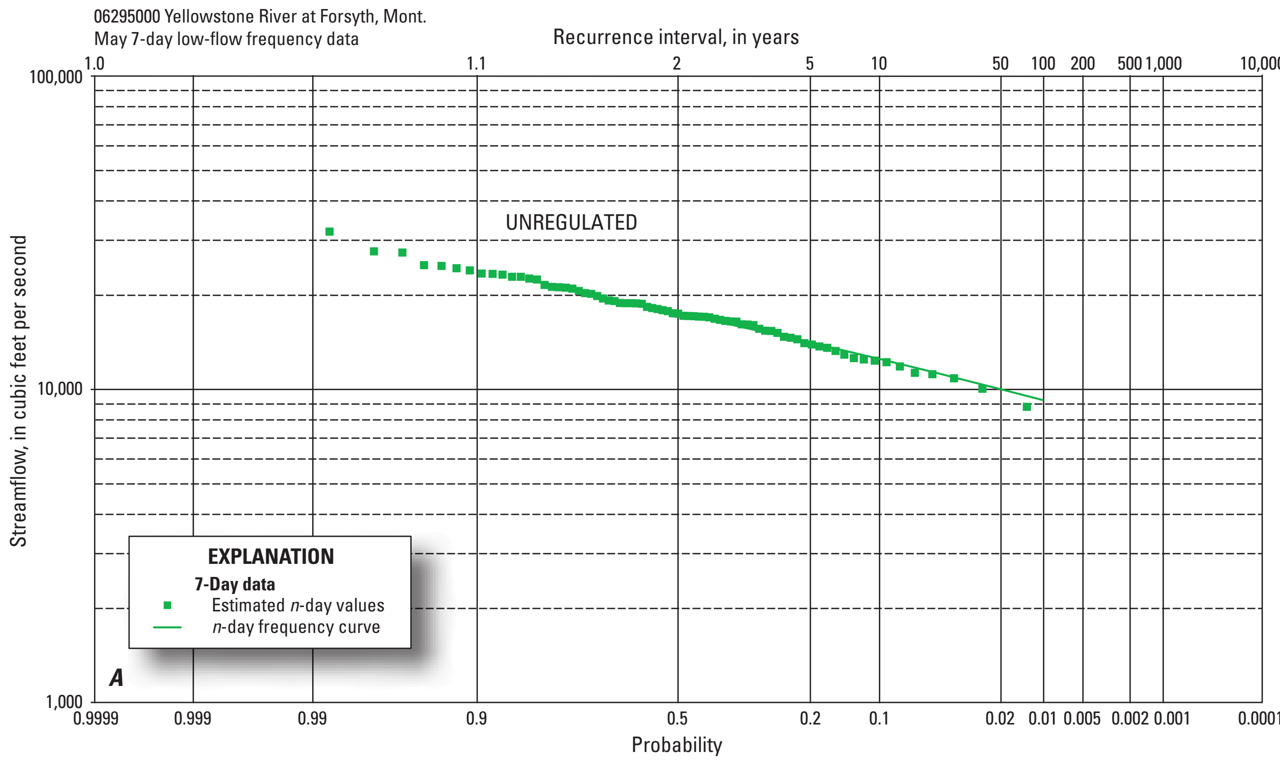


Figure 1–6–9. April 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



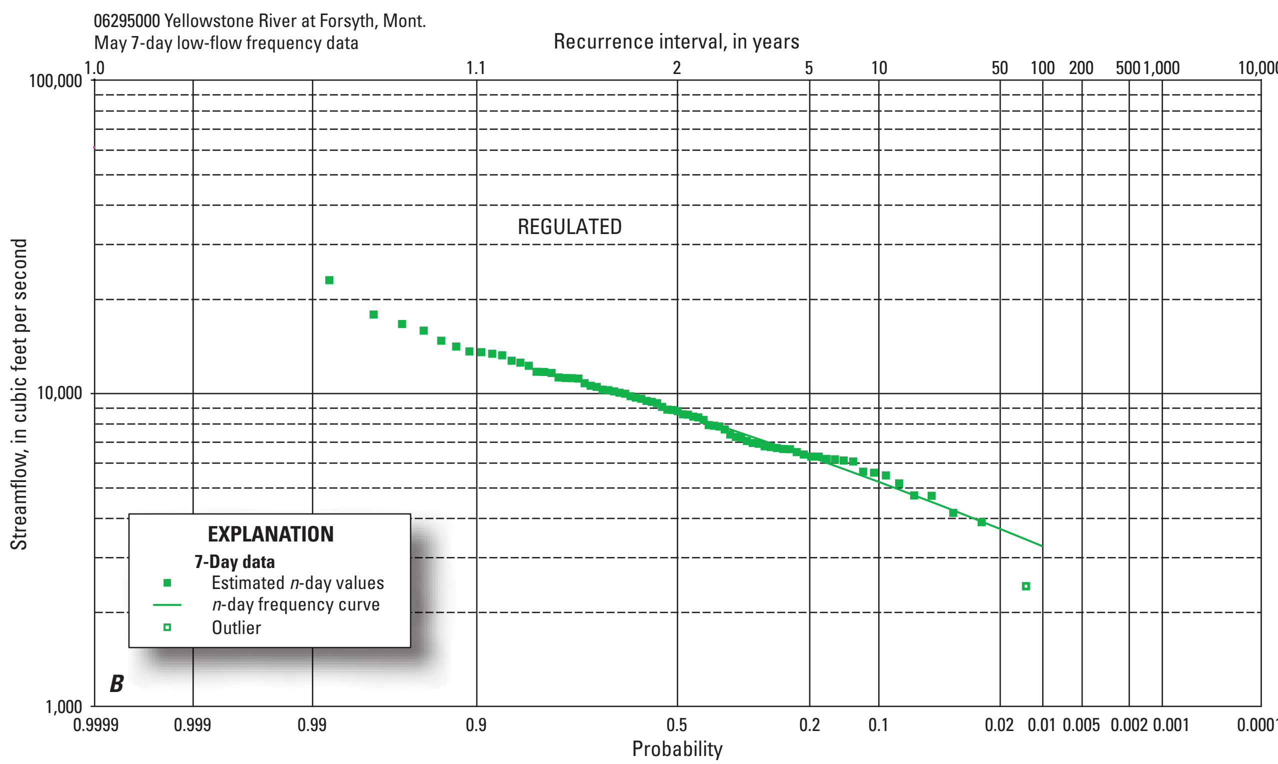
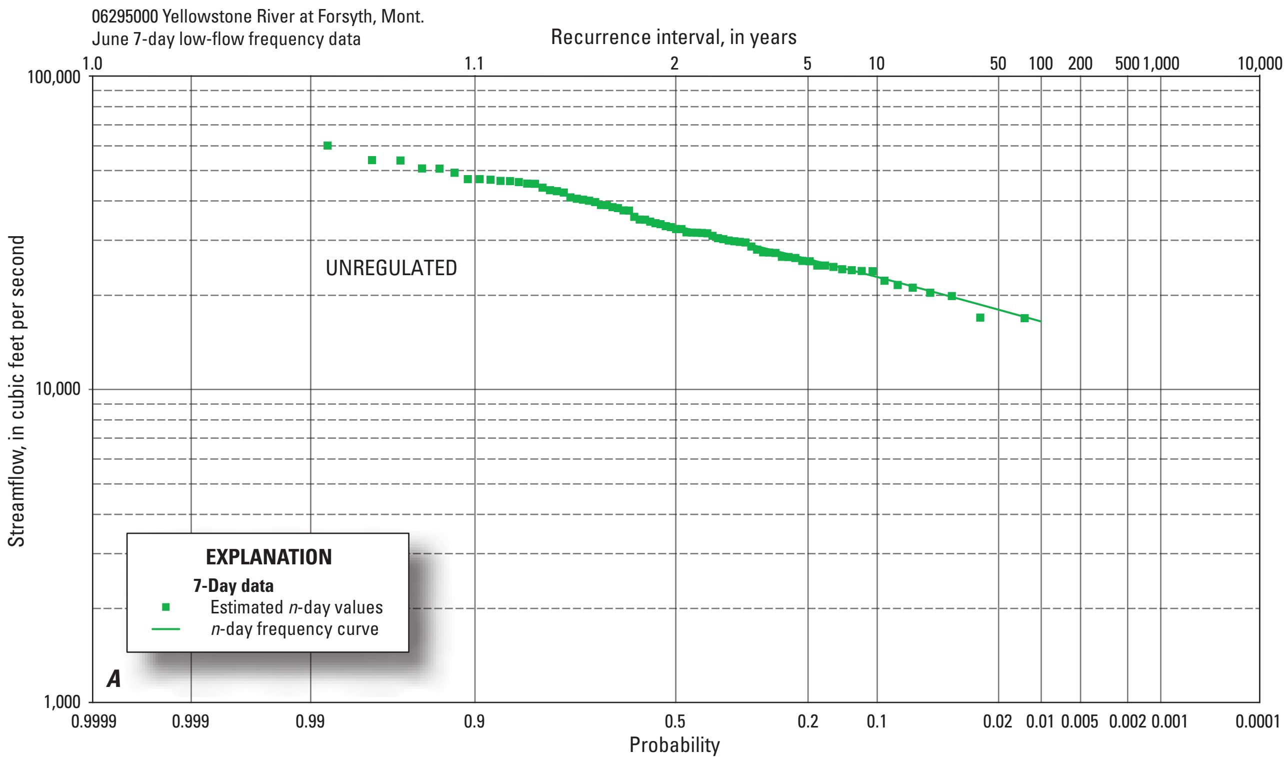


Figure 1–6–10. May 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



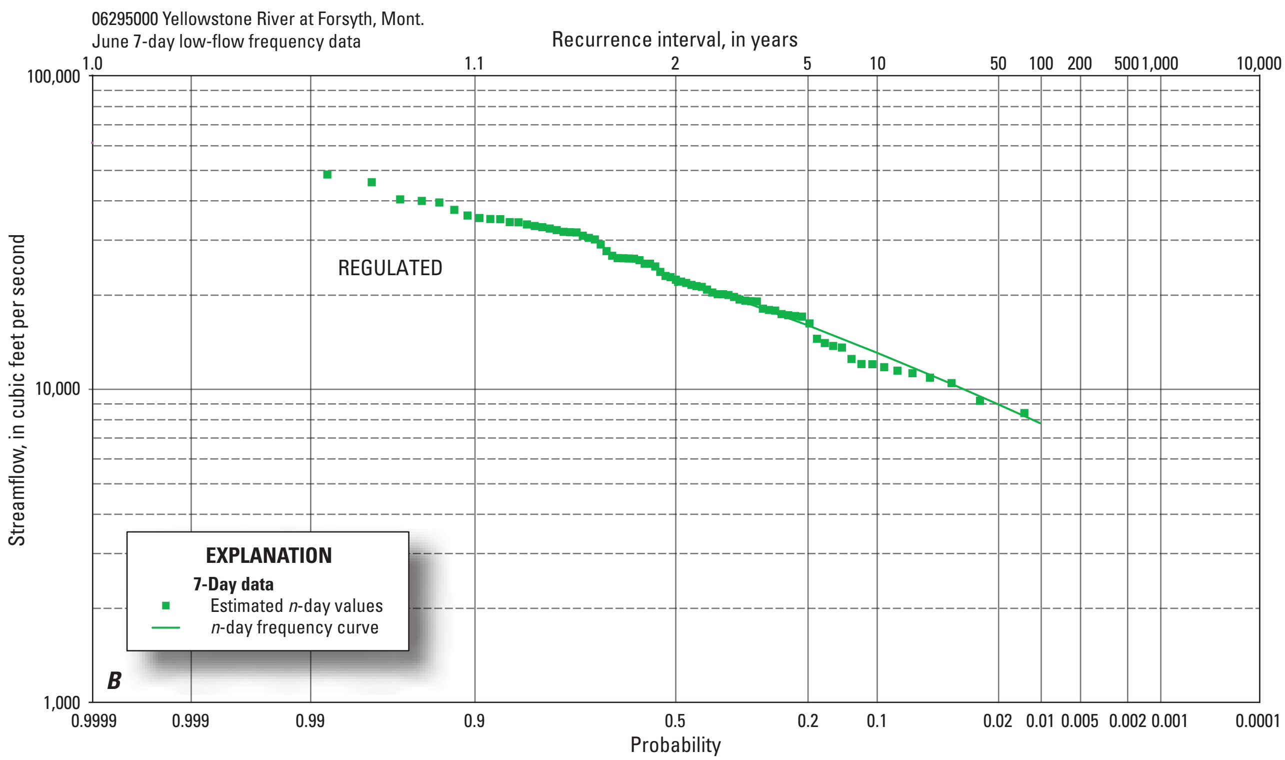


Figure 1–6–11. June 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

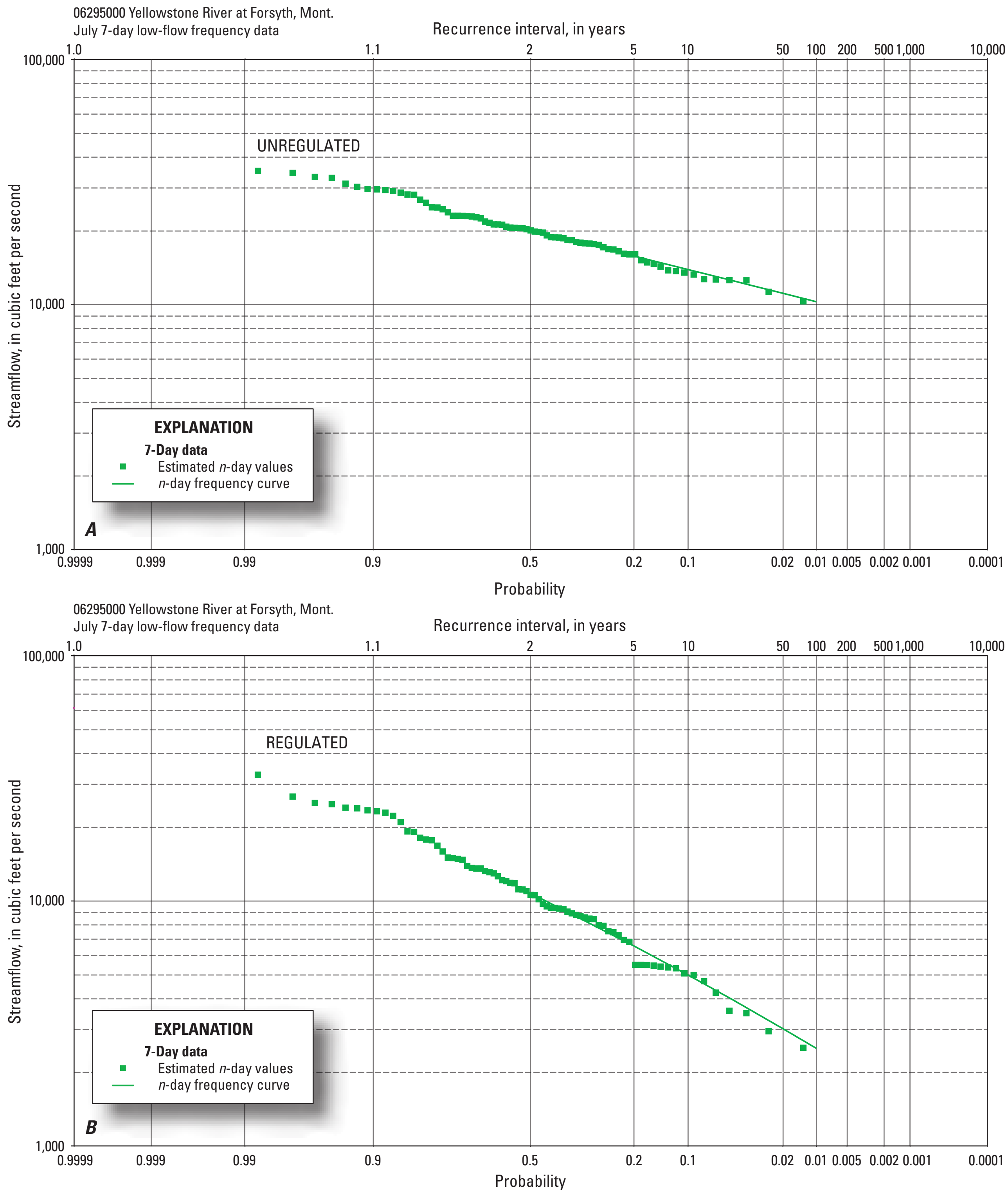


Figure 1–6–12. July 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

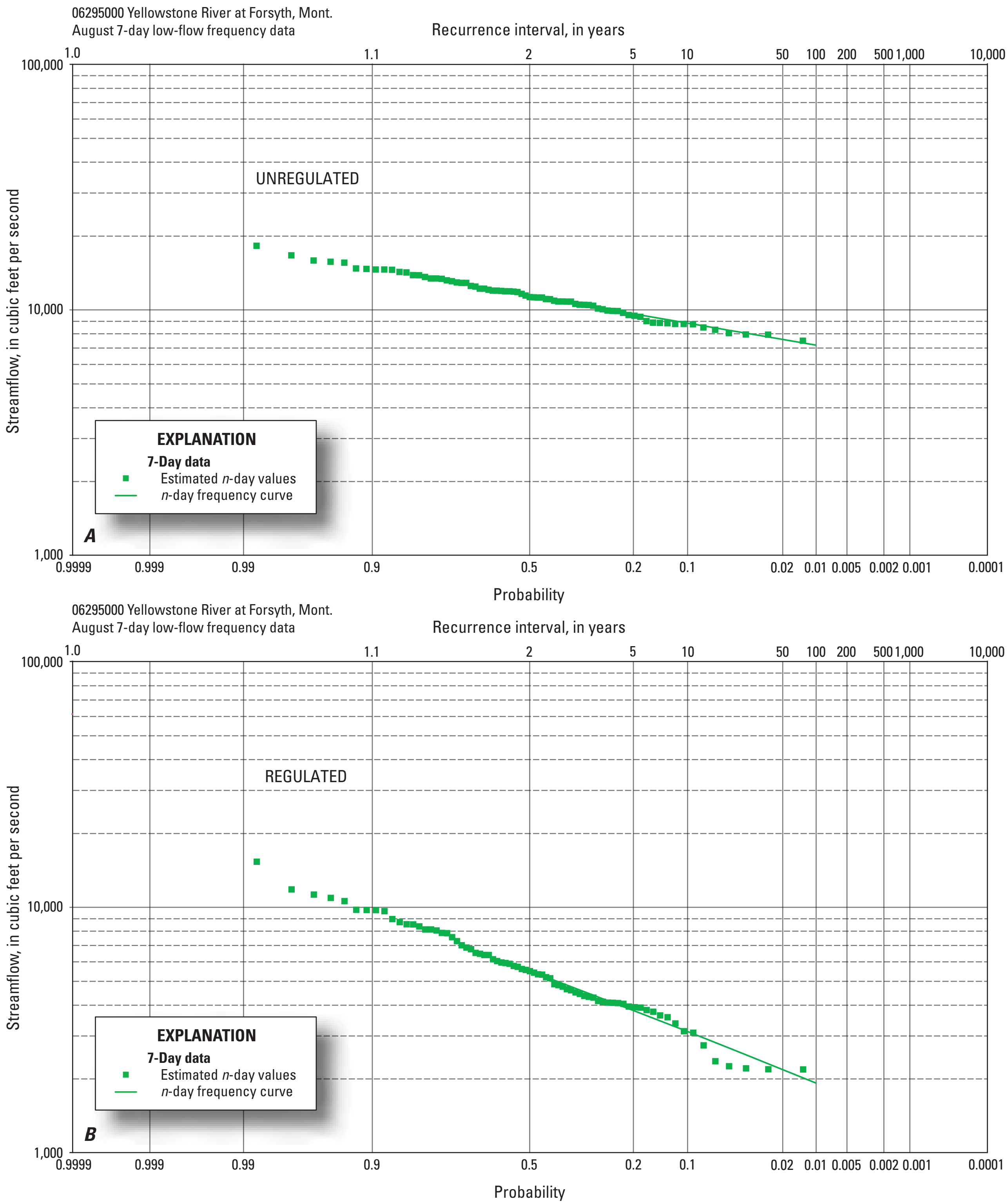


Figure 1–6–13. August 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

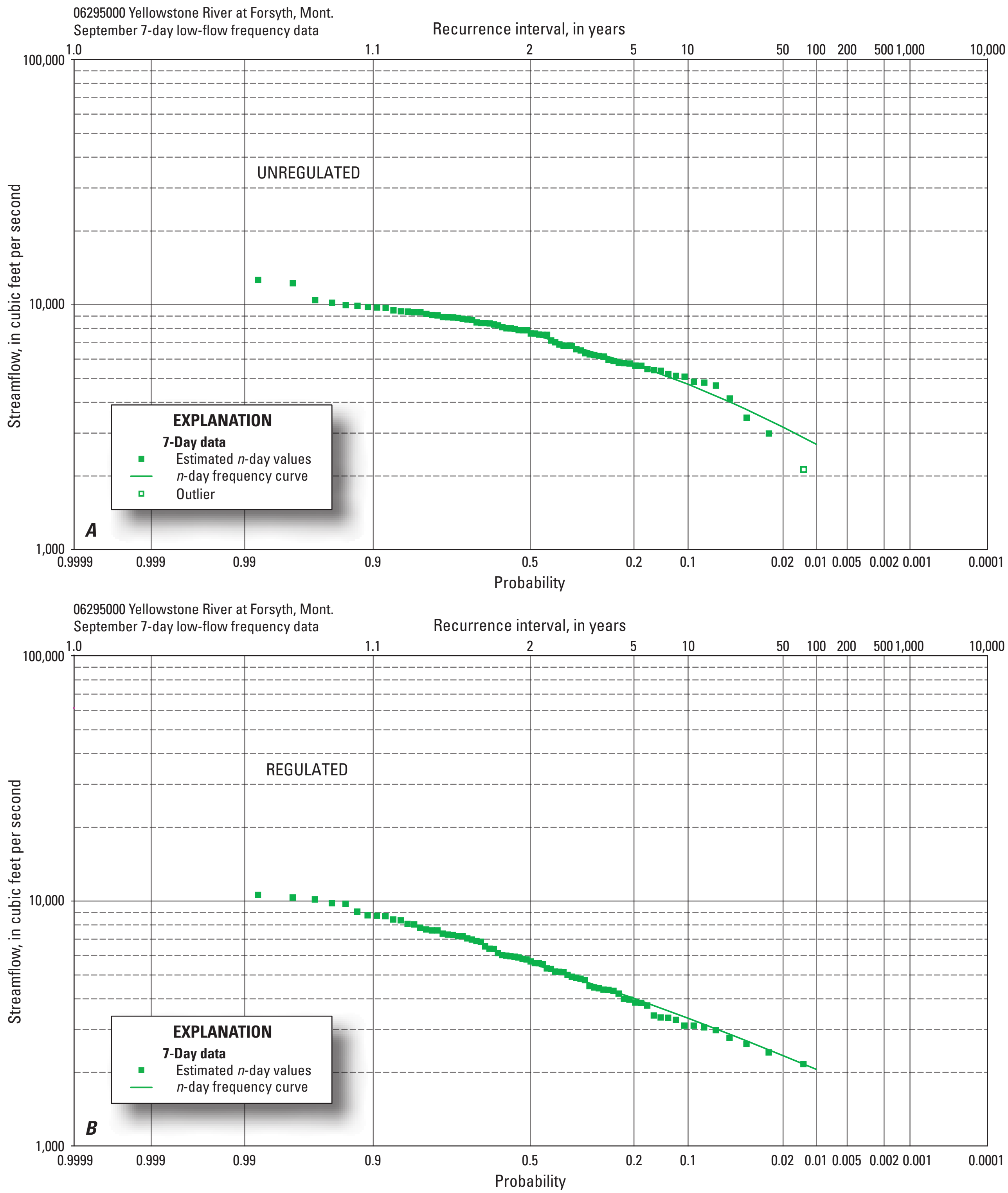
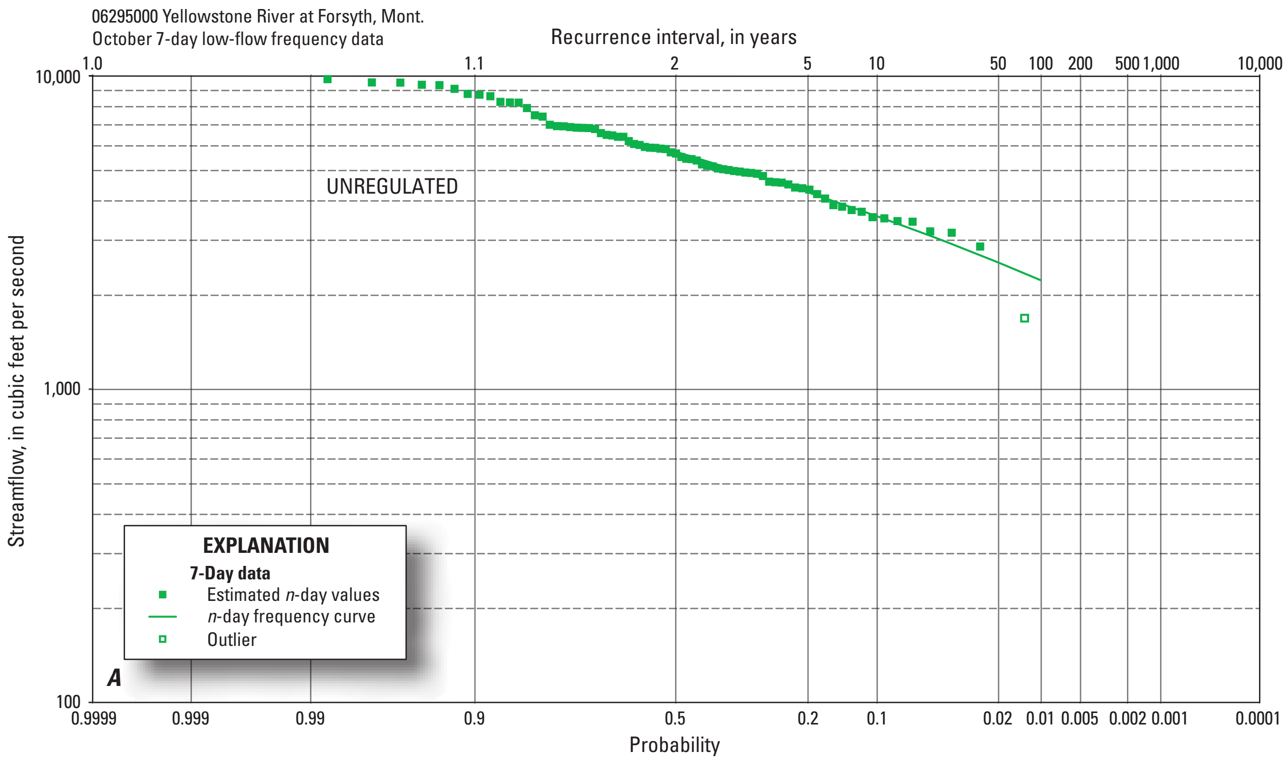


Figure 1–6–14. September 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



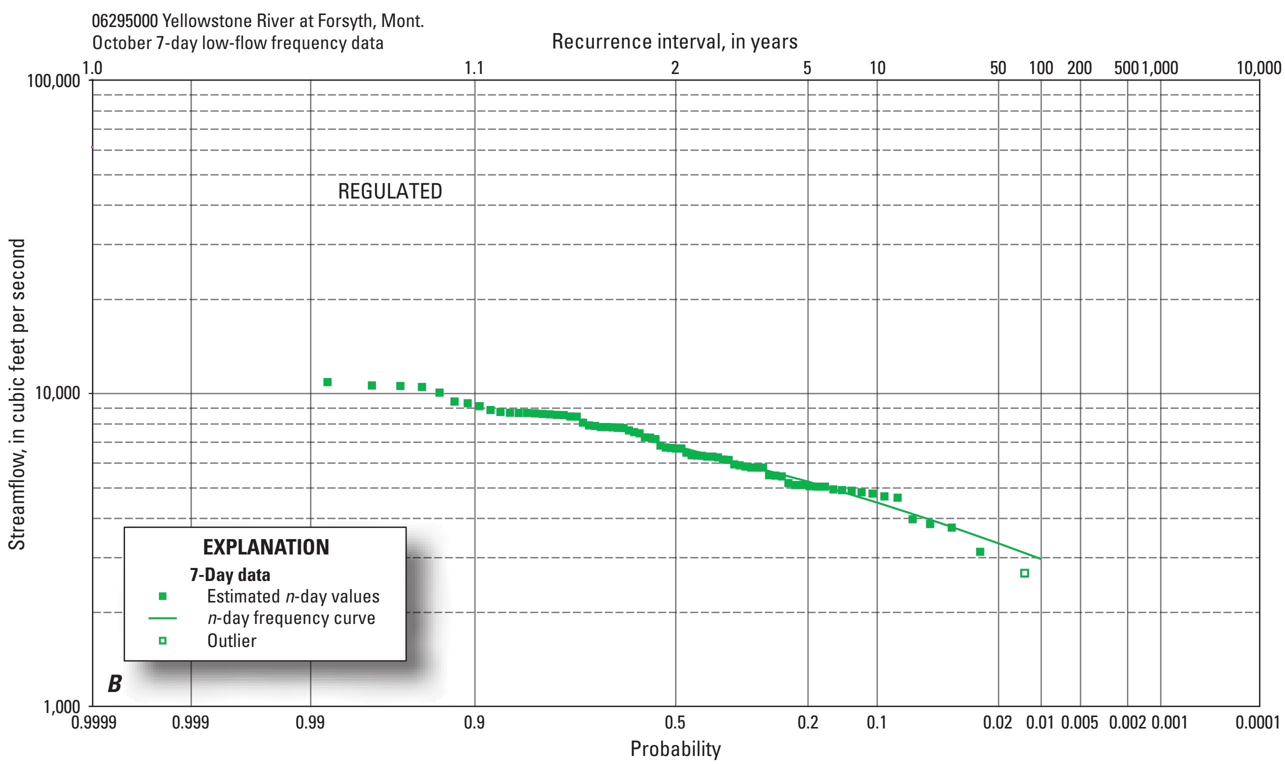
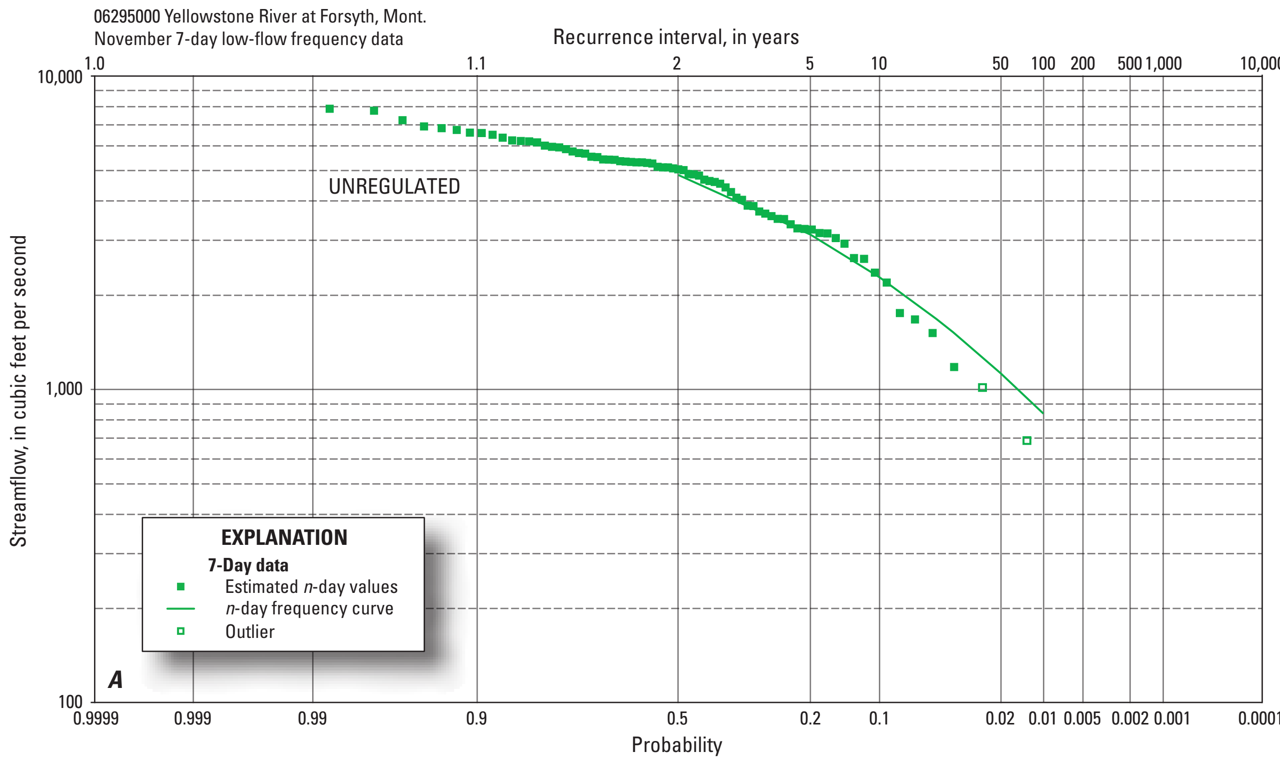


Figure 1–6–15. October 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



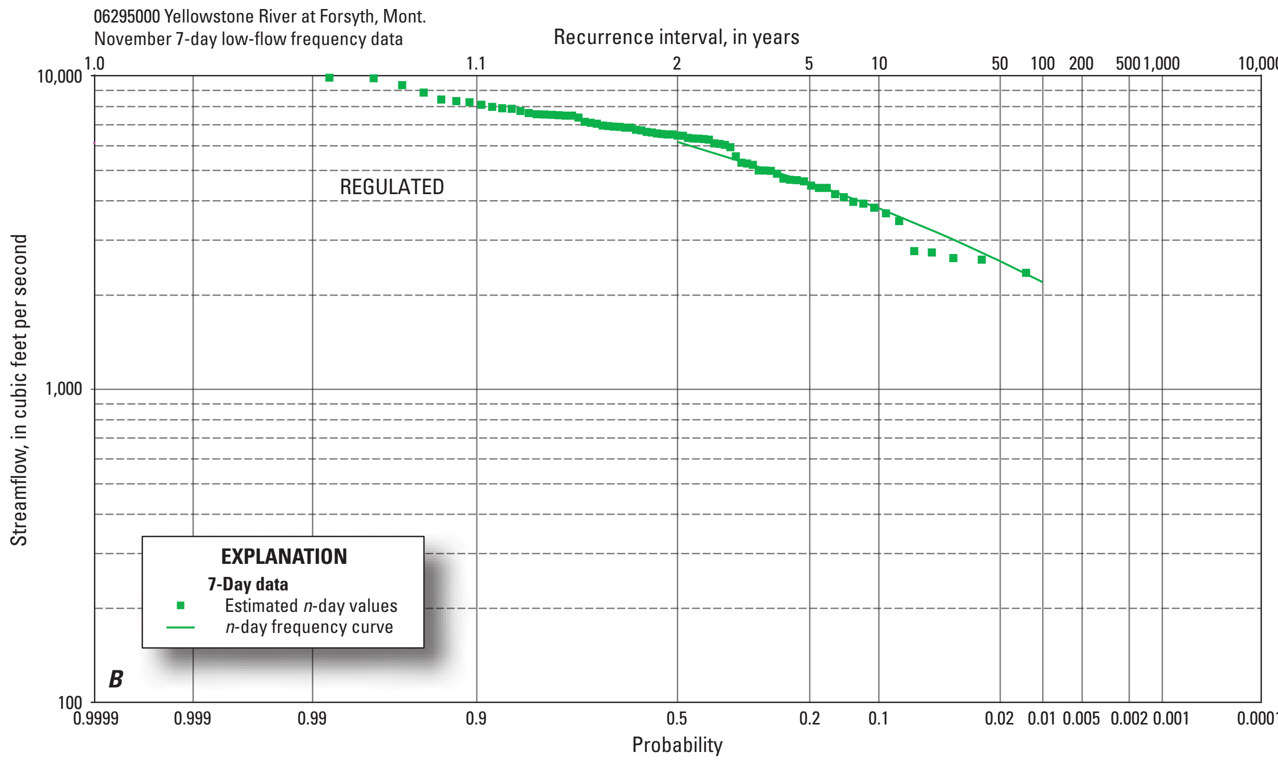
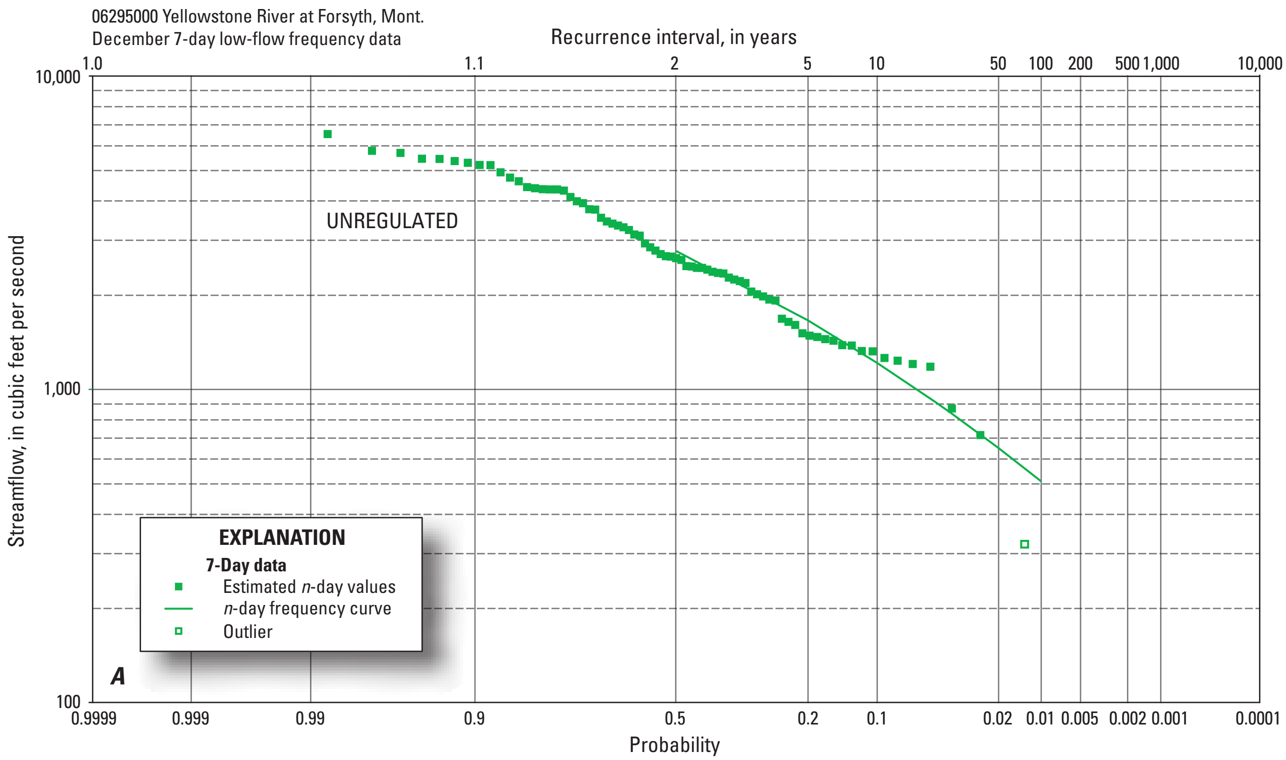


Figure 1–6–16. November 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.



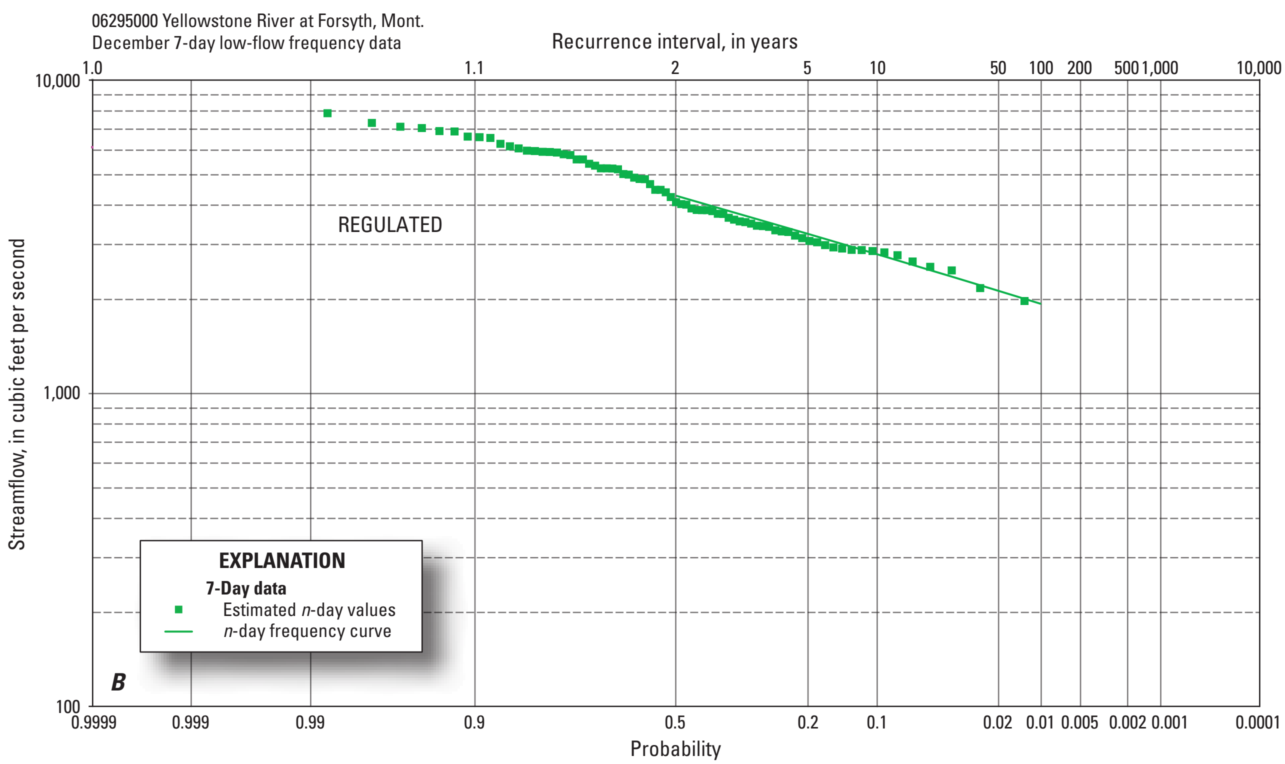


Figure 1–6–17. December 7-day low-flow frequency data for streamflow-gaging station 06295000 (Yellowstone River at Forsyth, Montana) for *A*, unregulated and *B*, regulated streamflow conditions, 1928–2002.

Appendix 2. Locations, Drainage Areas, and Annual *n*-day Low-Flow Frequency Data for Unregulated and Regulated Streamflow Conditions at Selected Locations on the Yellowstone River, Montana and Wyoming, 1928–2002

Appendix 2, presented in Microsoft® Excel spreadsheets, contains information about locations and drainage areas for selected streamflow-gaging stations and reach locations on the Yellowstone River. Appendix 2 also contains annual *n*-day low-flow frequency data at selected Yellowstone River streamflow-gaging stations; these data also were interpolated for selected locations on the Yellowstone River. For streamflow-gaging stations 06186500 and 06191500 (Yellowstone River at Yellowstone Lake Outlet Yellowstone National Park, Wyoming, and Yellowstone River at Corwin Springs, Montana) and for the reaches between those two streamflow-gaging stations, only data for unregulated conditions are included. For the remaining streamflow-gaging stations and reaches, data for unregulated and regulated streamflow conditions are included. The Excel spreadsheets are named sir2014-5155_APP_2.1_loc_and_da.xlsx and sir2014-5155_APP_2.2_lowflowfreq.xlsx. Locations of the streamflow-gaging stations and reach locations are shown on figures 2 and 3 (main report).

Appendix 2–1. Locations and drainage areas for selected streamflow-gaging station and reach locations on the Yellowstone River (*http://pubs.usgs.gov/sir/2014/5115/downloads/sir2014-5155_APP_2.1_loc_and_da.xlsx*).

Appendix 2–2. Annual, seasonal, and monthly *n*-day low-flow frequency data at selected locations on the Yellowstone River, Montana and Wyoming, for unregulated and regulated streamflow conditions, 1928–2002 (*http://pubs.usgs.gov/sir/2014/5115/downloads/sir2014-5155_APP_2.2_lowflowfreq.xlsx*).

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