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The Sediment Budget of the Illinois River

Misganaw Demissie, Renjie Xia, Laura Keefer, and Nani Bhowmik

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Executive Summary

Many major streams in Illinois drain into the Illinois River, which drains nearly half of the state. The Illinois Waterway with its system of locks and dams links Chicago and the Great Lakes to the Mississippi River, and thereby to the Gulf of Mexico. This linkage has significant transportation and commercial values for the state and the nation. In addition, with its numerous backwater lakes, wetlands, and floodplain forests, the Illinois River valley provides a significant habitat for fisheries, waterfowl, and other birds, and animals, making it an important ecological resource.

The Illinois River's environment has been subject to many impacts associated with watershed development, including waste discharges from urban areas, water-level control for navigation, and sediment and chemical inflow from agricultural lands. Water quality of the river was severely degraded for several decades prior to the 1970s when environmental regulations were enacted to control pollutant discharges. Since then the river water quality gradually has been improving. However, problems associated with erosion and sedimentation have not been improving and are recognized as the primary environmental problem in the Illinois River valley. The main sources of sediment to the Illinois River valley are watershed erosion, streambank erosion, and bluff erosion. The contribution of watershed erosion to the sedimentation problem in the Illinois River valley can be quantified by analyzing the sediment yields of tributary streams that drain into the valley. The contribution of bank erosion along the Illinois River and bluff erosion along the Illinois River valley are much more difficult to quantify at present because of the lack of data.

Sediment yields from tributary streams of the Illinois River were calculated based on suspended sediment load data collected by the U.S. Geological Survey (USGS). The duration of the sediment data ranges from one to 20 years, with most of the stations having less than five years of record. Sediment rating curves that relate daily sediment load and daily water discharge were developed for each sediment monitoring station based on existing data. Because rating curves often underestimate sediment yield, an improved rating curve procedure was developed to minimize the underestimation. Sediment rating curves then were used to calculate annual sediment yields from all tributary streams for which sediment load data were available. Annual sediment yields then were plotted against the annual water discharge to develop regional

equations for annual sediment yields. The data points coalesced into four different annual sediment yield equations, which were then used to calculate annual sediment yields by tributary streams into the Illinois River valley. A 20-year period (1981-2000) was used for the analysis. Tributary streams of the Spoon and LaMoine Rivers had the highest sediment yield rates. The mainstems of the Spoon, LaMoine, and Vermilion Rivers had the second highest sediment yield rates, followed by the Sangamon, Iroquois, and Des Plaines Rivers.

Sediment yield calculations were used to construct a quantitative sediment budget for the Illinois River valley. By using the four group equations developed from observed data, the sediment inflow into the Illinois River valley from tributary streams was calculated. The sediment outflow from the Illinois River valley was determined from data collected by the USGS at the Valley City monitoring station. On average, it was estimated that 12.1 million tons of sediment were delivered to the Illinois River valley annually during the period 1981-2000, and the average annual outflow of sediment from the Illinois River at Valley City was 5.4 million tons. This resulted in an estimated average annual deposition of 6.7 million tons of sediment delivered from tributary streams to the Illinois River valley. Because of improved datasets, the present estimate of sediment deposition for the 1981-2000 period is about 18 percent lower than the estimate for the 1981-1990 period. However, the total amount of sediment deposited in the Illinois River valley was probably even higher than our estimate because of the contribution of bank and bluff erosion along the mainstem of the Illinois River, which were not included in these calculations.

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Introduction

The Illinois River is the most significant river in the State of Illinois. The river drains nearly half of the state and has a drainage area of 28,906 square miles. Except for about a 4,000-square-mile-area in Indiana and Wisconsin, the watershed is located in Illinois (see Figure 1). The watershed contains the drainage basins of several of the state's significant rivers such as the Sangamon, LaMoine, Spoon, Mackinaw, Vermilion, Fox, Kankakee, and Des Plaines Rivers. Historically, the Illinois River has played a significant role in the development of the state, in terms of both commerce and transportation. It is the only waterway that links the Great Lakes to the Mississippi River, and thus to the Gulf of Mexico. In addition, with its numerous backwater lakes, wetlands, and floodplain forests, the Illinois River valley provides a significant habitat for fisheries, waterfowl, and other birds and animals, making it an important ecological resource.

The Illinois River's environment has been subjected to many impacts associated with watershed development, including waste discharges from urban areas, water-level control for navigation, and sediment and chemical inflow from agricultural and urban watersheds. The quality of the river was severely degraded for several decades prior to the 1970s when environmental regulations were enacted to control pollutant discharges. Since then the quality of the river gradually has been improving.

The most persistent and still unmanaged problem facing the Illinois River is sedimentation in the river channel and the backwater lakes. Based on sedimentation data for Peoria Lake, which is located along the Illinois River, it is very clear that the rate of sedimentation in Peoria Pool was significantly higher from 1965 to 1985 than from 1903 to 1965 (Demissie and Bhowmik, 1986; Demissie, 1997). Of special concern are the main channel and backwater lakes along the Illinois River.

Erosion and sedimentation have long been recognized as the principal causes for most of the environmental and ecological problems in the Illinois River valley. The Illinois River Action Plan of the Illinois State Water Plan Task Force (1987) ranks soil erosion and siltation as the number-one-priority problem. In their “Conference Summary and Suggestions for Action,” *Proceedings of the Governor's Conference on Management of the Illinois River System: The 1990s and Beyond*, Mathis and Stout (1987) state: "Most of the problems uppermost on the

Figure 1. Location of the Illinois River basin

minds of participants included significant problems with soil erosion and siltation. All discussion groups recognized that soil erosion and siltation from land use practices threatened the Illinois River, its backwater lakes and associated biota." Many bottomland lakes along the river valley have already lost a large part of their capacity to sediment accumulation, and continue to do so at a very high rate. Several lakes in the valley have completely filled in with sediment, and others will follow in the near future. Even though it is repeatedly acknowledged that erosion and sedimentation are the main problems in the Illinois River valley, detailed studies on the issue are rare.

One study for the Peoria Lake segment of the Illinois River, completed by the Illinois State Water Survey or ISWS (Demissie and Bhowmik, 1986), has resulted in tremendous public interest and a call for action to remedy the problems associated with erosion and sedimentation in the Illinois River valley. For the first time, the attention and efforts of local, state, and federal agencies have been focused on attainable erosion control and lake restoration projects. Findings and recommendations from the 1986 report have formed the basis for most projects and proposals for managing the sedimentation problem in Peoria Lake.

A follow-up study analyzed the erosion and sedimentation problem for the entire Illinois River (Demissie et al., 1992). The 1992 report provided important facts and numbers on erosion and sedimentation based on data available up to that time. It has been used as a basis for developing management alternatives in the Illinois River watershed and along the river valley. Several of the recommendations developed as part of the *Integrated Management Plan for the Illinois River Watershed* (State of Illinois, 1997) were based on the results of the study. Stream sediment data used for the 1992 report were collected by the U.S. Geological Survey (USGS) from 1981-1990 (Coupe et al., 1989; Fitzgerald et al., 1984, 1985, 1986, 1987, 1988; Richards et al., 1983, 1991; Sullivan et al., 1990; USGS, 1982).

The 1992 report estimated the delivery of 13.8 million tons of sediment to the Illinois River valley annually for the period 1981-1990. The average annual sediment outflow at Valley City was calculated to be 5.6 million tons, resulting in an estimated 8.2 million tons of sediment deposition in the Illinois River valley annually. The present report updates the 1992 report by including sediment data collected from 1986-2000. The purpose of one of the major data collection efforts from 1994-1997 by the USGS was to develop a suspended sediment budget for LaGrange Pool (Gaugush, 1999). All suspended sediment data collected by the USGS since 1990 appear in the USGS Water Resources Data reports (Harris et al., 2002; La Tour et al., 1993, 1999, 2000, 2001; Richards et al., 1992; Wicker et al., 1995, 1996, 1997, 1998; Zuehls et al., 1994). Major conclusions of the USGS study can be summarized as follows:

1) Suspended sediment discharges from LaGrange Pool were significantly higher than those from Pool 13 on the Mississippi River even though the drainage area for Pool 13 is more than three times greater than that of LaGrange Pool.

2) “The Illinois River and its tributaries in the area of the LaGrange Pool contribute much higher suspended sediment loads on an area basis than the Mississippi River and its tributaries at Pool 13” (Gaugush, 1999).

3) In terms of sediment sources, LaGrange Pool receives most of its sediment from tributary streams rather than from the Illinois River mainstem, while the opposite is true for Pool 13.

Acknowledgments

This report is based on research partially supported by the U.S. Army Corps of Engineers (USACOE), Rock Island District, and the Environmental Management Technical Center of the U.S. Geological Survey. Dr. Michael Schwar of the U.S. Army Corps of Engineers was the Project Manager and coordinated the review and comments from several USACOE staff members. His assistance and the review comments and suggestions were very helpful and greatly appreciated. We also appreciate the review and valuable comments received from the Center for Watershed Science staff through the internal review process. Becky Howard prepared the final report, Eva Kingston edited the report, and Linda Hascall prepared the illustrations.

Erosion and Sediment Yield

Sediment Data

The main task of this project was to collect and analyze sediment data from different sources so that reliable and consistent procedures could be developed to calculate sediment movement to and from the Illinois River valley. The most relevant data for this purpose are the sediment discharge data at gaging stations. All streamgaging stations with sediment discharge data within the Illinois River watershed were identified, and then the data were assembled in a consistent format for further analysis. Table 1 presents an updated summary (1981-2000) of the available sediment discharge data and identifies the 44 gaging stations, the drainage area, and the river basin. The table also provides information on the period of record and the type of sediment data collected at each station. Figure 2 shows station locations. Two types of sediment discharge data were available: mean daily sediment discharge from the U.S. Geological Survey (USGS) and instantaneous sediment discharge based on daily and weekly data collected by the ISWS and the U.S. Army Corps of Engineers (USACOE). The period of record varied from a partial year to 20 years.

Even though the availability of these datasets is very good, several problems are associated with combining the different datasets. The first major problem is the inconsistency between datasets. The USGS processed mean daily data, which can be used directly to calculate daily, monthly, or annual sediment yields. The ISWS and USACOE data, however, are based primarily on instantaneous daily or weekly sediment samples and cannot be used directly to calculate daily, monthly, or annual sediment yields. The ISWS sediment data collection program initially was designed to be consistent with and the same as that of the USGS. The Illinois In-stream Benchmark Sediment Network was initiated in 1980 with 50 monitoring stations (Allgire and Demissie, 1995). However, program funding was drastically reduced after the first year and has been decreasing since then (Allgire and Demissie, 1995). Decisions then were made to continue data collection on a weekly basis at 31 stations instead of discontinuing the program altogether or collecting data consistent with USGS data at only three or four stations. This decision enabled the ISWS to have a statewide, albeit sparse, coverage to monitor trends in sediment concentrations in Illinois streams. It is also possible to compute instantaneous sediment loads based on the instantaneous sediment concentrations; however, these loads will not be consistent with the mean daily sediment load. Daily suspended sediment concentration data collected by the USACOE have some gaps (Beckert, 2002). However, the data have not been processed to determine mean daily concentrations that can be used directly to compute daily average loads for comparison with the USGS data. Based on the literature related to sediment load calculations, it is not appropriate to mix the two datasets until a procedure is developed that can generate sediment load data from instantaneous weekly samples that is consistent with the mean daily sediment load determined from daily samples. Sediment concentration data are not

Table 1. Suspended Sediment Monitoring Stations within the Illinois River Basin, 1981-2000

						Record type and frequency (Collecting Agency, Water Years)	
ISWS Station code	*USGS station number*	*USGS station name*	*Drainage area (sq mi))*	*River basin*	*Period of record*	*Mean daily*	*Instantaneous daily or weekly*
107	05550000	Fox River at Algonquin	1403.0	FOX	1981-82		SWS 1981-82
108	05529000	Des Plaines River near Des Plaines	360.0	DES PLAINES	1981		SWS 1981
109	05532500	Des Plaines River at Riverside	630.0	DES PLAINES	1979-82	USGS 1979-82	
110	05551200	Ferson Creek near St. Charles	51.7	FOX	1981-82		SWS 1981-82
114	05551540	Fox River at Montgomery	1732.0	FOX	1981-83		SWS 1981-83
115	05539000	Hickory Creek at Joliet	107.0	DES PLAINES	1981		SWS 1981
116	05540500	DuPage River at Shorewood	324.0	DUPAGE	1981		SWS 1981
117	05552500	Fox River at Dayton	2642.0	FOX	1981		SWS 1981
118	05556500	Big Bureau Creek at Princeton	196.0	BUREAU	1981-90		SWS 1981-90
122	05555300	Vermilion River near Lenore	1251.0	VERMILION	1981, 84-2000	USGS 1981	SWS 1984-2000
123	05542000	Mazon River near Coal City	455.0	MAZON	1981-2000		SWS 1981-2000
124	05527500	Kankakee River near Wilmington	5150.0	KANKAKEE	1978-2000	USGS 1978-82, 93-95	SWS 1983-2000
125	05520500	Kankakee River at Momence	2294.0	KANKAKEE	1978-2000	USGS 1978-81, 93-95	SWS 1982-85, 88-90, 93-2000
126	05568800	Indian Creek near Wyoming	62.7	SPOON	1981	USGS 1981	
130	05548105	Nippersink above Wonder Lake	84.5	FOX	1994-97	USGS 1994-97	
131	05548110	Nippersink below Wonder Lake	97.3	FOX	1994-97	USGS 1994-97	
227	05543500	Illinois River at Marseilles	8259.0	ILLINOIS	1975-82		
229	05569500	Spoon River at London Mills	1072.0	SPOON	1981-87, 94-2000		SWS 1981-87, 94-2000
230	05566500	East Branch Panther Creek at El Paso	30.5	MACKINAW	1981-82		SWS 1981-82
231	05554490	Vermilion River at McDowell	551.0	VERMILION	1981-82		SWS 1981-82
232	05526000	Iroquois River near Chebanse	2091.0	KANKAKEE	1978-83, 93-95	USGS 1978-81, 93-95	SWS 1982-83
233	05525000	Iroquois River at Iroquois	686.0	KANKAKEE	1978-82, 93-95	USGS 1978-80, 93-95	SWS 1981-82
234	05525500	Sugar Creek at Milford	446.0	KANKAKEE	1981-83		SWS 1981-83
235	05564400	Money Creek near Towanda	49.0	MACKINAW	1981		SWS 1981
236	05567510	Mackinaw River below Congerville	776.0	MACKINAW	1981-2000	USGS 1983-86	SWS 1981-82, COE 1987-2000
237	05568005	Mackinaw River below Green Valley	1092.0	MACKINAW	1981		SWS 1981
238	05570350	Big Creek at St. David	28.0	SPOON	1972-80	USGS 1972-80	
239	05570370	Big Creek near Bryant	41.2	SPOON	1972-86	USGS 1972-86	
240	05570380	Slug Run near Bryant	7.1	SPOON	1975-80	USGS 1975-80	
241	05570000	Spoon River at Seville	1636.0	SPOON	1981, 94-97	USGS 1981, 94-97	COE 1987-2000
242	05584500	LaMoine River at Colmar	655.0	LA MOINE	1981-88, 93-2000		SWS 1981-88, 93-2000
244	05584685	Grindstone Creek near Birmingham	45.4	LA MOINE	1981	USGS 1981	
245	05585000	LaMoine River at Ripley	1293.0	LA MOINE	1981, 83-90, 93-2000	USGS 1981, 94-97	SWS 1983-90, 93-2000
246	05583000	Sangamon River near Oakford	5093.0	SANGAMON	1981, 83-86, 94-97	USGS 1981, 83-86, 94-97	
247	05582000	Salt Creek near Greenview	1804.0	SANGAMON	1981-83		SWS 1981-83
248	05578500	Salt Creek near Rowell	335.0	SANGAMON	1981-83		SWS 1981-83
249	05572000	Sangamon River at Monticello	550.0	SANGAMON	1981-94		SWS 1981-96
252	05576500	Sangamon River at Riverton	2618.0	SANGAMON	1981-83, 87-2000		SWS 1981-83
253	05586100	Illinois River at Valley City	26743.0	ILLINOIS	1980-2000	USGS 1980-2000	
254	05576022	South Fork Sangamon River below Rochester	870.0	SANGAMON	1981-82		SWS 1981-82
259	05587000	Macoupin Creek near Kane	868.0	MACOUPIN	1981		SWS 1981
260	05563800	Illinois River at Pekin	14585.0	ILLINOIS	1994-96	USGS 1994-1996	
261	05559600	Illinois River at Chillicothe	13543.0	ILLINOIS	1992-2000	USGS 1992-2000	
444	05584680	Grindstone Creek near Industry	35.5	LA MOINE	1981	USGS 1981	

Note: USGS – U.S. Geological Survey, SWS – State Water Survey; COE – U.S. Army Corps of Engineers.

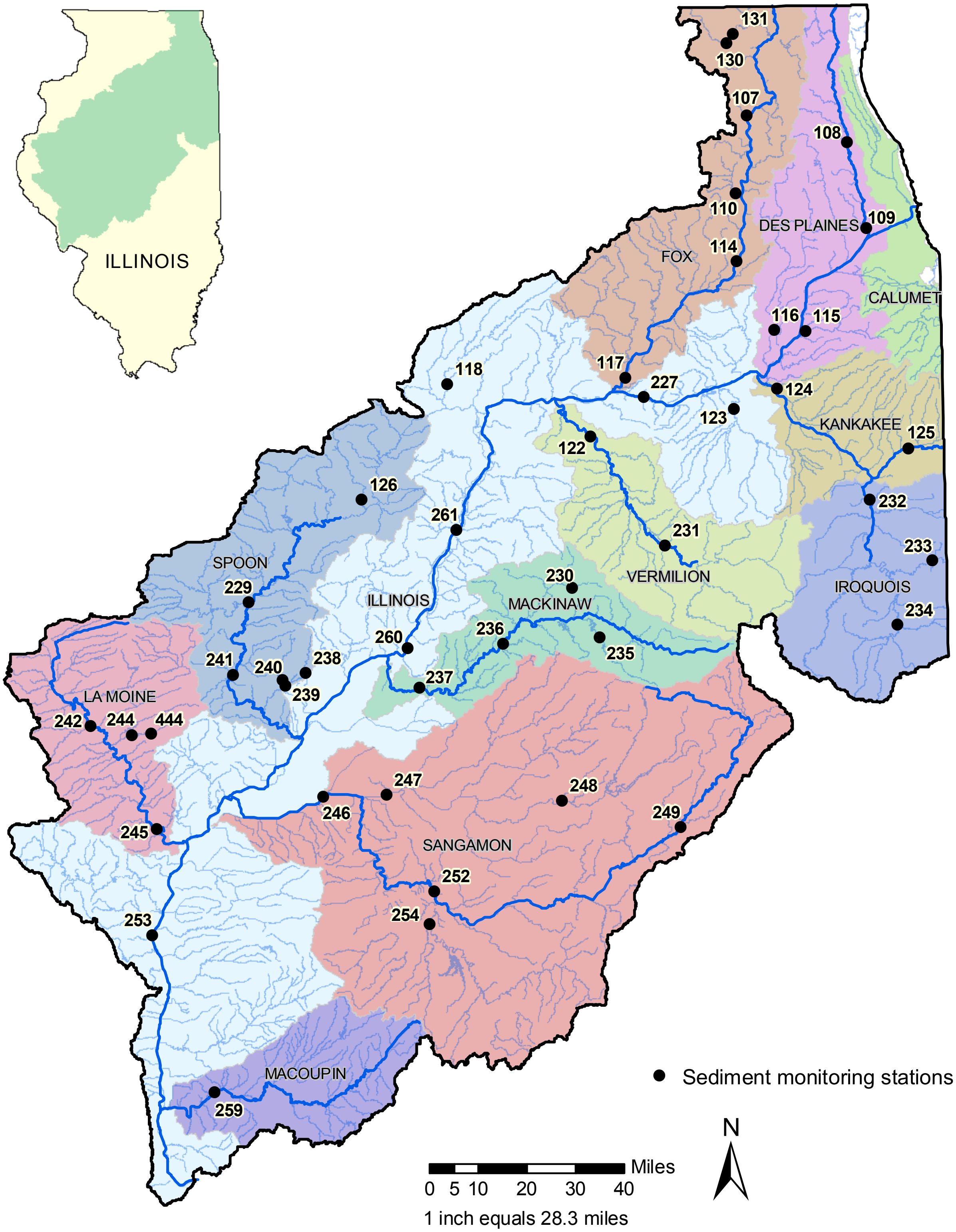

Figure 2. Locations of available in-stream sediment data
within the Illinois River watershed, 1981-2000

collected only for the purposes of calculating sediment budgets but are used to evaluate long-term trends in concentrations and sediment loads in streams and trends in watershed soil erosion.

The ISWS is continuing its research effort to develop reliable procedures that would enable use of instantaneous data to calculate periodic sediment yields consistent with USGS data. However, efforts to develop a reliable procedure have not yet been successful. Factors such as sampling frequency and the occurrence of flood events at different times complicate the problem. Furthermore, a sufficient number of concurrent mean daily and instantaneous data are not available. As a result, the sediment yield calculations for the 1992 report and also this report were based on the USGS mean daily sediment data.

The second problem was the duration of the record, which varies from a partial year to 20 years. In most cases, the record is only one to four years long. Although it is difficult to develop long-term sediment budgets based on short-term records, the procedures described in this report were developed to overcome this problem.

The type of sediment analysis that can be conducted depends on the type and quality of available data. Good quality, long-term streamflow data are available for a large number of gaging stations in the Illinois River basin. These data are collected through the USGS cooperative streamgaging network. The sediment data are sporadic and of short duration, however. A combination of the two datasets enables the type of analysis described in this report. If there were long-term sediment data similar to the streamflow data (from 10-50 years duration), a much more detailed and accurate analysis would have been possible. Collection of streamflow data continues as before, while collection of sediment data has been cut significantly by both the USGS and ISWS. Understanding of this major environmental and natural resource problem will not significantly improve in the near future without additional and sustained data collection. It is therefore very important that environmental and natural resources agencies both in the state and federal governments support the maintenance of the streamgaging network and the initiation of an expanded long-term sediment data collection program in Illinois.

Sediment Yield

A watershed's sediment yield is the amount of sediment that eventually leaves a watershed and is available for deposition at other locations. In terms of sedimentation studies, sediment yield is one of the most important parameters that needs to be determined to calculate the rate of sediment accumulation. Sediment yield is generally a small fraction of the total gross erosion in the watershed, which includes sheet, rill, gully, streambank, and streambed erosion. All the soils eroded in a watershed are not transported and delivered to streams that drain out of the watershed. Depending on many physical factors, a certain percentage of the eroded soils will be removed from one location for deposition at another location within the same watershed.

In the case of the Illinois River valley, it is important to determine how much sediment is delivered into the valley from different tributary streams to evaluate the magnitude and pattern of sedimentation in the river and backwater lakes. Therefore, procedures needed to be developed to calculate the sediment yields of all tributary streams to the Illinois River. Generally, there are four different methods for determining sediment yield (Glymph, 1975; Holeman, 1975). These methods are based on 1) suspended sediment data at gaging stations, 2) gross erosion and sediment delivery ratio, 3) reservoir sedimentation data, and 4) sediment transport or predictive equations.

The method based on suspended sediment data at gaging stations requires the collection of sufficient suspended sediment load data to develop sediment rating curves from which sediment yield can be calculated by several procedures. To determine the total sediment yield, it is necessary to measure or estimate the bed load in addition to the suspended load. Bed load measurements are very rare and limited in Illinois. There are no standard procedures and equipment to sample bed load accurately for different types of streams. Graf (1983) used a bed load sampler developed by the USGS (Helley and Smith, 1971) to measure bed load for nine streams in Illinois and identified many of the difficulties in measuring bed load. She also recommended using those results with great caution. Nakato (1981) concluded that bed load of tributary streams in the Rock Island District's reach of the Mississippi River ranged from 6 to 26 percent, with an average of 11 percent of the total suspended load. Researchers at ISWS generally have used the 5 to 25 percent estimate given by Simons and Senturk (1977) for large and deep rivers. The different estimates are general but adequate for the level of analysis performed for this report.

The method based on the gross erosion and sediment delivery ratio first determines gross erosion from all sources of sediment by using empirical equations and then applies sediment delivery ratios to the different components of gross erosion to obtain sediment yields. The sediment delivery ratio is the ratio of sediment delivered at the outlet of the watershed to total gross erosion within the watershed. Multiplying the total gross erosion by the sediment delivery ratio provides the sediment yield.

The method based on reservoir sedimentation data relies on regional relationships developed among sediment yield, sedimentation surveys, and drainage area. The sediment yield between surveys is determined by dividing accumulated sediment by trap efficiency of the reservoir.

The method based on sediment transport or predictive equations relies either on sediment transport equations that are used to calculate the stream's rate of sediment transport using flows, channel geometry, and sediment characteristics or regional sediment yield equations that are functions of climatic and watershed variables such as rainfall, runoff, drainage area, soil type, and slope.

Sediment Yield Calculations for the Illinois River Basin

After evaluating the availability of different types of sediment data for the Illinois River watershed, it was decided that sediment yield calculations based on available suspended sediment load data would provide the most reliable values. Even though most station data are for short periods, suspended sediment data are available for about 44 stations within the watershed. Data from some of these stations eventually were used to develop regional sediment yield equations to estimate sediment yield when monitored data were not available, which was over 60 percent of the time. Therefore a procedure based on these data should provide more reliable values than other procedures that rely on empirical equations.

The first task for this procedure was to evaluate the available suspended sediment data and develop the best sediment rating curves that relate sediment load and streamflow for each sediment monitoring station. Once sediment rating curves are developed, sediment yields over selected periods of time can be calculated based on streamflow records that are generally for much longer periods than records for sediment load data.

One of the major problems with most sediment load rating curve methodologies is that they underestimate annual sediment yields (Ferguson, 1986; Walling and Webb, 1988). Therefore special considerations are necessary before applying sediment load rating curves to calculate sediment yields from watersheds. Different procedures for developing sediment load rating curves were evaluated as to their adequacy in properly estimating annual sediment loads. An improved procedure was developed that minimizes the underestimation of annual sediment yields by sediment rating curves (Appendix A). This procedure was the basis for all annual sediment yield calculations for this report. Analysis results for one station (Mackinaw River at Congerville) are discussed to demonstrate the type of analysis performed to develop the best sediment yield estimate for each stream.

Four years of mean daily suspended sediment data were available for the Mackinaw River at Congerville station. Initially, each year of data was analyzed individually. For each year, a sediment load equation of the form given in Equation 1 was developed,

$$\log Q_S = a + b\,(\log Q_W)^c \tag{1}$$

where Q_S is the daily sediment load in tons; Q_W is the daily mean water discharge in cubic feet per second (cfs); and a, b, and c are coefficients determined through a regression and optimization procedure. This form of the sediment rating curve was found to be superior to other equations for calculating annual sediment budgets (Appendix A). The analysis resulted in different equations for the different years (Figure 3). Table 2 shows the variation of the coefficients in Equation 1 from year to year, and Figure 4 illustrates the differences in the sediment rating curves for the different years. Because these differences are due to the year-to-year variation of many variables, including storm types, land cover, and timing of storm events, it will be difficult to develop equations that take all these factors into consideration. Another alternative that avoids the year-to-year variation is to combine all data for all years and determine

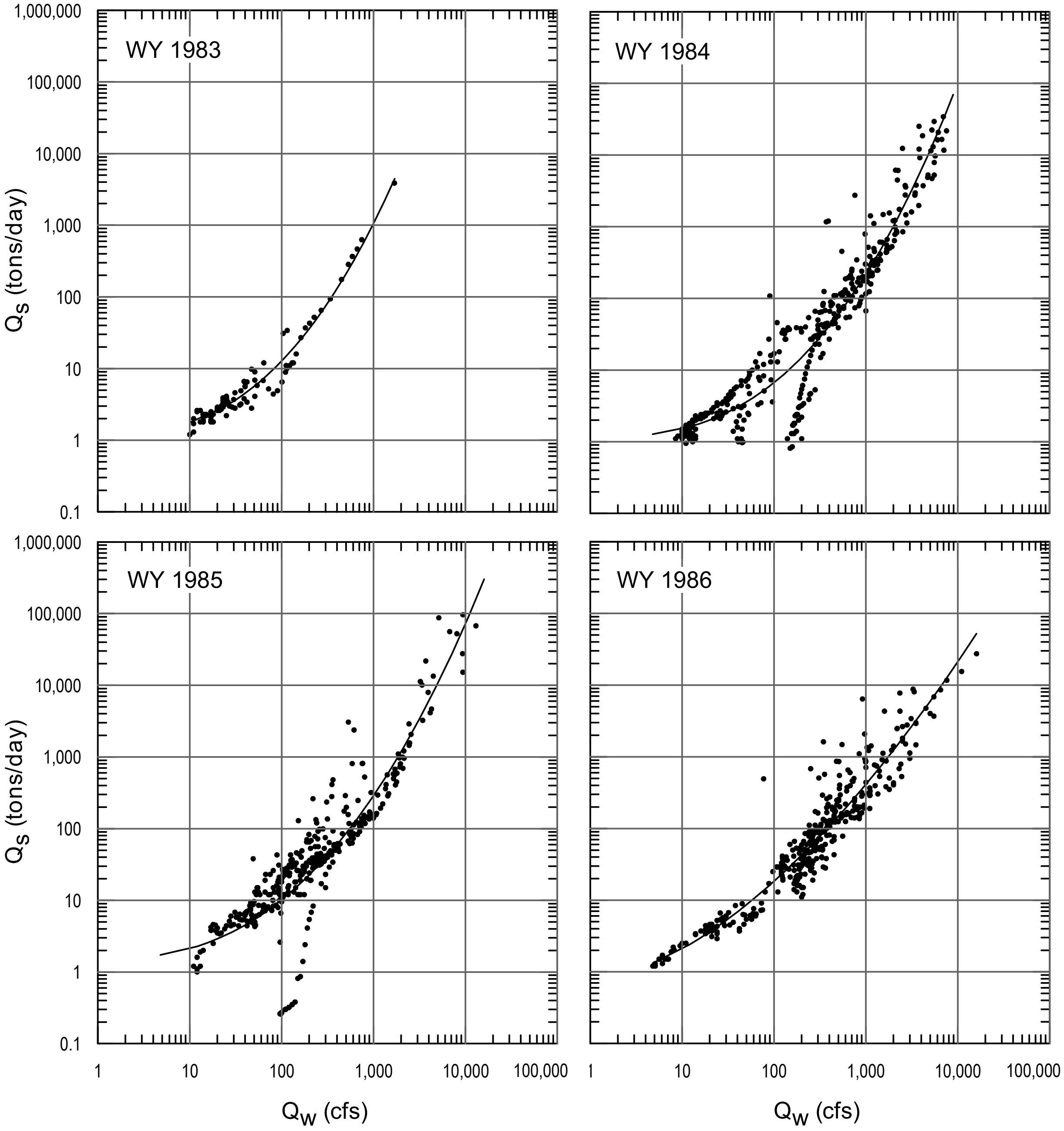

Figure 3. Yearly sediment load curves for Mackinaw River at Congerville (0557510)

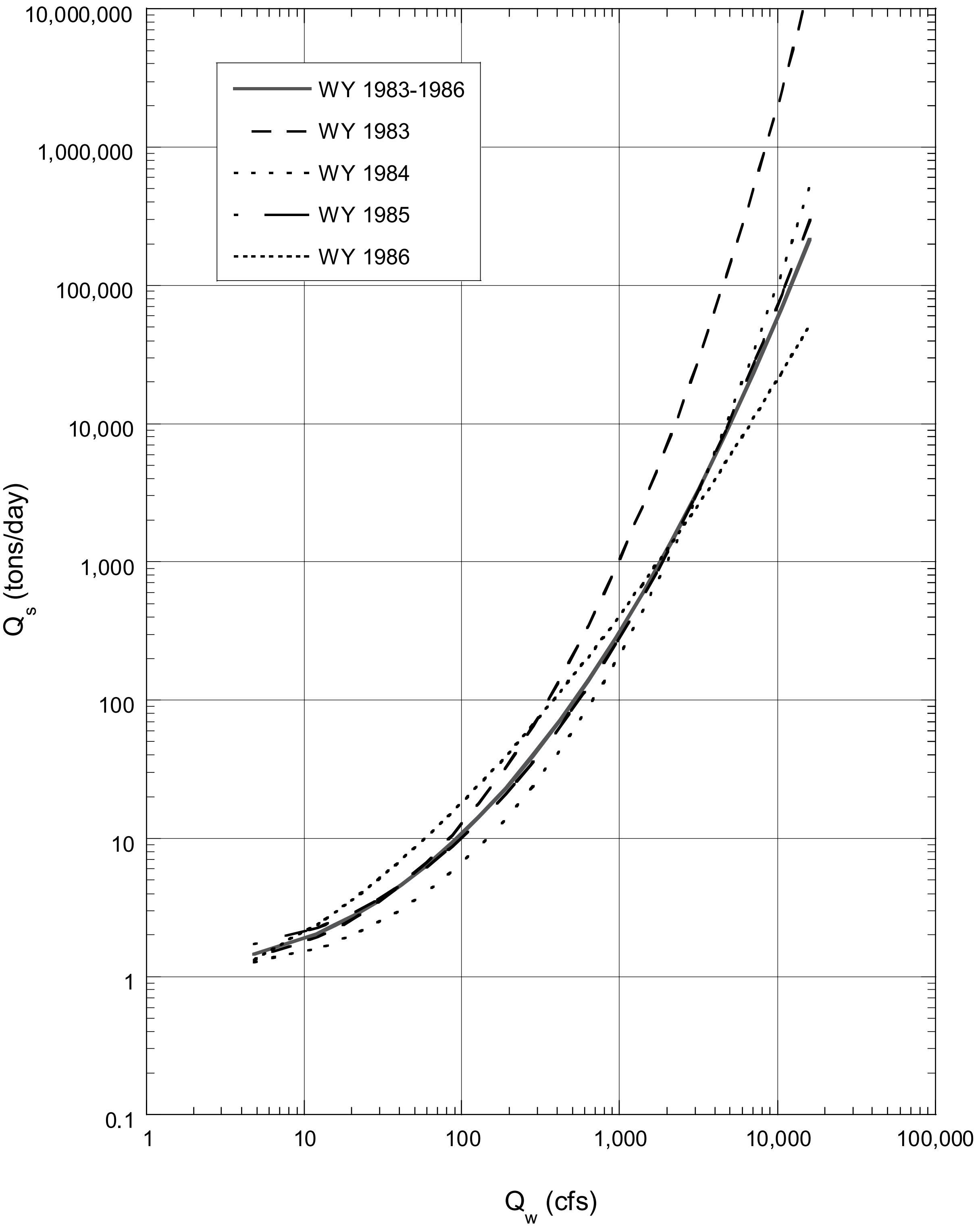

Figure 4. Comparison of yearly sediment load curves for Mackinaw River at Congerville (05567510)

Table 2. Sediment Load Regression Coefficients for Mackinaw River at Congerville

Water Year	*a*	*b*	*c*
1983	0.0773	0.1694	2.6
1984	0.0632	0.1171	2.7
1985	0.1802	0.1462	2.5
1986	-0.0981	0.4191	1.7
1983-1986	0.0794	0.1931	2.3

an optimum sediment rating curve for the period of record. Figure 5 shows those results for the Mackinaw River at Congerville. The period of record curve (Figure 5) was compared to the individual year rating curves (Figure 4). As expected, the period of record curve tends to average out the year-to-year variation in sediment load estimates. For the purposes of long-term sediment budget analysis, it seems logical to use the sediment load equations derived from the period of record data. Therefore similar equations for the period of record were developed for all USGS stations using all the available data. Analysis results for all stations are shown in Appendix B.

After developing the sediment load equations that relate the daily suspended sediment load to the daily mean discharge, annual sediment loads were calculated. This was done by adding daily loads using the daily water discharge records for all 16 sediment monitoring stations within the watershed for a 20-year period (1981-2000). Then regional relationships were developed between annual sediment loads (measured and calculated) and annual water discharges based on data from 16 stations for application to watersheds without sediment monitoring stations. Figure 6 shows analysis results. The regional relationships were aggregated into four groups represented by the following equations:

$$\log(Q_s{}^A) = -2.82 + 1.80\ \log(Q_w{}^A) \tag{2}$$

$$\log(Q_s{}^A) = -3.38 + 1.64\log(Q_w{}^A) \tag{3}$$

$$\log(Q_s{}^A) = -4.77 + 1.75\log(Q_w{}^A) \tag{4}$$

$$\log(Q_s{}^A) = -5.55 + 1.79\log(Q_w{}^A) \tag{5}$$

where $Q_s{}^A$ and $Q_w{}^A$ are the annual sediment load and water discharge, respectively.

The group with the highest annual sediment yield rate, represented by Equation 2, includes mainly smaller tributary streams in the Spoon and LaMoine River watersheds. The group with the second highest annual sediment yield rate, represented by Equation 3 includes the mainstem of the Spoon, LaMoine, and Vermilion Rivers. The group with the third highest annual sediment yield rate represented by Equation 4, includes the Sangamon, Iroquois, and

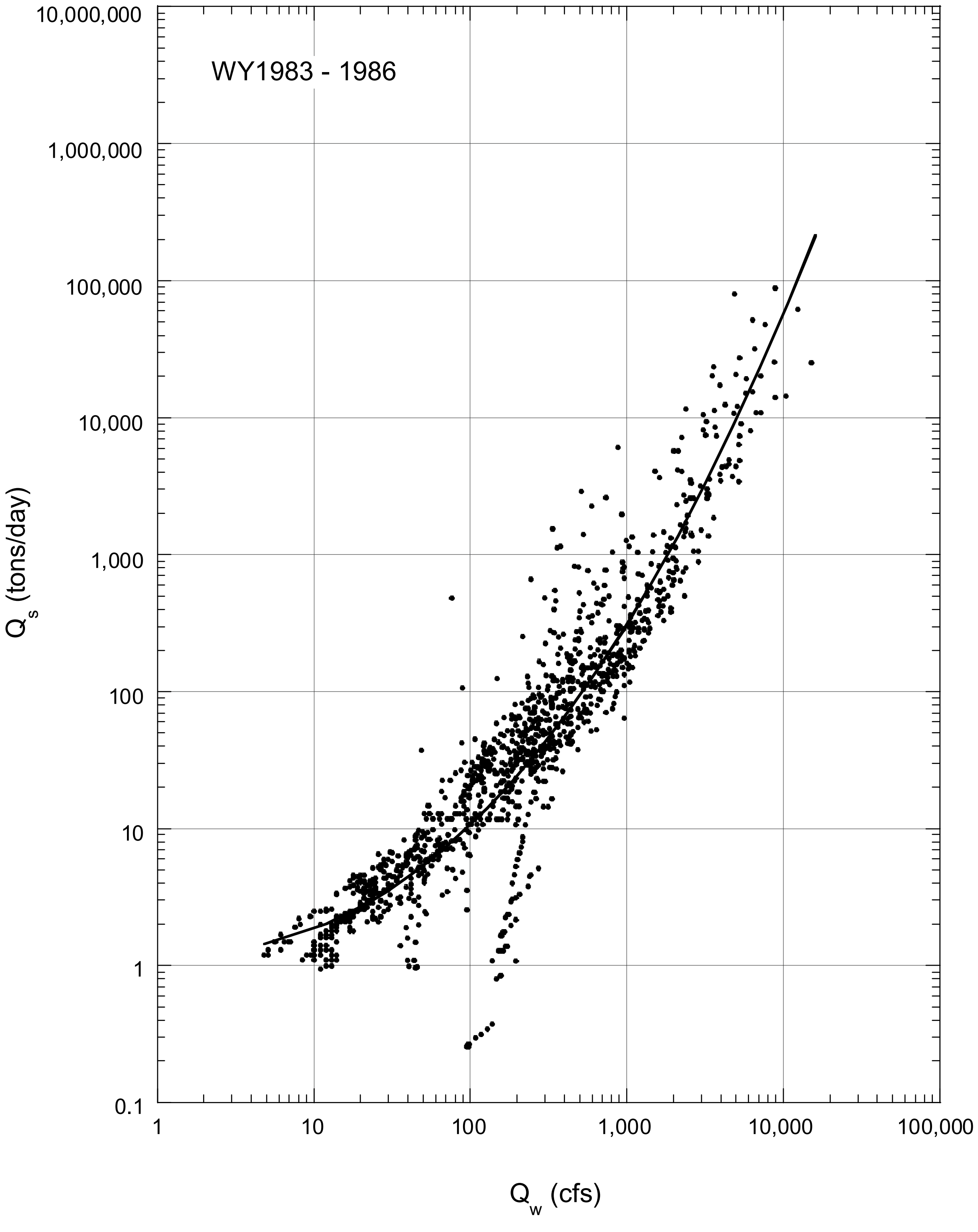

Figure 5. Comparison of multi-year sediment load curve to data points for Mackinaw River at Congerville (05567510)

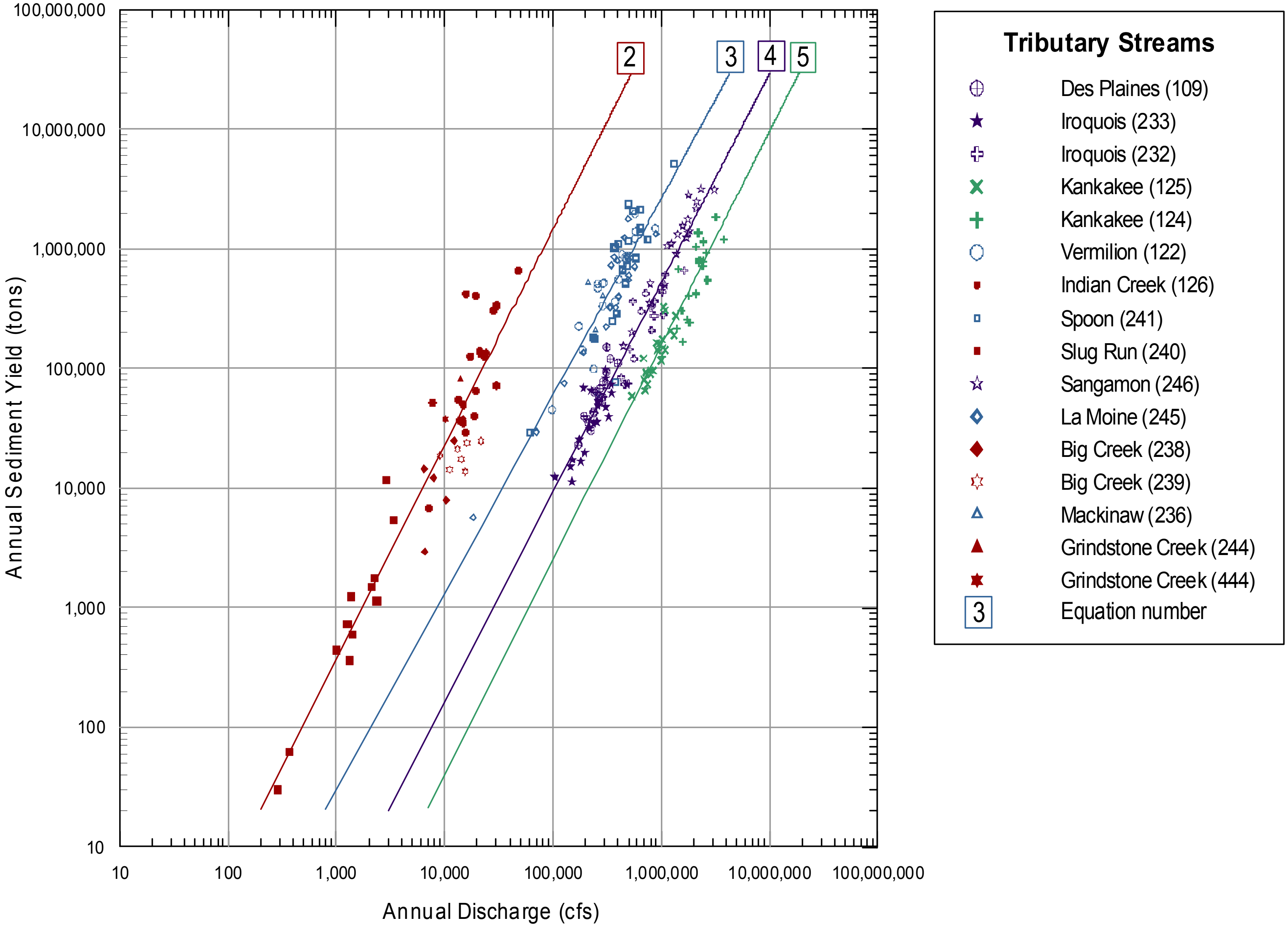

Figure 6. Annual sediment yield equations for tributary streams in the Illinois River valley

Des Plaines Rivers. The group with the least annual sediment yield rate, represented by Equation 5, includes stations on the Kankakee River. These four equations were then used to calculate annual sediment yields for tributary streams to the Illinois River.

Tables 3 and 4 summarize the results of the annual water discharge and sediment yield calculations for the 20-year analysis period. Table 3 contains annual water discharges of all tributary streams of the Illinois River required in the calculation of the annual sediment yield. Table 4 contains calculated annual sediment yield values for all tributary streams calculated using Equations 2-5 and the annual water discharges in Table 3 and then increased by 5-25 percent to account for bed load.

Sediment Budget Estimate for the Illinois River Valley

The main purpose of collecting and analyzing all the sediment load data for the tributary streams is to develop a quantitative sediment budget for the Illinois River valley. By calculating the difference between the amount of sediment that flows into and out of the valley, it is possible to estimate the amount of sediment deposited in the valley. Because sediment inflow/outflow varies significantly from year to year, it is necessary to select a reasonable period of time to represent long-term records of the Illinois River. After evaluating the USGS streamflow records for the Illinois River and the period during which most of the sediment data were collected, a 20-year period of analysis (1981-2000) was used. After the analysis period was selected, the sediment inflow from all tributary streams and the sediment outflow from the Illinois River needed to be determined for the duration of the period. Data in Table 4 were used to estimate sediment inflows for the 20-year analysis period.

The measured sediment load of the Illinois River at the USGS Valley City gaging station was used as the sediment outflow for the 20-year analysis period. The amount and percent of sediment deposited in the Illinois River valley were calculated by determining the difference between the computed total inflow from tributary streams and outflow at Valley City. Table 5 gives the computed total sediment deposited annually in the valley and its percentage to the total inflow of sediment.

The sediment budget estimate for the Illinois River valley given in Table 5 shows that, in the period 1981-2000, tributary streams delivered an average of 12.1 million tons of sediment to the Illinois River valley per year. The measured sediment load in the Illinois River at Valley City, 61.3 miles upstream of the junction of the Illinois River with the Mississippi River, averaged 5.4 million tons per year. This left, on average, about 6.7 million tons or 55 percent of the sediment estimated to be delivered from tributary streams for deposition within the valley every year. The present sediment budget estimate for the 20-year period from 1981 to 2000 is lower than the previous estimate in 1992 for the 10-year period from 1981 to 1990. This is primarily due to the additional sediment data that were available for the present study that improved the sediment rating curves and thus the sediment budget estimate. This report does not address the role of climatic and physical changes between the two periods on sediment budget estimates

Table 3. Computed Annual Water Discharge of Tributary Streams in the Illinois River Basin, 1981-2000

River/stream	*Drainage area (sq mi)*	*Annual water discharge (cfs-days * 1000)*																				
		WY81	*WY82*	*WY83*	*WY84*	*WY85*	*WY86*	*WY87*	*WY88*	*WY89*	*WY90*	*WY91*	*WY92*	*WY93*	*WY94*	*WY95*	*WY96*	*WY97*	*WY98*	*WY99*	*WY2000*	*Average*
Des Plaines River	2111	1846.1	1834.6	2086.4	1867.2	1855.8	2044.8	2043.7	1768.4	1626.8	1933.5	1990.7	1852.7	2356.1	1543.0	1759.8	1783.0	1667.0	1738.3	1759.2	1446.8	1840.2
Kankakee River	5165	2205.1	2465.2	2443.5	2268.2	2100.5	2231.2	1739.2	1395.5	1829.2	2381.5	3200.8	1593.8	3801.4	2661.0	2090.6	1803.7	2447.1	2601.3	1557.9	1026.6	2192.2
Mazon River	524	190.0	237.0	240.9	199.5	143.5	199.9	110.7	81.6	138.4	199.8	308.8	108.3	344.4	135.5	193.0	188.7	188.7	188.7	137.8	55.3	179.5
Fox River	2658	760.1	942.9	1189.3	834.2	774.0	988.6	888.0	756.9	469.8	771.4	843.4	629.9	1446.7	652.7	815.2	1003.7	733.9	760.8	929.3	750.7	847.1
Vermilion River	1331	463.4	616.8	609.7	429.5	277.3	469.6	313.4	199.2	184.3	509.0	606.3	253.0	939.6	397.8	492.4	276.6	306.3	523.2	307.3	104.2	413.9
Big Bureau Creek	536.8	170.6	213.4	217.8	126.6	151.9	177.9	126.1	149.6	27.0	188.5	197.4	110.3	364.9	161.8	238.7	148.5	123.4	205.2	238.0	108.9	172.3
Mackinaw River	1136	447.6	384.1	518.1	431.8	310.9	364.7	299.1	91.6	43.3	374.7	387.3	175.0	909.3	321.9	415.9	160.5	163.9	439.2	318.7	59.1	330.8
Spoon River	1855	615.1	732.3	733.6	498.9	563.2	545.7	460.2	264.1	69.3	560.8	526.4	399.6	1480.7	435.7	726.6	420.4	428.7	856.2	664.8	279.3	563.1
Sangamon River	5418	1906.7	1898.5	2255.2	1873.0	1316.6	1680.4	1078.3	830.3	568.3	1512.9	1954.6	1152.7	3309.2	2470.4	1818.5	1205.4	844.2	2237.6	1471.8	478.7	1593.2
LaMoine River	1350	519.3	524.5	505.1	421.9	480.4	527.8	361.1	73.0	19.1	382.1	352.6	200.7	934.5	323.1	589.6	411.7	274.0	518.9	395.1	132.2	397.3
McKee Creek	444	170.8	172.5	166.1	138.7	158.0	173.6	118.8	24.0	6.3	125.7	116.0	66.0	307.4	106.3	193.9	135.4	90.1	170.6	130.0	43.5	130.7
Aux Sable Creek	187	67.8	84.6	86.0	71.2	51.2	71.3	39.5	29.1	49.4	71.3	110.2	38.7	122.9	48.4	85.1	54.7	59.0	95.8	49.2	19.8	65.3
Nettle Creek	53.2	19.3	24.1	24.5	20.3	14.6	20.3	11.2	8.3	14.1	20.3	31.3	11.0	35.0	13.8	24.2	15.6	16.8	27.3	14.0	5.6	18.6
Waupecan Creek	57.3	20.8	25.9	26.3	21.8	15.7	21.9	12.1	8.9	15.1	21.9	33.8	11.8	37.7	14.8	26.1	16.8	18.1	29.4	15.1	6.1	20.0
Bills Run	33.2	12.0	15.0	15.3	12.6	9.1	12.7	7.0	5.2	8.8	12.7	19.6	6.9	21.8	8.6	15.1	9.7	10.5	17.0	8.7	3.5	11.6
Hog Run	40	14.5	18.1	18.4	15.2	11.0	15.3	8.4	6.2	10.6	15.3	23.6	8.3	26.3	10.3	18.2	11.7	12.6	20.5	10.5	4.2	14.0
Covel Creek	74.1	26.9	33.5	34.1	28.2	20.3	28.3	15.7	11.5	19.6	28.3	43.7	15.3	48.7	19.2	33.7	21.7	23.4	38.0	19.5	7.8	25.9
Little Vermilion	126	40.1	50.1	51.1	29.7	35.7	41.8	29.6	35.1	6.3	44.2	46.3	26.0	85.7	38.0	56.0	34.8	29.0	48.2	55.9	25.6	40.5
Cedar Creek	51.2	16.3	20.4	20.8	12.1	14.5	17.0	12.0	14.3	2.6	18.0	18.8	10.6	34.8	15.4	22.8	14.2	11.8	19.6	22.7	10.4	16.4
Spring Creek	92.1	29.3	36.6	37.4	21.7	26.1	30.5	21.6	25.7	4.6	32.3	33.9	19.0	62.6	27.8	41.0	25.5	21.2	35.2	40.8	18.7	29.6
Negro Creek	48.6	15.4	19.3	19.7	11.5	13.8	16.1	11.4	13.5	2.4	17.1	17.9	10.0	33.0	14.7	21.6	13.4	11.2	18.6	21.5	9.9	15.6
Allforks Creek	44.3	14.1	17.6	18.0	10.4	12.5	14.7	10.4	12.3	2.2	15.6	16.3	9.2	30.1	13.4	19.7	12.3	10.2	16.9	19.6	9.0	14.2
Sandy Creek	146	44.1	52.6	49.3	41.1	44.8	40.4	36.6	25.7	7.4	52.3	43.4	31.7	109.6	31.8	53.3	30.0	30.6	63.0	54.9	22.7	43.3
Crow Creek (west)	81.7	24.7	29.4	27.6	23.0	25.1	22.6	20.5	14.4	4.2	29.3	24.3	17.7	61.3	17.8	29.8	16.8	17.1	35.3	30.7	12.7	24.2
Strawn Creek	33.8	10.2	12.2	11.4	9.5	10.4	9.3	8.5	6.0	1.7	12.1	10.0	7.3	25.4	7.4	12.3	6.9	7.1	14.6	12.7	5.3	10.0
Crow Creek	130	39.2	46.8	43.9	36.6	39.9	35.9	32.6	22.9	6.6	46.5	38.6	28.2	97.6	28.4	47.4	26.7	27.2	56.1	48.9	20.2	38.5
Senachwine Creek	90	27.2	32.4	30.4	25.4	27.6	24.9	22.6	15.9	4.6	32.2	26.8	19.5	67.6	19.6	32.8	18.5	18.8	38.8	33.8	14.0	26.7
Snag Creek	99.1	29.9	35.7	33.4	27.9	30.4	27.4	24.9	17.5	5.1	35.5	29.5	21.5	74.4	21.6	36.2	20.4	20.7	42.8	37.3	15.4	29.4
Richland Creek	47	14.2	16.9	15.9	13.2	14.4	13.0	11.8	8.3	2.4	16.8	14.0	10.2	35.3	10.3	17.1	9.7	9.8	20.3	17.7	7.3	13.9
Farm Creek	61.3	24.2	20.7	28.0	23.3	16.8	19.7	16.1	4.9	2.3	22.0	24.0	8.3	48.8	17.2	21.9	9.4	9.3	23.4	16.6	2.6	18.0
Kickapoo Creek	306	92.3	110.2	103.2	86.2	93.9	84.6	76.8	53.9	15.6	109.6	91.0	66.5	229.8	66.7	111.7	62.9	64.1	132.0	115.1	47.6	90.7
Lost Creek	46.9	18.5	15.9	21.4	17.8	12.8	15.1	12.3	3.8	1.7	16.9	18.3	6.4	37.3	13.2	16.8	7.2	7.1	17.9	12.7	2.0	13.8
Lamarsh Creek	40.9	12.3	14.7	13.8	11.5	12.6	11.3	10.3	7.2	2.1	14.6	12.2	8.9	30.7	8.9	14.9	8.4	8.6	17.6	15.4	6.4	12.1
Copperas Creek	127	38.3	45.8	42.8	35.8	39.0	35.1	31.9	22.4	6.5	45.5	37.8	27.6	95.4	27.7	46.3	26.1	26.6	54.8	47.8	19.7	37.6
Spring Lake Slough	36.5	14.4	12.3	16.6	13.9	10.0	11.7	9.6	2.9	1.4	13.1	14.3	5.0	29.0	10.2	13.1	5.6	5.5	13.9	9.9	1.5	10.7
Buckheart Creek	39.1	11.8	14.1	13.2	11.0	12.0	10.8	9.8	6.9	2.0	14.0	11.6	8.5	29.4	8.5	14.3	8.0	8.2	16.9	14.7	6.1	11.6
Quiver Creek	261	102.8	88.3	119.0	99.2	71.4	83.8	68.7	21.0	9.7	93.8	102.0	35.5	207.7	73.2	93.4	40.2	39.6	99.6	70.5	11.0	76.5
Otter Creek	126	48.5	49.0	47.1	39.4	44.8	49.3	33.7	6.8	1.8	35.7	32.9	18.7	87.2	30.2	55.0	38.4	25.6	48.4	36.9	12.3	37.1
Sugar Creek	162	62.3	62.9	60.6	50.6	57.6	63.3	43.3	8.8	2.3	45.9	42.3	24.1	112.1	38.8	70.8	49.4	32.9	62.3	47.4	15.9	47.7
Little Creek	30.8	11.8	12.0	11.5	9.6	11.0	12.0	8.2	1.7	0.4	8.7	8.0	4.6	21.3	7.4	13.5	9.4	6.3	11.8	9.0	3.0	9.1
Indian Creek	286	105.7	77.2	120.1	85.1	50.4	77.5	57.1	41.5	13.2	73.3	111.5	39.5	152.2	98.6	53.6	69.6	17.9	97.4	55.3	11.0	70.4
Camp Creek	38.6	14.3	10.4	16.2	11.5	6.8	10.5	7.7	5.6	1.8	9.9	15.0	5.3	20.5	13.3	7.2	9.4	2.4	13.1	7.5	1.5	9.5
Coon Run Ditch	61.7	22.8	16.7	25.9	18.4	10.9	16.7	12.3	9.0	2.8	15.8	24.0	8.5	32.8	21.3	11.6	15.0	3.9	21.0	11.9	2.4	15.2
Mauvaise Terre Creek	178	65.8	48.0	74.8	53.0	31.4	48.2	35.5	25.8	8.2	45.6	69.4	24.6	94.7	61.4	33.4	43.3	11.1	60.6	34.4	6.8	43.8
	25765.2	10406.4	11191.4	12243.2	10087.5	9030.2	10417.1	8308.5	6137.4	5221.3	10025.7	11680.3	7137.1	18433.2	10066.8	10504.2	8299.4	7891.3	11568.0	8928.6	4853.0	9621.5
Missing area	977.8	398.6	425.8	410.4	424.8	268.3	443.8	136.7	147.2	165.1	343.1	458.2	253.9	689.5	432.7	326.9	200.8	280.5	474.0	230.3	78.5	329.5
Total inflow	26743.0	10805.0	11617.3	12653.6	10512.3	9298.5	10861.0	8445.2	6284.5	5386.5	10368.7	12138.5	7391.0	19122.7	10499.5	10831.2	8500.2	8171.8	12042.0	9158.9	4931.5	9951.0
Outflow from Illinois River at Valley City	26743.0	10194.6	11561.2	12497.6	10006.2	9178.4	9542.8	7729.2	5798.3	4415.8	9812.7	11458.1	6956.4	17087.0	10890.1	10735.3	8032.9	7866.5	11363.5	8954.7	4870.2	9447.6
Percent difference		-6	0	-1	-5	-1	-14	-9	-8	-22	-6	-6	-6	-12	4	-1	-6	-4	-6	-2	-1	-5

Table 4. Computed Annual Sediment Yield from Tributary Streams in the Illinois River Basin, 1981-2000

River/stream	*Drainage area (sq mi)*	*Equation number*	*Annual sediment yield (tons * 1000)*																				
			WY81	*WY82*	*WY83*	*WY84*	*WY85*	*WY86*	*WY87*	*WY88*	*WY89*	*WY90*	*WY91*	*WY92*	*WY93*	*WY94*	*WY95*	*WY96*	*WY97*	*WY98*	*WY99*	*WY2000*	*Average*
Des Plaines River	2111	-	151.1	159.3	272.7	176.3	192.1	188.9	281.6	129.5	105.4	202.0	207.6	144.5	284.4	116.6	151.8	181.1	160.4	156.3	198.7	122.8	179.1
Kankakee River	5165	5	1711.8	985.0	958.0	838.4	730.7	814.1	521.2	351.4	570.4	914.9	1553.4	445.7	2113.5	682.5	528.2	556.3	960.5	1071.5	427.9	202.8	846.9
Mazon River	524	3	210.1	301.8	309.9	227.7	132.8	228.3	86.8	52.6	125.1	228.3	465.2	83.8	556.2	120.8	215.6	207.9	207.9	207.9	124.3	27.9	206.0
Fox River	2658	4	353.7	515.4	773.3	416.1	365.1	559.9	464.1	351.1	152.6	362.9	424.2	254.7	1089.0	271.1	399.8	574.9	332.6	354.2	502.5	346.1	443.2
Vermilion River	1331	3	1045.1	1381.2	1355.0	763.9	373.2	883.8	456.0	217.3	191.2	1008.5	1342.7	321.1	2750.4	673.8	955.3	371.6	439.2	1054.8	441.6	75.1	805.0
Big Bureau Creek	536.8	3	227.9	332.6	344.2	137.8	187.3	244.7	136.9	182.6	10.3	269.6	291.6	109.2	823.6	208.5	401.9	180.2	132.0	311.3	399.9	106.9	252.0
Mackinaw River	1136	3	891.3	694.1	1132.5	716.6	928.6	368.7	460.8	66.4	19.5	666.2	703.4	191.7	2843.9	519.8	785.3	384.2	172.1	864.2	511.3	32.5	647.7
Spoon River	1855	3	2788.3	1995.3	2001.4	1064.9	1298.2	1233.1	932.7	375.9	42.1	1289.3	1162.4	740.3	6316.8	852.9	1882.3	1396.1	981.2	2577.2	1703.4	412.1	1552.3
Sangamon River	5418	4	3593.7	1910.0	2580.5	2237.6	1402.0	1973.4	710.9	450.3	232.1	1284.6	2009.7	798.8	5043.2	3026.0	1572.0	1347.7	650.4	2545.3	1224.3	172.0	1738.2
LaMoine River	1350	3	2220.0	1155.7	1086.4	809.1	1000.7	1167.6	627.3	45.8	5.1	688.1	603.3	239.9	2974.1	522.9	887.5	999.6	453.8	1135.3	726.9	121.1	873.5
McKee Creek	444	2 & 3	447.3	455.2	426.0	310.7	390.1	460.2	236.6	14.5	1.4	261.3	226.9	84.7	1254.1	194.8	558.8	297.7	145.9	446.6	277.1	40.8	326.5
Aux Sable Creek	187	2 & 3	220.1	326.9	336.5	240.3	133.3	241.0	83.8	48.5	124.9	241.0	524.6	80.6	637.8	120.3	330.7	150.1	171.6	408.6	124.0	24.3	228.4
Nettle Creek	53.2	2	76.0	113.1	116.4	83.0	45.9	83.2	28.8	16.6	43.0	83.2	181.8	27.7	221.2	41.4	114.4	51.7	59.2	141.4	42.7	8.3	78.9
Waupecan Creek	57.3	2	86.8	129.2	133.0	94.8	52.5	95.1	32.9	19.0	49.2	95.1	207.7	31.6	252.7	47.3	130.7	59.1	67.6	161.6	48.8	9.5	90.2
Bills Run	33.2	2	32.6	48.5	49.9	35.6	19.7	35.7	12.3	7.1	18.4	35.7	77.9	11.9	94.8	17.8	49.0	22.2	25.4	60.6	18.3	3.6	33.8
Hog Run	40	2	45.5	67.7	69.7	49.7	27.5	49.9	17.3	10.0	25.8	49.9	108.9	16.6	132.5	24.8	68.5	31.0	35.4	84.7	25.6	5.0	47.3
Covel Creek	74.1	2 & 3	49.1	72.9	75.1	53.6	29.7	53.8	18.7	10.8	27.9	53.7	117.1	18.0	142.4	26.8	73.8	33.5	38.3	91.2	27.6	5.4	51.0
Little Vermilion	126	2 & 3	85.9	128.1	132.9	50.4	69.8	92.6	50.0	67.9	3.2	102.6	111.5	39.8	334.3	78.1	156.6	67.0	48.1	119.4	155.7	38.5	96.6
Cedar Creek	51.2	2	56.0	83.7	86.8	32.8	45.4	60.4	32.5	44.2	2.0	67.0	72.8	25.9	219.4	50.9	102.4	43.6	31.3	78.0	101.8	25.0	63.1
Spring Creek	92.1	2 & 3	57.3	85.5	88.6	33.6	46.5	61.7	33.3	45.3	2.1	68.4	74.3	26.5	223.2	52.1	104.4	44.6	32.1	79.7	103.9	25.6	64.4
Negro Creek	48.6	2	51.0	76.2	79.1	29.8	41.4	55.0	29.6	40.3	1.9	61.0	66.3	23.5	199.8	46.4	93.2	39.7	28.5	71.0	92.7	22.8	57.5
Allforks Creek	44.3	2	43.2	64.5	66.9	25.3	35.0	46.6	25.1	34.1	1.6	51.6	56.1	19.9	169.1	39.3	78.9	33.6	24.1	60.1	78.5	19.3	48.7
Sandy Creek	146	2 & 3	101.8	139.8	124.3	90.0	105.0	87.1	73.2	39.0	4.2	138.2	99.1	56.6	519.9	57.0	143.0	51.3	53.0	193.0	151.0	31.1	112.9
Crow Creek (west)	81.7	2 & 3	48.6	66.8	59.4	43.0	50.1	41.6	34.9	18.6	2.0	66.0	47.3	27.0	249.0	27.2	68.3	24.4	25.3	92.3	72.1	14.8	53.9
Strawn Creek	33.8	2	24.2	33.3	29.6	21.4	24.9	20.7	17.4	9.2	1.0	32.9	23.6	13.4	124.4	13.5	34.0	12.1	12.5	46.0	35.9	7.4	26.9
Crow Creek	130	2 & 3	82.7	113.6	101.0	73.2	85.3	70.8	59.5	31.7	3.5	112.3	80.6	46.0	422.4	46.3	116.2	41.7	43.1	156.8	122.7	25.3	91.7
Senachwine Creek	90	2 & 3	57.8	79.4	70.6	51.1	59.6	49.4	41.5	22.1	2.4	78.5	56.3	32.1	296.1	32.3	81.3	29.1	30.0	109.7	85.8	17.6	64.1
Snag Creek	99.1	2 & 3	59.5	81.7	72.6	52.6	61.3	50.9	42.7	22.7	2.5	80.8	57.9	33.0	304.1	33.3	83.6	29.9	30.9	112.8	88.2	18.2	66.0
Richland Creek	47	2	43.7	60.1	53.4	38.7	45.1	37.4	31.4	16.7	1.8	59.5	42.6	24.2	224.9	24.4	61.5	21.9	22.7	83.1	65.0	13.3	48.6
Farm Creek	61.3	2 & 3	60.8	46.2	79.1	57.0	31.6	42.1	29.5	3.5	0.9	51.6	60.0	9.0	214.8	33.1	51.2	11.3	11.0	57.5	30.9	1.1	44.1
Kickapoo Creek	306	2 & 3	382.4	525.1	466.9	338.2	394.2	327.1	274.9	146.3	15.9	519.3	372.3	212.4	1954.1	214.0	537.2	192.4	198.9	725.1	567.1	116.8	424.0
Lost Creek	46.9	2	70.3	53.5	91.5	66.0	36.6	48.7	34.1	4.1	1.0	59.6	69.3	10.4	248.7	38.2	59.2	13.0	12.7	66.5	35.7	1.3	51.0
Lamarsh Creek	40.9	2	34.1	46.8	41.6	30.1	35.1	29.1	24.5	13.0	1.4	46.3	33.2	18.9	175.2	19.0	47.9	17.1	17.7	64.8	50.6	10.4	37.8
Copperas Creek	127	2 & 3	79.4	109.0	96.9	70.2	81.8	67.9	57.1	30.4	3.3	107.7	77.3	44.1	405.1	44.4	111.5	40.0	41.3	150.4	117.7	24.3	88.0
Spring Lake Slough	36.5	2	44.8	34.1	58.3	42.0	23.3	31.0	21.7	2.6	0.6	38.0	44.2	6.6	158.6	24.4	37.8	8.3	8.1	42.4	22.7	0.8	32.5
Buckheart Creek	39.1	2	31.4	43.2	38.4	27.8	32.4	26.9	22.6	12.0	1.3	42.7	30.6	17.4	161.6	17.5	44.2	15.8	16.3	59.7	46.7	9.6	34.9
Quiver Creek	261	2 & 3	463.6	352.8	602.4	434.8	241.7	321.4	225.5	27.2	6.8	393.2	457.0	69.2	1631.3	252.6	390.7	86.4	84.2	438.1	235.9	8.5	336.2
Otter Creek	126	2 & 3	120.8	123.0	114.9	83.3	105.1	124.3	63.1	3.6	0.3	69.8	60.5	22.1	345.4	51.7	151.6	79.8	38.5	120.6	74.1	10.5	88.1
Sugar Creek	162	2 & 3	189.3	192.7	180.1	130.5	164.7	194.9	98.9	5.7	0.5	109.4	94.7	34.6	541.4	81.0	237.6	125.0	60.4	189.0	116.1	16.4	138.2
Little Creek	30.8	2	31.7	32.2	30.1	21.8	27.5	32.6	16.5	0.9	0.1	18.3	15.8	5.7	91.0	13.5	39.8	20.9	10.0	31.6	19.4	2.7	23.1
Indian Creek	286	2 & 3	487.2	277.6	612.5	330.4	129.5	279.7	161.7	91.5	11.8	253.2	535.6	83.6	935.4	430.0	144.5	230.6	20.3	420.9	153.1	8.5	279.9
Camp Creek	38.6		44.2	25.1	55.6	29.9	11.7	25.3	14.6	8.2	1.1	22.9	48.6	7.5	85.1	39.0	13.0	20.9	1.8	38.2	13.8	0.8	25.4
Coon Run Ditch	61.7	2 & 3	69.2	39.3	87.0	46.8	18.3	39.6	22.9	12.9	1.6	35.9	76.1	11.8	133.1	61.0	20.4	32.7	2.8	59.7	21.6	1.2	39.7
Mauvaise Terre	178	2 & 3	208.6	118.9	262.3	141.5	55.5	119.8	69.2	39.2	5.1	108.4	229.3	35.8	400.5	184.1	61.9	98.8	8.7	180.2	65.6	3.6	119.9
	25765.2		17180.3	13676.	15803.	10648.	9367.6	11066.0	6716.7	3142.2	1824.3	10529.5	13201.4	4558.2	38298.8	9472.2	12177.6	8276.7	5948.0	15519.3	9549.2	2191.1	10957.4
Missing area	977.8	2 & 3	1398.8	1569.6	1471.5	1563.3	700.4	1687.6	216.3	245.9	300.5	1076.0	1784.0	636.4	3646.9	1614.2	989.3	422.4	756.9	1893.5	536.8	82.3	1129.6
Total inflow	26743.0		18579.1	15245.	17275.	12211.	10068.0	12753.6	6933.0	3388.0	2124.8	11605.5	14985.5	5194.6	41945.7	11086.4	13166.9	8699.1	6704.9	17412.8	10085.9	2273.3	12087.0
Outflow from Illinois River at Valley City	26743.0		7350.5	9018.6	5985.9	5217.3	5438.3	7881.9	4629.2	2059.6	1805.4	7051.8	10050.9	3716.2	5462.6	5482.1	5559.9	5385.8	4096.6	4629.2	4415.2	2911.4	5407.4
Percent difference			60	41	65	57	46	38	33	39	15	39	33	28	87	51	58	38	39	73	56	-28	55

Table 5. Sediment Budget Estimate for the Illinois River, 1981-2000

Water Year	*Total inflow from tributary streams (tons × 1000)*	*Outflow from Illinois River at Valley City (tons × 1000)*	*Deposition (tons × 1000)*	*Percent deposited*
WY81	18579.1	7350.5	11228.6	60
WY82	15245.9	9018.6	6227.3	41
WY83	17275.0	5985.9	11289.1	65
WY84	12211.5	5217.3	6994.2	57
WY85	10068.0	5438.3	4629.7	46
WY86	12753.6	7881.9	4871.7	38
WY87	6933.0	4629.2	2303.8	33
WY88	3388.0	2059.6	1328.4	39
WY89	2124.8	1805.4	319.4	15
WY90	11605.5	7051.8	4553.7	39
WY91	14985.5	10050.9	4934.6	33
WY92	5194.6	3716.2	1478.4	28
WY93	41945.7	5462.6	36483.1	87
WY94	11086.4	5482.1	5604.3	51
WY95	13166.9	5559.9	7607.0	58
WY96	8699.1	5385.8	3313.3	38
WY97	6704.9	4096.6	2608.3	39
WY98	17412.8	4629.2	12783.6	73
WY99	10085.9	4415.2	5670.7	56
WY2000	2273.3	2911.4	-638.1	-28
Average	12087.0	5407.4	6679.5	55

It should be noted, however, that the sediment deposition estimated might not have been the total amount of sediment deposited in the valley. Additional sediment from bank and bluff erosion along the mainstem of the Illinois River also is deposited in the valley. Data presently available are not sufficient, however, to make a reasonable estimate of the amount of sediment generated from such erosion along the Illinois River.

Figure 7a shows the variability and trend of total sediment inflow, outflow, and deposition in the Illinois River valley. Corresponding water discharges also are shown (Figure 7b). The major flux of sediment into the valley in 1993 was due to the major floods in Illinois and Upper Mississippi River basin that year. The low-flow years of 1988, 1989, and 2000 resulted in the least amount of sediment inflow into the valley. The percentage of sediment deposited in the valley tends to follow the total inflow, with the highest percentage (87%) during high inflow in 1993 and the lowest percentage (15%) during low inflow in 1989. The very high sediment deposition rate in 1993 was caused primarily by the high floodwaters along the Mississippi River during the Great Mississippi Flood, which created a backwater effect on the Illinois River (Demissie, 1996). However, not all high sedimentation rates were due to Mississippi River backwater effects; other factors such as high flows from tributary streams would have increased sedimentation rates independent of Mississippi River backwaters.

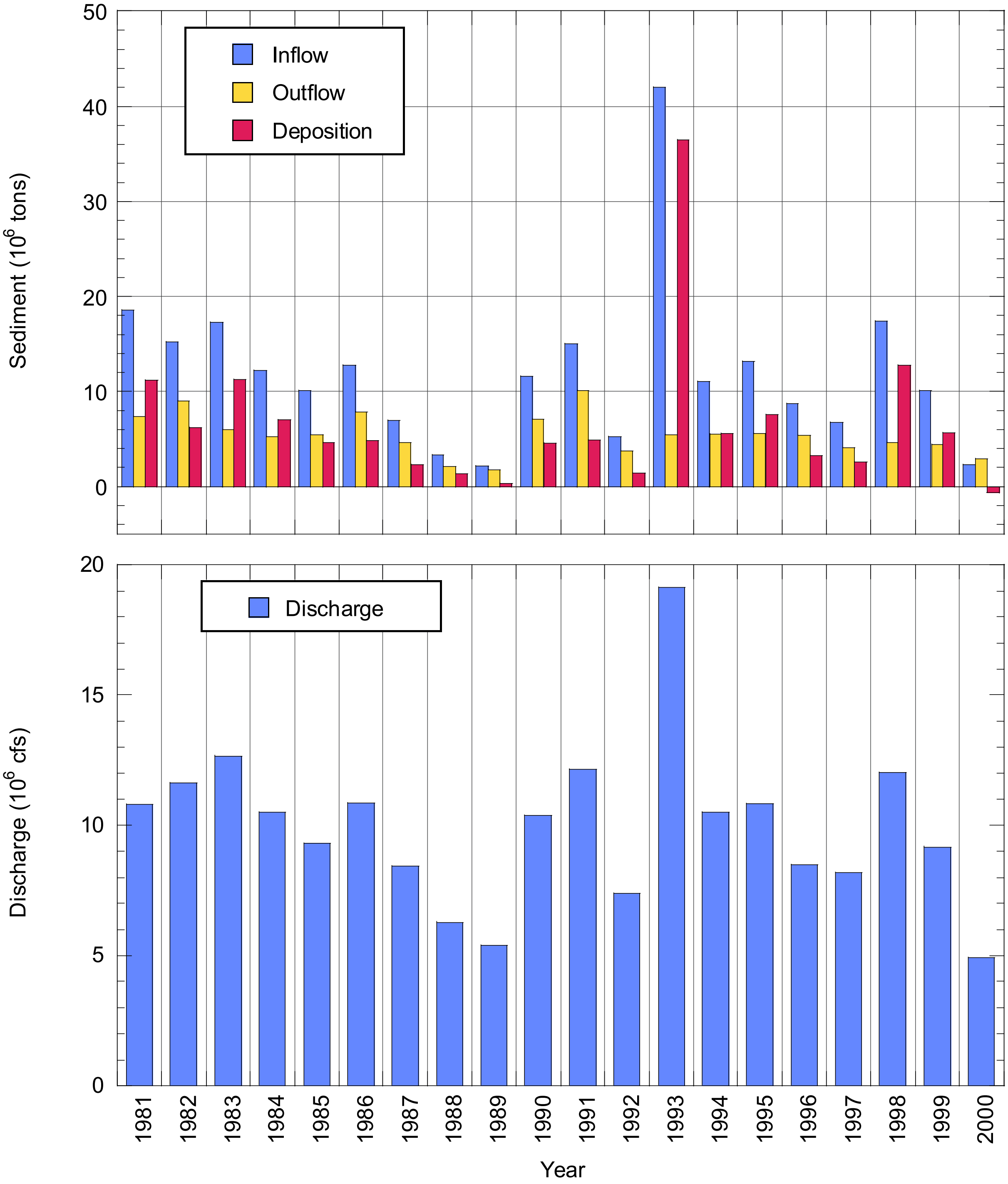

Figure 7. Variability and trend in the computed inflow, outflow, and deposition of sediment in the Illinois River valley, 1981-2000

Estimates for Water Year 2000 resulted in -28 percent deposition, implying more outflow than inflow. Because Water Year 2000 was a low-flow year, the total amount of sediment was small (the -28% deposition was only 19% of the average annual sediment inflow), so it is not certain whether or not there was a real net scour of sediment from the Illinois River valley in Water Year 2000.

Figures 8 and 9 schematically represent the water and sediment budget estimates of the Illinois River. The computed inflow of water and sediment from tributary streams is shown at the inlet points, and the width of the core represents either the water discharge or sediment load. No unexpected variation appears in the water budget (Figure 8). The discharge of the Illinois River increases gradually in the downstream direction, with the Kankakee and Sangamon Rivers being the major contributors. On the other hand, the computed sediment load in the Illinois River drastically increases both in the Peoria and LaGrange Pools (Figure 9). The most sediment flows into LaGrange Pool from the Spoon, Sangamon, LaMoine, and Mackinaw Rivers, the main contributors. The Spoon River delivers the most sediment per unit area among the major tributaries to the Illinois River. The Vermilion and Kankakee Rivers contribute significant sediment into the Peoria and the Dresden Pools, respectively. In general, the lower Illinois River receives much more sediment than the upper Illinois River. It also should be noted that Figure 9 is a cumulative sediment budget for the whole Illinois River valley. Sediment entrapment and thus deposition within each pool could not be calculated for each pool from available data. Therefore, sediment deposition within each pool is not quantified and shown at each lock and dam location (Figure 9); instead the estimated total sediment deposition within the valley is shown at Valley City.

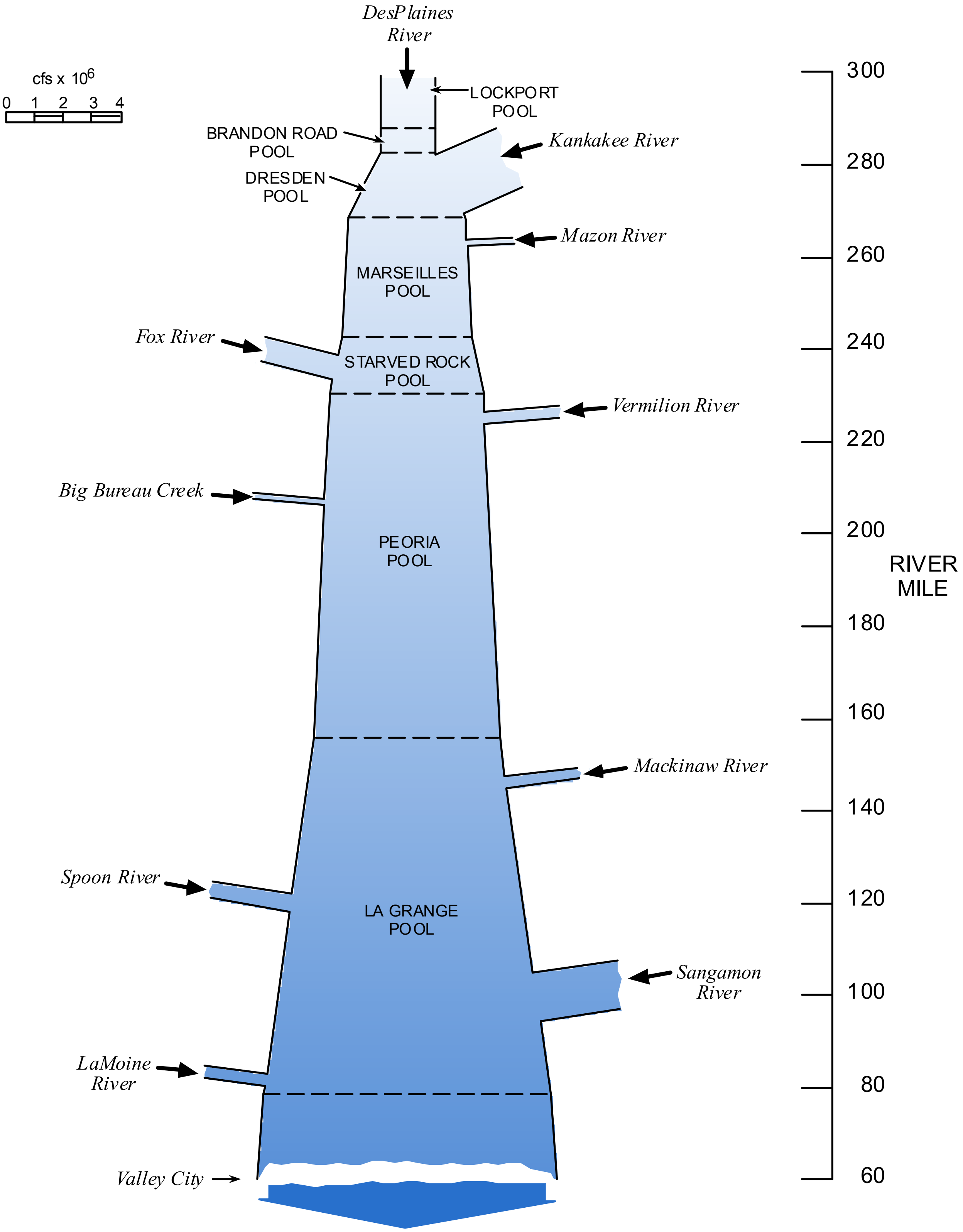

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Figure 8. Water budget estimate for the Illinois River, 1981-2000

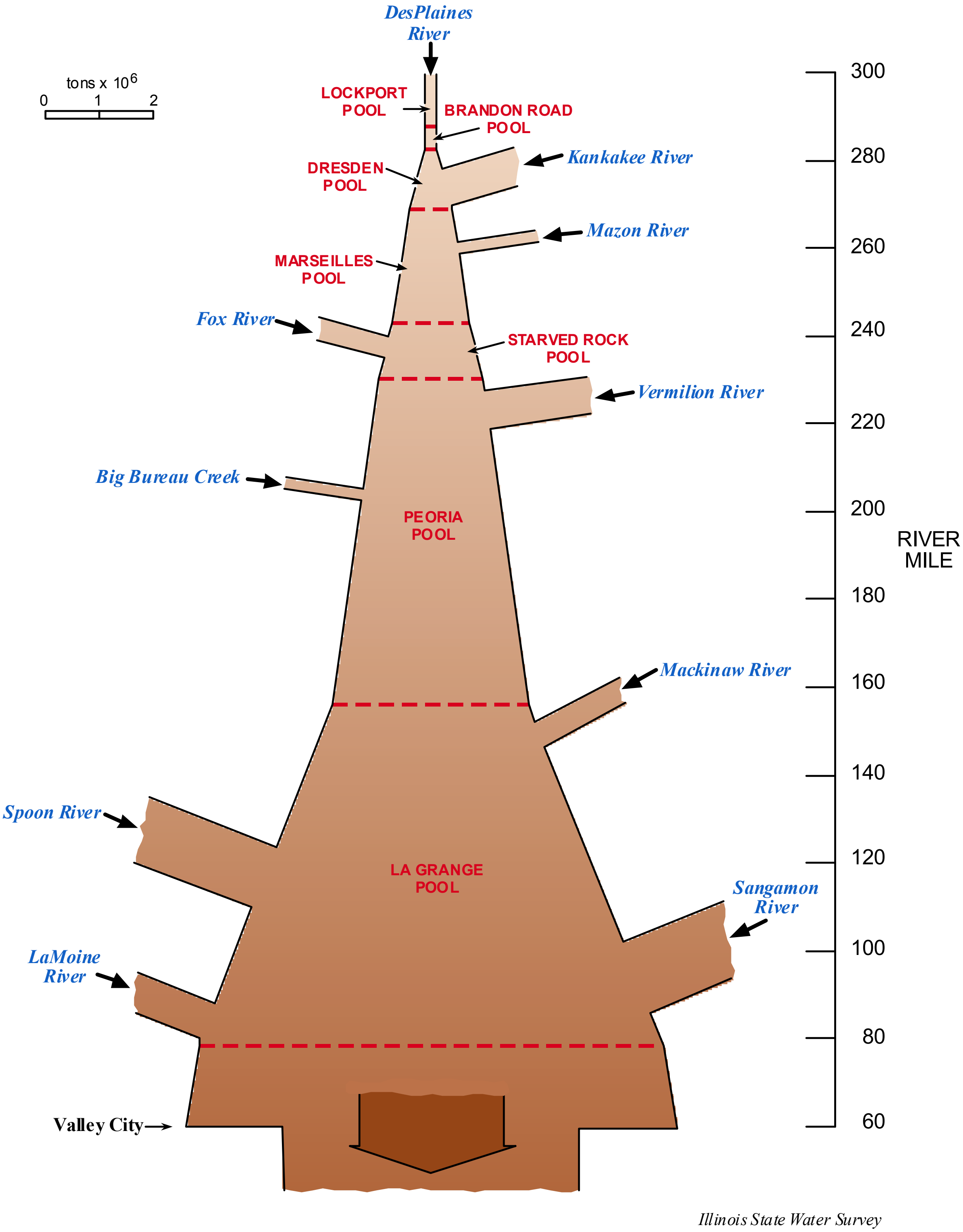

Figure 9. Sediment budget estimate for the Illinois River, 1981-2000

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Appendix A. Comparison of the Nonlinear Rating Curve Method with the Linear Rating Curve Method for Estimating Annual Suspended Sediment Loads

The method of estimating sediment loads based on sediment rating curves assumes sufficient data points to develop reliable relationships between water discharges and sediment concentrations or loads. Rating curves are developed using regression methods to fit either linear or nonlinear curves through the data points. Once rating curves are developed, they and water discharge values are used to estimate sediment loads. The most frequently used sediment rating curve is the power curve, which can be written as follows:

$$Q_s = a_1 Q_w^{b_1} \tag{A-1}$$

where Q_s = suspended sediment load
Q_w = water discharge
and
a_1, b_1 = regression coefficients

Equation A-1 generally is transformed into a logarithmic form resulting in a linear equation, Equation A-2:

$$\log Q_s = a + b \log Q_w \tag{A-2}$$

where a and b are regression coefficients equivalent to log a_1 and log b_1, respectively. Several researchers have shown that linear rating equations based on logarithmic transformed values generally underestimate sediment loads (Ferguson, 1986; Walling and Webb, 1988; Koch and Smillie, 1986). Ferguson argued that the major reason for the underestimation is a statistical bias that is introduced when the power law equation (A-1) is transformed into a linear regression equation (A-2) after logarithmic transformation. He proposed a bias correction factor that varied with the mean square error of the linear regression. The sediment load after applying Ferguson's correction factor is given by:

$$Q_s = e^{2.65*MSE} \text{ x } Q_s^1 \tag{A-3}$$

where Q_s = corrected sediment load
Q_s^1 = sediment load computed from the linear regression
MSE = mean square error of the linear regression

After using the linear regression method and applying Ferguson's correction factor for estimating annual sediment loads for several rivers in the Illinois River basin, there were still significant underestimations and, in some cases, overestimations.

After evaluating different methods, and the nature of the problem with the linear regression, it was decided to test the performance of a nonlinear regression equation that fits the data better:

$$\log Q_s = a + b\ (\log Q_w)^c \qquad \text{(A-4)}$$

All the terms were as defined before except for c, the third regression coefficient. Results from the nonlinear regression method were found to be significantly better than from other methods. Comparison of the results from the nonlinear regression and linear regression methods before and after applying Ferguson's correction factor are given in Table A1. The regression coefficients, the standard errors, and the correlation coefficients for all the regression analyses are given in Table A2.

The comparisons were performed for three monitoring stations: one station had four years of data and two stations had seven years of data each. As shown in Table A1, the relative differences of the sediment loads calculated using the nonlinear regression method from the measured load are significantly smaller than those based on the linear regression method with or without Ferguson's correction factor. The relative difference, *RD*, is defined as:

$$RD = \frac{Q_s\,(\text{caculated}) - Q_s\,(\text{measured})}{Q_s\,(\text{measured})} \times 100$$

For the Mackinaw River at Congerville, the relative difference for the annual sediment load based on the nonlinear regression method varied from -5.52 percent to +3.43 percent. For the period of record (1983-1986), the overall relative difference was 7.94 percent. Based on the linear regression method, the relative difference for the annual sediment load ranged from -44.47 to -80.26 percent. For the period of record, the overall relative difference was -71.87 percent. By applying Ferguson's correction factor, the relative differences for the annual sediment loads were reduced to -29.02 to -59.16 percent and for the period of record to -50.90 percent.

For the Kankakee River near Wilmington, the relative difference for the annual sediment load based on the nonlinear regression method ranged from -12.32 percent to +5.07 percent. For the period of record, the overall relative difference was -2.8 percent. Based on the linear regression method, the relative difference for the annual sediment load ranged from -52.47 to -18.67 percent. For the period of record, the overall relative difference was -42.78 percent. Applying Ferguson's correction factor reduced the relative differences for the annual sediment loads to -43.21 to -4.01 percent and for the period of record to -22.49 percent.

For the Sangamon River near Oakford, the relative difference for the annual sediment load based on the nonlinear regression method ranged from 1.29 to +0.42 percent. For the period of record, the overall relative difference for the sediment load was -0.83 percent. Based on the linear regression method, the relative difference for the annual sediment load ranged from -38.87 percent to +4.68 percent. For the period of record, the relative difference was -10.88 percent. Applying Ferguson's correction factor in this case resulted in overestimation of the period of record sediment load by 24.53 percent and the annual sediment loads by 12.33 to 56.44 percent, with the exception of 1984 where the annual load was underestimated by 14.39 percent.

In almost all cases, the nonlinear regression method estimated the measured sediment load better than the linear regression method with or without Ferguson's correction factor.

Table A1. Comparison of Linear and Nonlinear Regression Methods for Estimating Sediment Loads

		Linear regression $\log Q_s = a + b \log Q_w$			Linear regression with Ferguson's correction (Ferguson, 1986)			Nonlinear regression method $\log Q_s = a + b (\log Q_w)^c$		
Station name	*Water Year*	*Q_s measured (tons)*	*Q_s computed (tons)*	*Relative difference (%)*	*Q_s measured (tons)*	*Q_s computed (tons)*	*Relative difference (%)*	*Q_s measured (tons)*	*Q_s computed (tons)*	*Relative difference (%)*
Mackinaw River at Congerville (05567510)	**1983-1986**	**1,139,592**	**320,518**	**-71.87**	**1,139,592**	**559,543**	**-50.90**	**1,139,592**	**1,230,086**	**7.94**
	1983	6,524	2,367	-63.72	6,524	2,664	-59.16	6,524	6,688	2.52
	1984	403,172	106,356	-73.62	403,172	195,854	-51.42	403,172	415,649	3.09
	1985	522,469	103,142	-80.26	522,469	233,636	-55.28	522,469	493,616	-5.52
	1986	207,427	115,182	-44.47	207,427	147,225	-29.02	207,427	214,544	3.43
Kankakee River near Wilmington (05527500)	**1979-1982, 1993-1995**	**5,750,994**	**3,290,852**	**-42.78**	**5,750,994**	**4,457,663**	**-22.49**	**5,750,994**	**5,590,111**	**-2.80**
	1979	932,767	611,375	-34.46	932,767	867,908	-6.95	932,767	936,698	0.42
	1980	678,084	322,306	-52.47	678,084	385,059	-43.21	678,084	660,039	-2.67
	1981	1,365,482	947,759	-30.59	1,365,482	1,171,809	-14.18	1,365,482	1,373,102	0.56
	1982	785,748	491,413	-37.46	785,748	668,027	-14.98	785,748	825,602	5.07
	1993	1,023,216	670,975	-34.42	1,023,216	982,173	-4.01	1,023,216	897,163	-12.32
	1994	544,397	392,755	-27.86	544,397	470,167	-13.64	544,397	520,618	-4.37
	1995	421,300	342,658	-18.67	421,300	387,992	-7.91	421,300	419,366	-0.46
Sangamon River near Oakford (05583000)	**1981, 1983-1986, 1995-1996**	**9,728,174**	**8,669,852**	**-10.88**	**9,728,174**	**12,114,385**	**24.53**	**9,728,174**	**9,647,671**	**-0.83**
	1981	2,815,112	2,713,099	-3.62	2,815,112	3,648,576	29.61	2,815,112	2,826,944	0.42
	1983	229,024	203,247	-11.26	229,024	235,299	2.74	229,024	229,077	0.02
	1984	1,752,803	1,071,427	-38.87	1,752,803	1,500,640	-14.39	1,752,803	1,735,160	-1.01
	1985	1,098,240	1,092,063	-0.56	1,098,240	1,496,017	36.22	1,098,240	1,091,518	-0.61
	1986	1,545,839	1,518,355	-1.78	1,545,839	2,099,430	35.81	1,545,839	1,547,695	0.12
	1995	1,231,423	1,150,500	-6.57	1,231,423	1,383,246	12.33	1,231,423	1,215,509	-1.29
	1996	1,055,731	1,105,089	4.68	1,055,731	1,651,556	56.44	1,055,731	1,056,200	0.04

Table A2. Regression Parameters for the Linear and Nonlinear Regression Methods

		Log $Q_s = a + b \log Q_w$				*Ferguson method*	*Nonlinear regression method* log $Q_s = a + b (\log Q_w)^c$				
Station name	*Water Year*	*a*	*b*	*Standard error*	*R-squared*	*Correction factor*	*a*	*b*	*c*	*Standard error*	*R-squared*
Mackinaw River at Congerville (05567510)	**1983-1986**	**-1.4899**	**1.3319**	**0.4585**	**0.8064**	**1.7457**	**0.0794**	**0.1931**	**2.3**	**0.4150**	**0.8413**
	1983	-1.2593	1.2626	0.2113	0.8952	1.1256	0.0773	0.1694	2.6	0.1320	0.9587
	1984	-1.6254	1.3506	0.4800	0.8367	1.8415	0.0632	0.1171	2.7	0.3755	0.8998
	1985	-1.7962	1.4333	0.5555	0.6954	2.2652	0.1802	0.1462	2.5	0.5142	0.7382
	1986	-1.1545	1.2493	0.3043	0.8808	1.2782	-0.0981	0.4191	1.7	0.2814	0.8978
Kankakee River near Wilmington (05527500)	**1979-1982, 1993-1995**	**-3.2345**	**1.6290**	**0.3384**	**0.7836**	**1.3546**	**1.4793**	**0.0017**	**5.0**	**0.3379**	**0.7841**
	1979	-3.2523	1.6725	0.3636	0.8178	1.4196	0.8558	0.0260	3.3	0.3609	0.8200
	1980	-2.9990	1.6086	0.2591	0.8361	1.1947	1.5402	0.0013	5.3	0.2580	0.8371
	1981	-4.7711	2.0798	0.2830	0.8715	1.2364	0.5523	0.0305	3.3	0.2849	0.8694
	1982	-2.9302	1.5458	0.3404	0.7147	1.3594	1.5677	0.00228	4.6	0.3209	0.7457
	1993	-3.5527	1.6930	0.3792	0.5752	1.4638	2.2326	0.000014	8.0	0.3608	0.6141
	1994	-4.2582	1.8430	0.2605	0.8152	1.1971	1.2229	0.0031	4.6	0.2744	0.7945
	1995	-4.1029	1.8344	0.2166	0.9050	1.1323	0.5920	0.0206	3.5	0.2282	0.8942
Sangamon River near Oakford (05583000)	**1981, 1983-1986, 1995-1996**	**-3.0942**	**1.7511**	**0.3553**	**0.8727**	**1.3973**	**-1.4350**	**0.7687**	**1.4**	**0.3592**	**0.8699**
	1981	-3.6285	1.9260	0.3344	0.9331	1.3448	-2.5763	1.2600	1.2	0.3381	0.9314
	1983	-2.6039	1.6678	0.2351	0.9249	1.1577	0.9194	0.0455	3.1	0.2618	0.9061
	1984	-2.8333	1.6473	0.3566	0.8727	1.4006	1.2063	0.0114	3.9	0.3804	0.8547
	1985	-3.7512	1.9195	0.3446	0.8644	1.3699	-3.7510	1.9194	1.0	0.3446	0.8644
	1986	-2.8026	1.6973	0.3497	0.8210	1.3827	-2.2755	1.3634	1.1	0.3507	0.8194
	1995	-2.5125	1.5689	0.2637	0.8992	1.2023	-1.6296	1.0223	1.2	0.2637	0.8989
	1996	-3.0374	1.7338	0.3894	0.8309	1.4945	-3.6567	2.1676	0.9	0.3884	0.8313

Appendix B. Results of Sediment Load Analysis

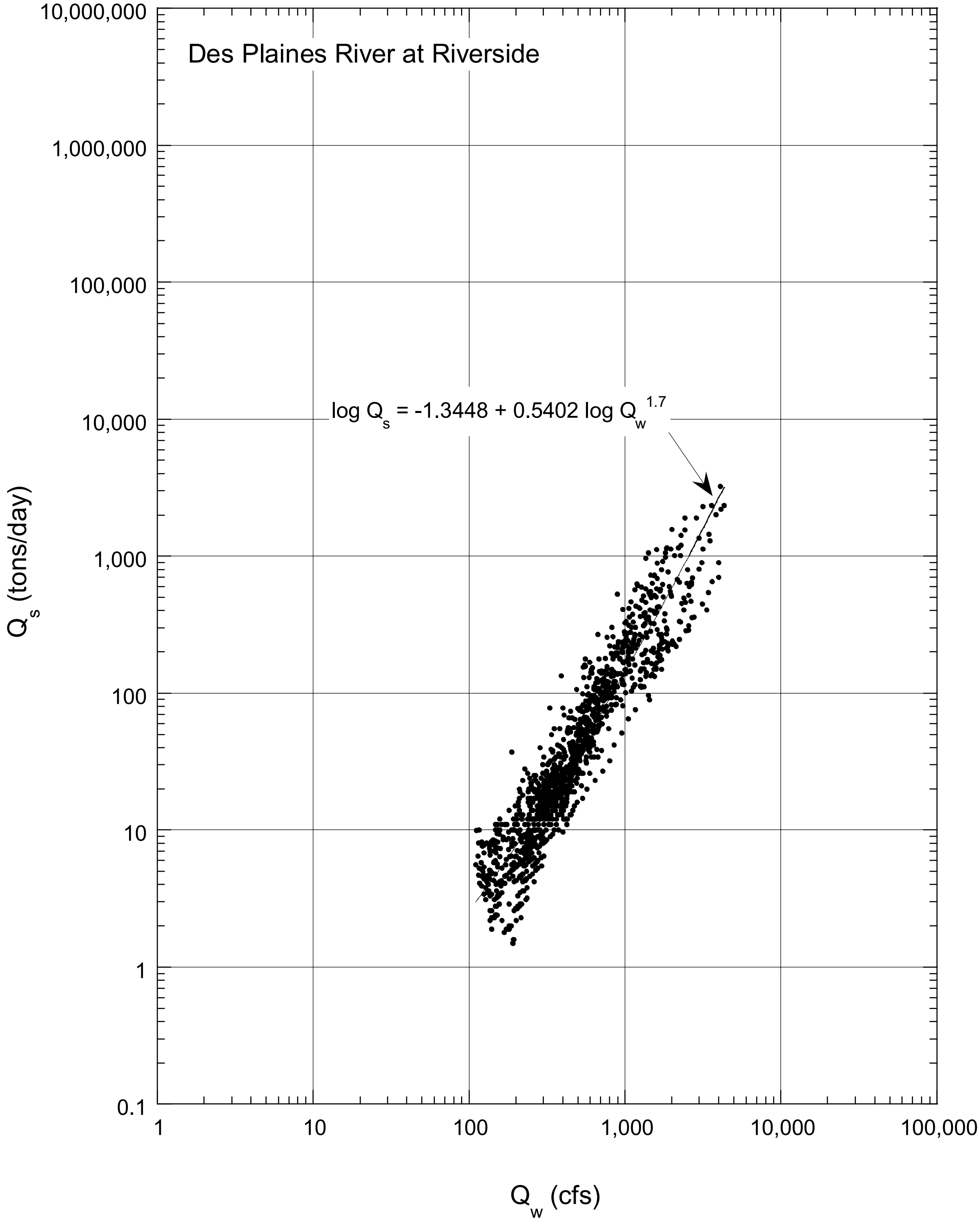

Figure B1. Comparison of multi-year sediment load curve with data for Des Plaines River at Riverside

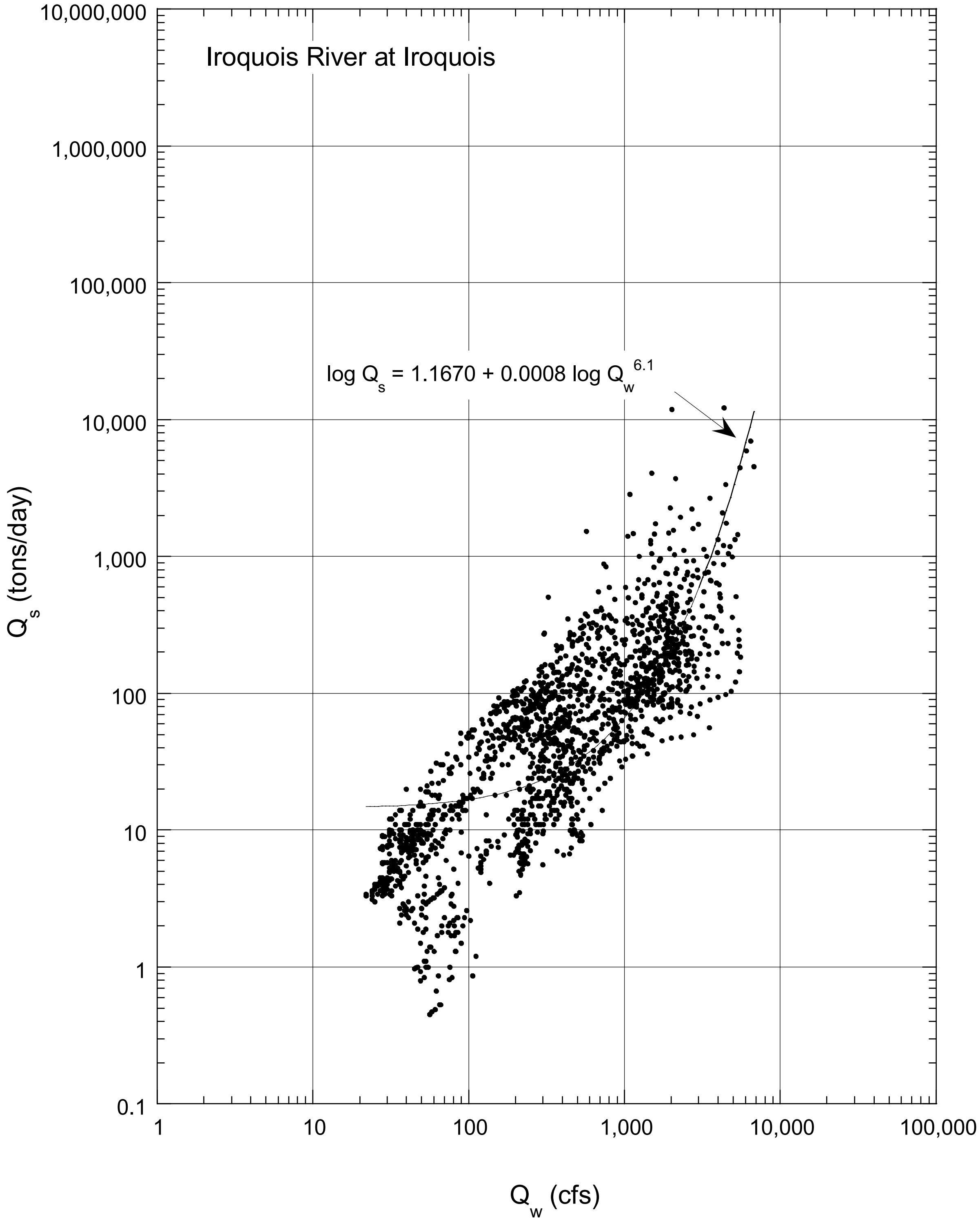

Figure B2. Comparison of multi-year sediment load curve with data for Iroquois River at Iroquois

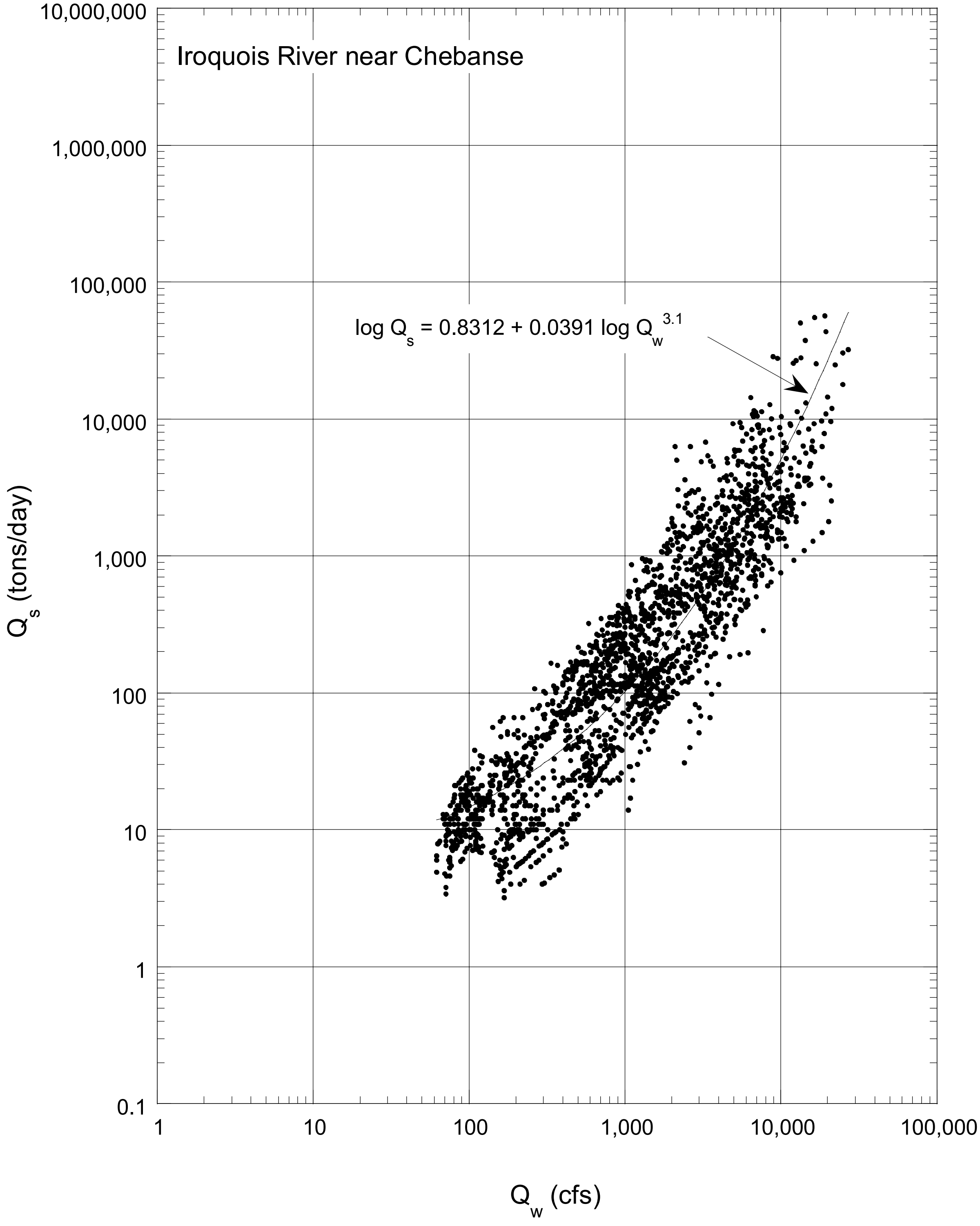

Figure B3. Comparison of multi-year sediment load curve with data for Iroquois River near Chebanse

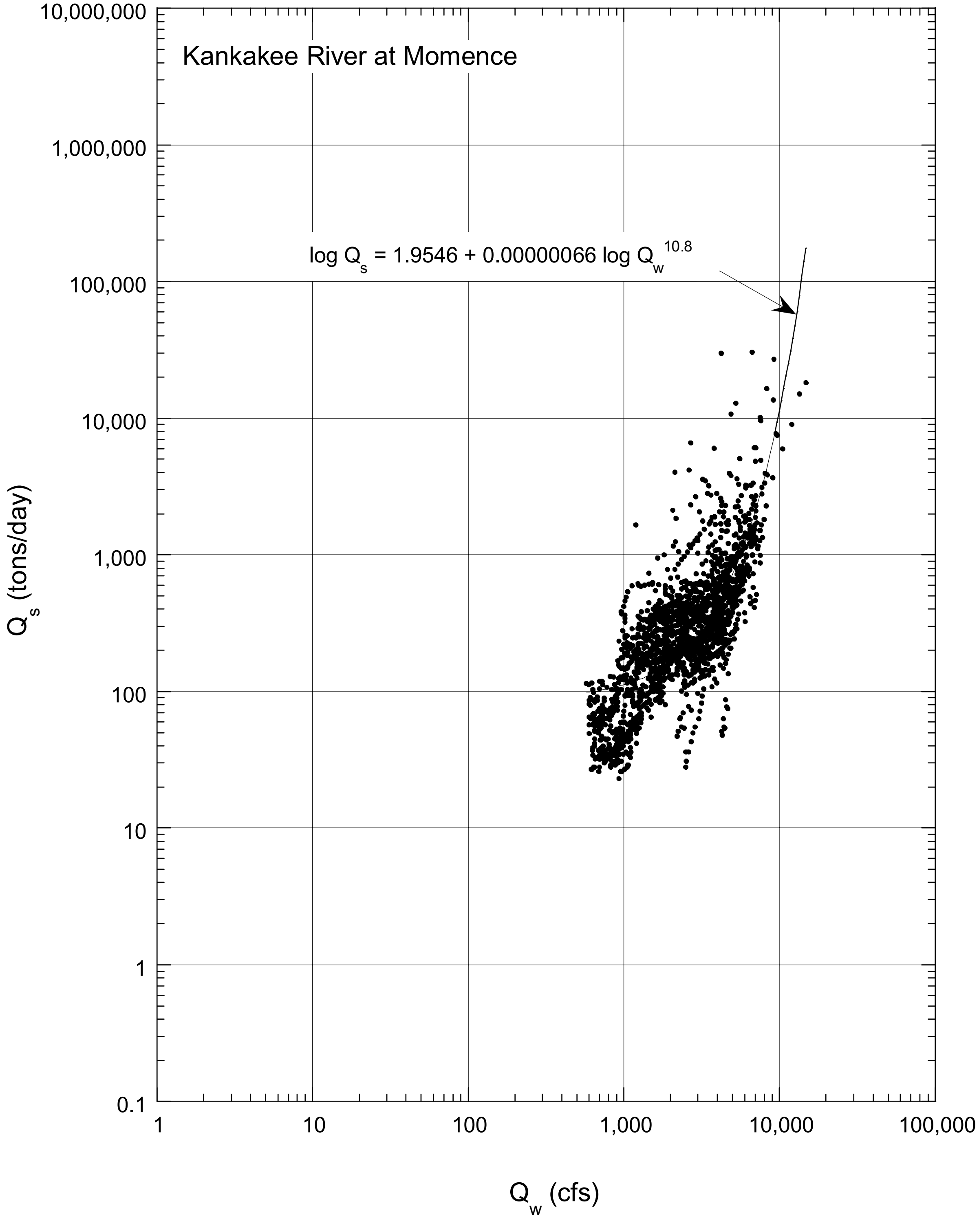

Figure B4. Comparison of multi-year sediment load curve with data for Kankakee River at Momence

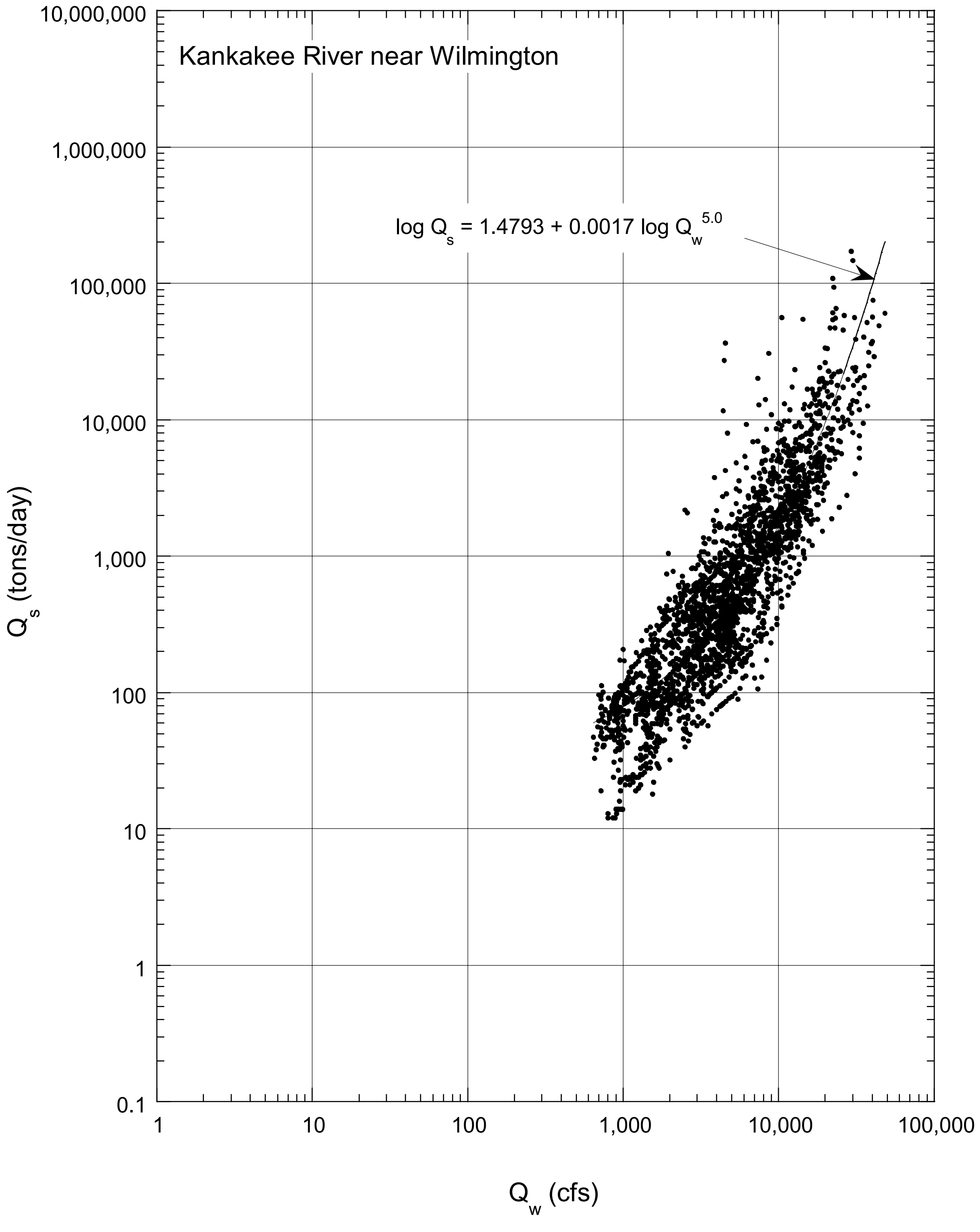

Figure B5. Comparison of multi-year sediment load curve with data for Kankakee River near Wilmington

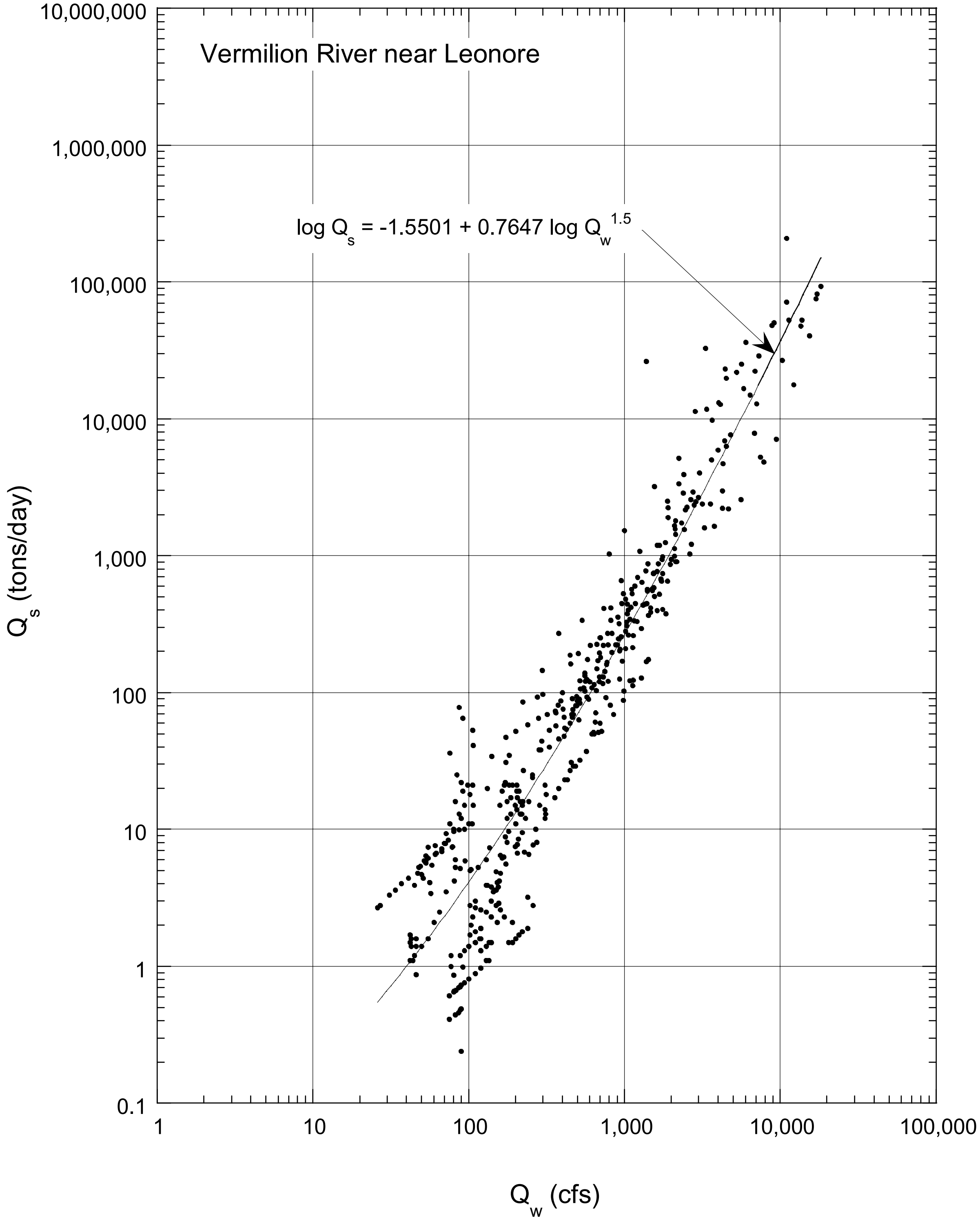

Figure B6. Comparison of multi-year sediment load curve with data for Vermilion River near Leonore

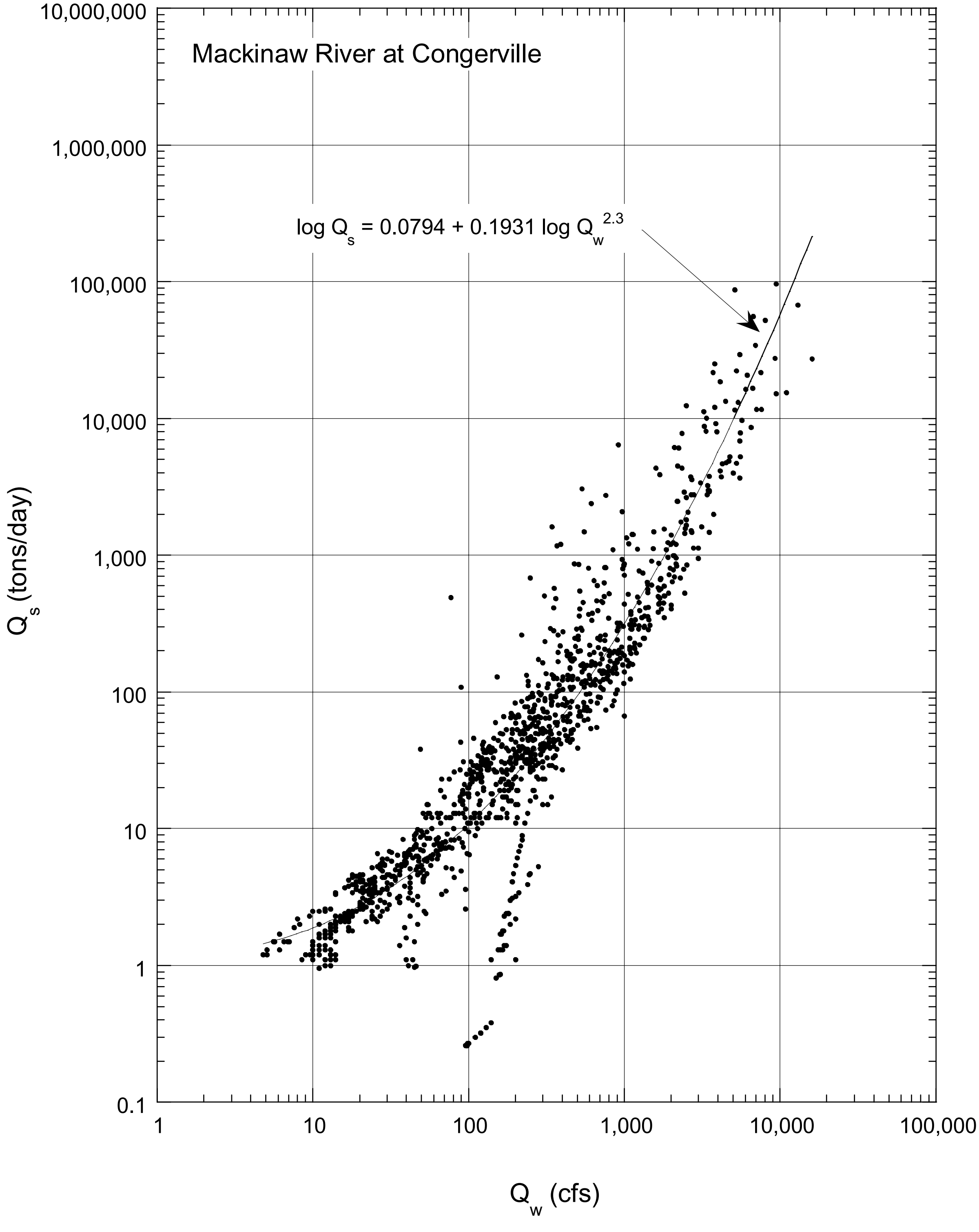

Figure B7. Comparison of multi-year sediment load curve with data for Mackinaw River at Congerville

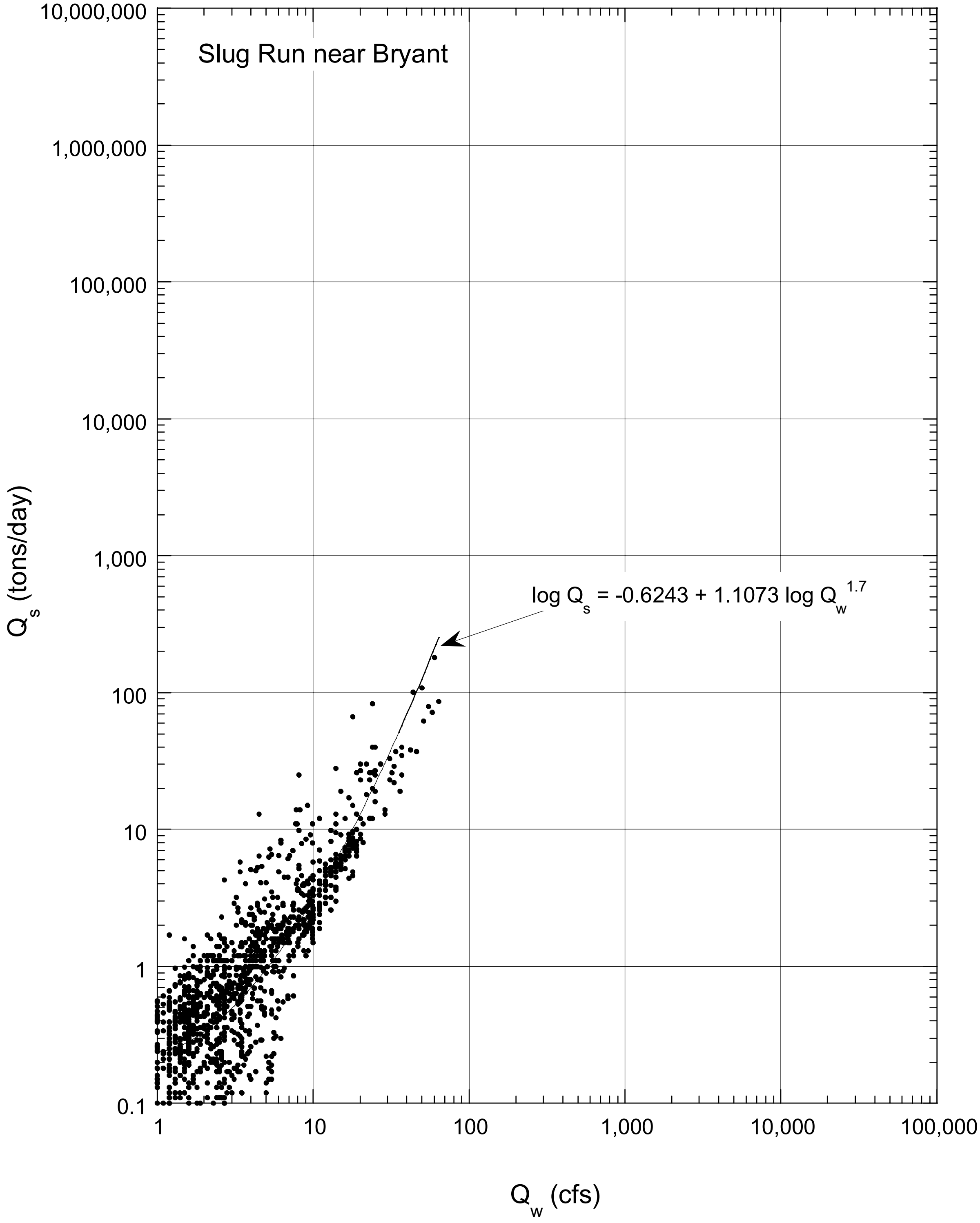

Figure B8. Comparison of multi-year sediment load curve with data for Slug Run near Bryant

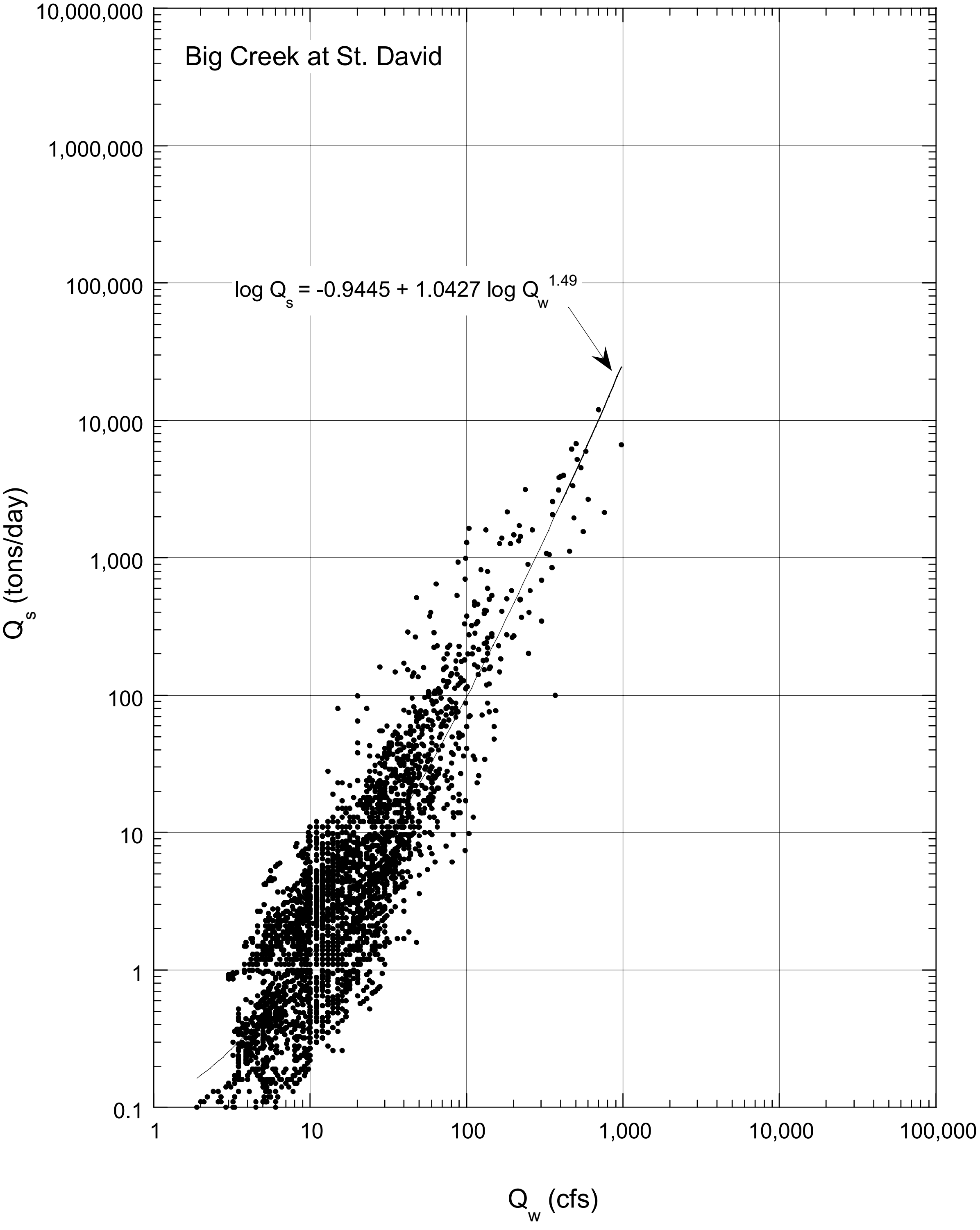

Figure B9. Comparison of multi-year sediment load curve with data for Big Creek at St. David

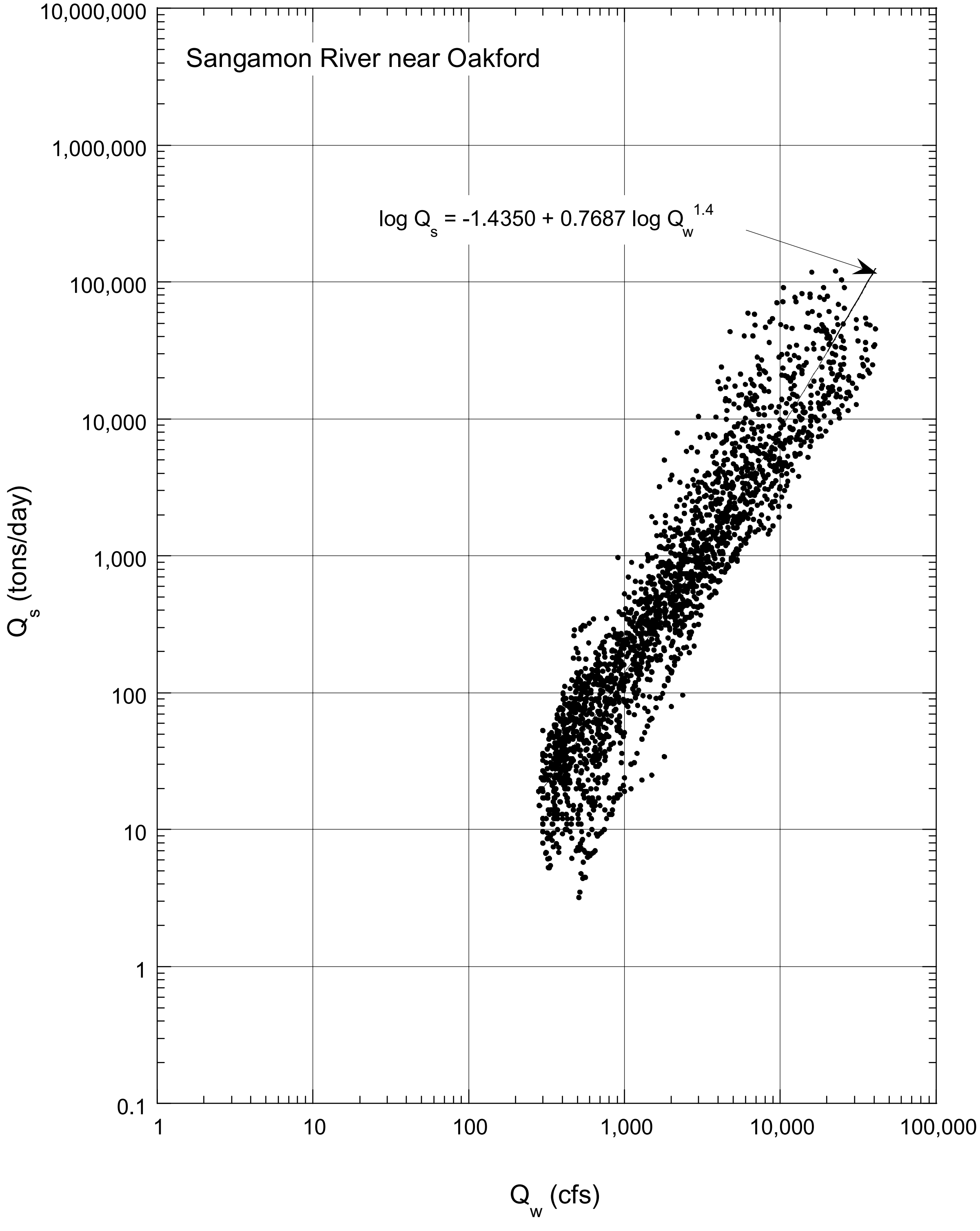

Figure B10. Comparison of multi-year sediment load curve with data for Sangamon River near Oakford

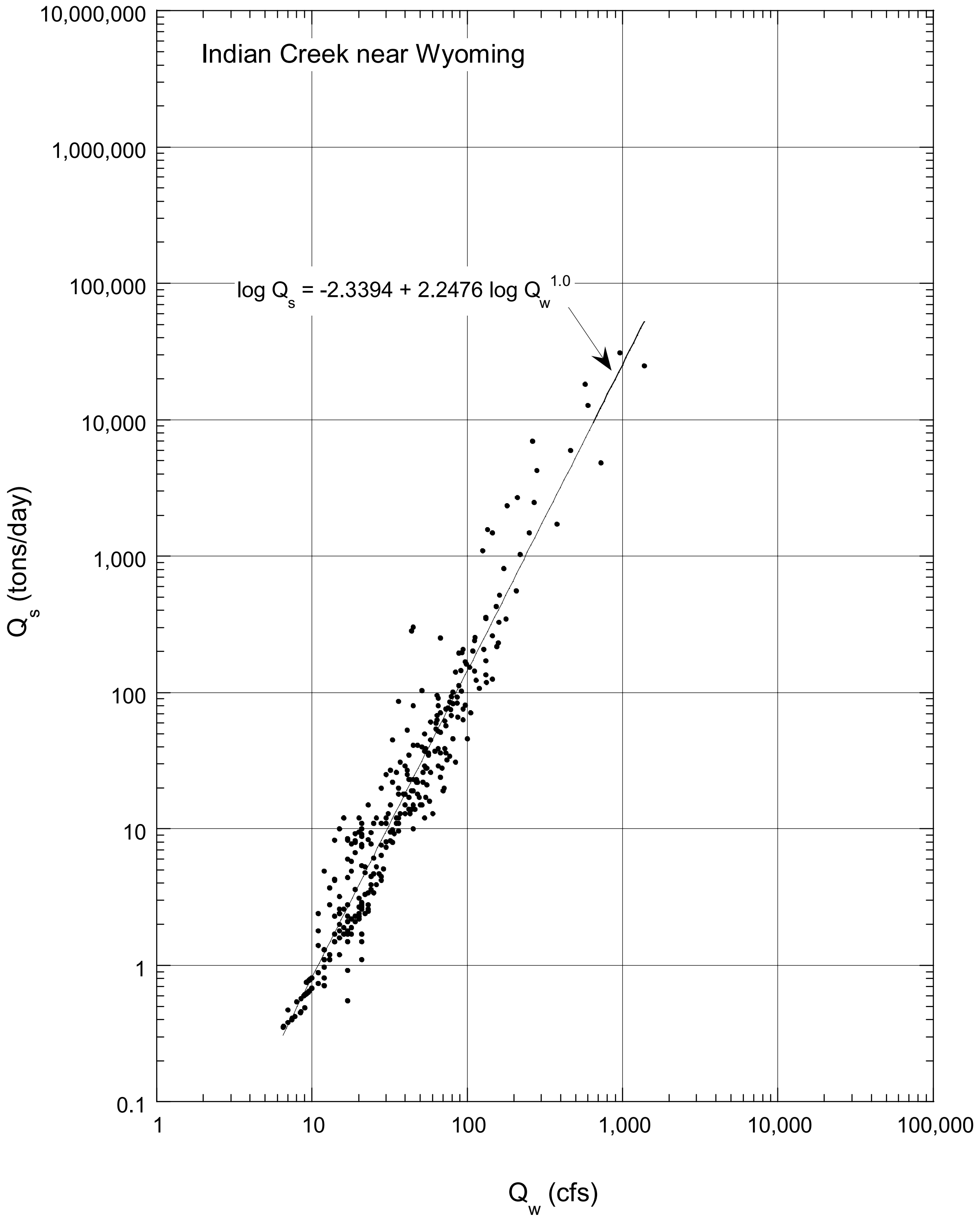

Figure B11. Comparison of multi-year sediment load curve with data for Indian Creek near Wyoming

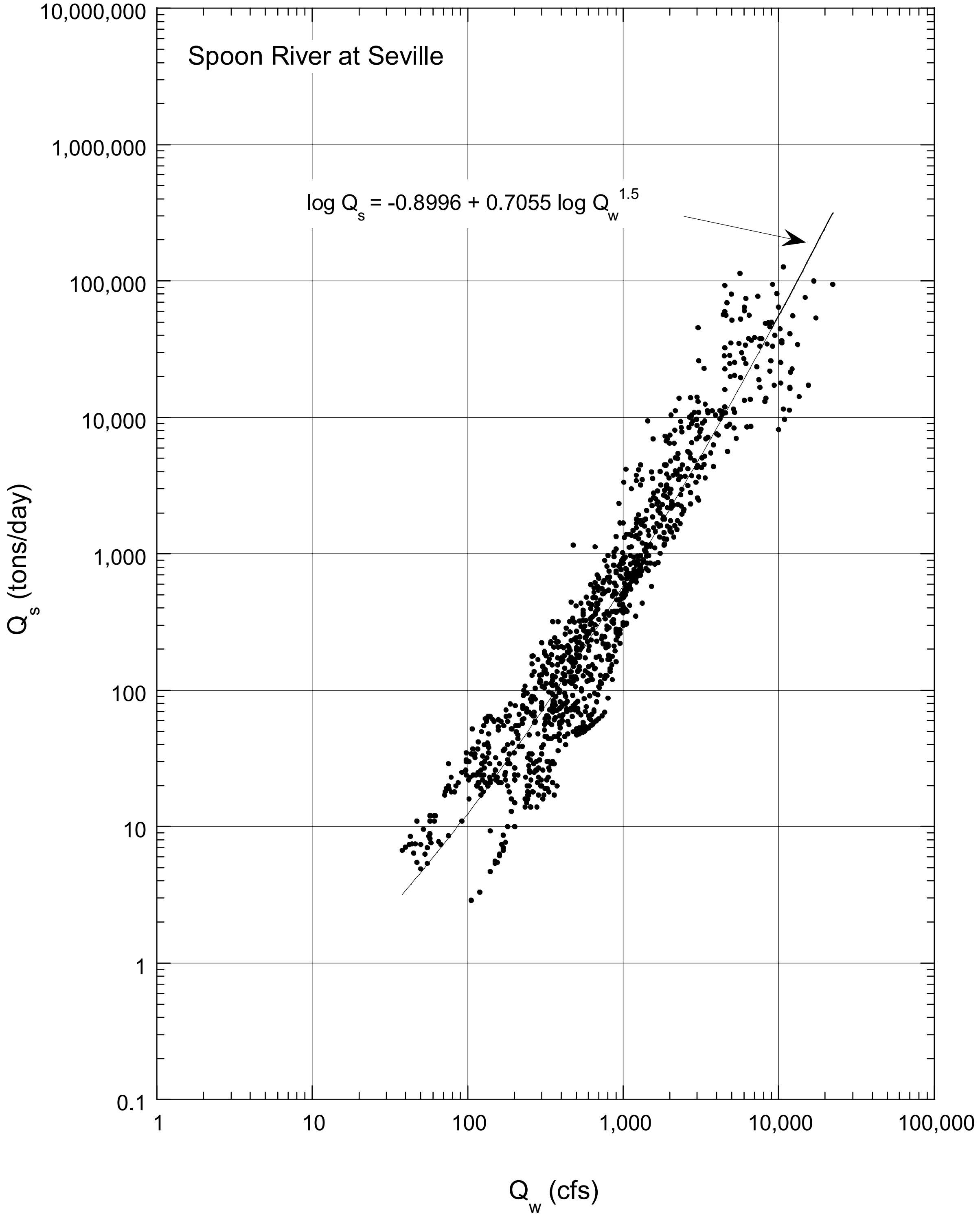

Figure B12. Comparison of multi-year sediment load curve with data for Spoon River at Seville

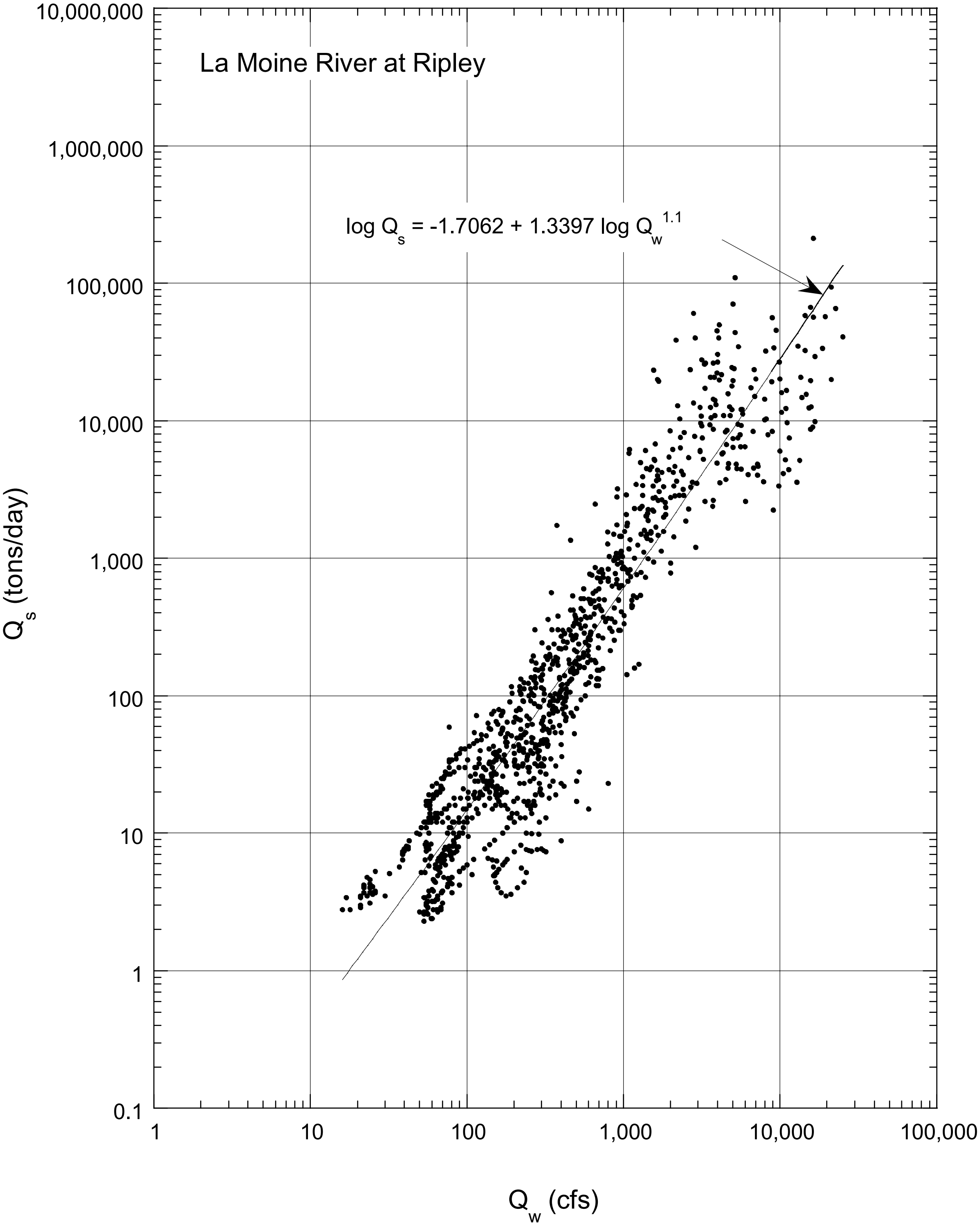

Figure B13. Comparison of multi-year sediment load curve with data for La Moine River at Ripley

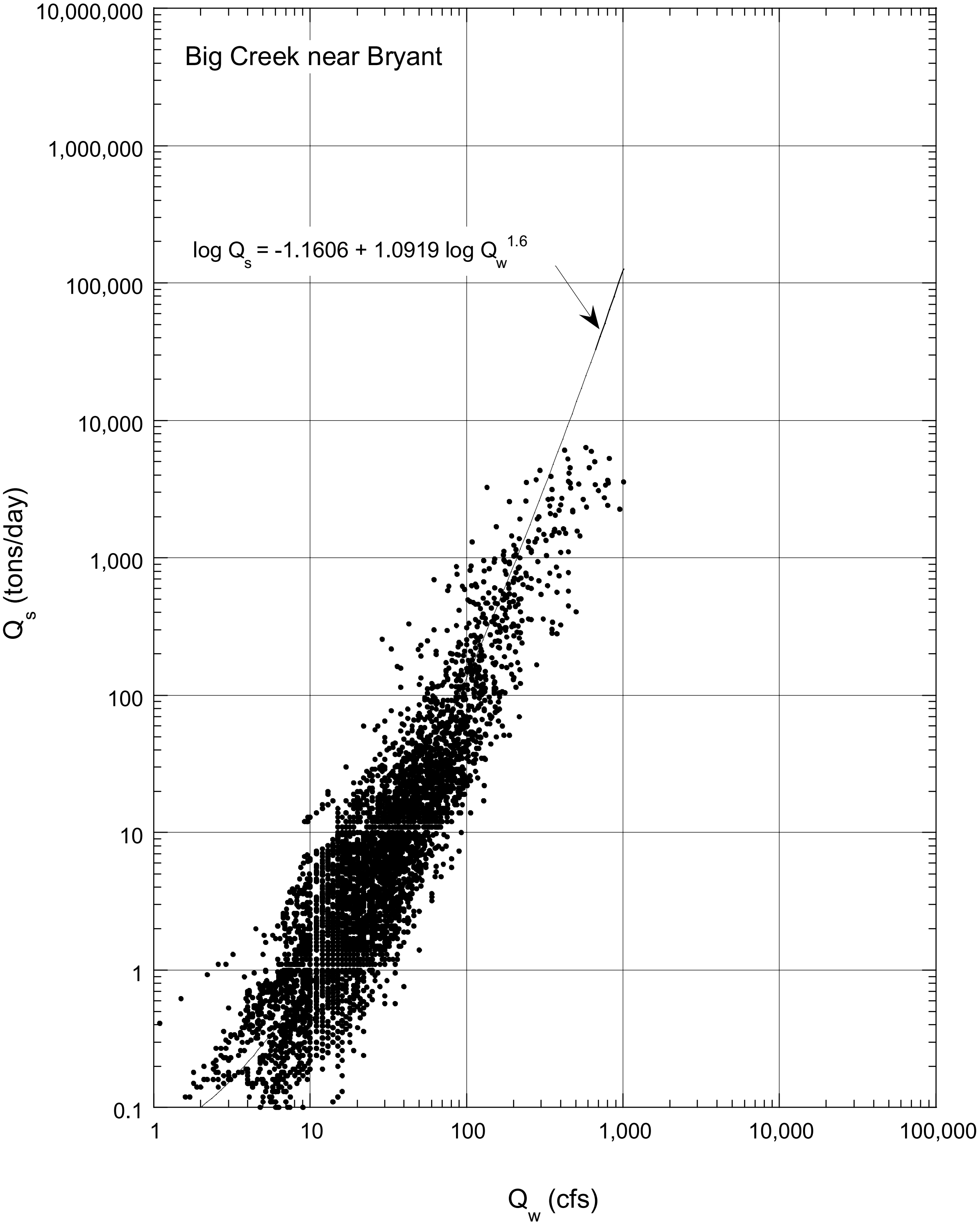

Figure B14. Comparison of multi-year sediment load curve with data for Big Creek near Bryant

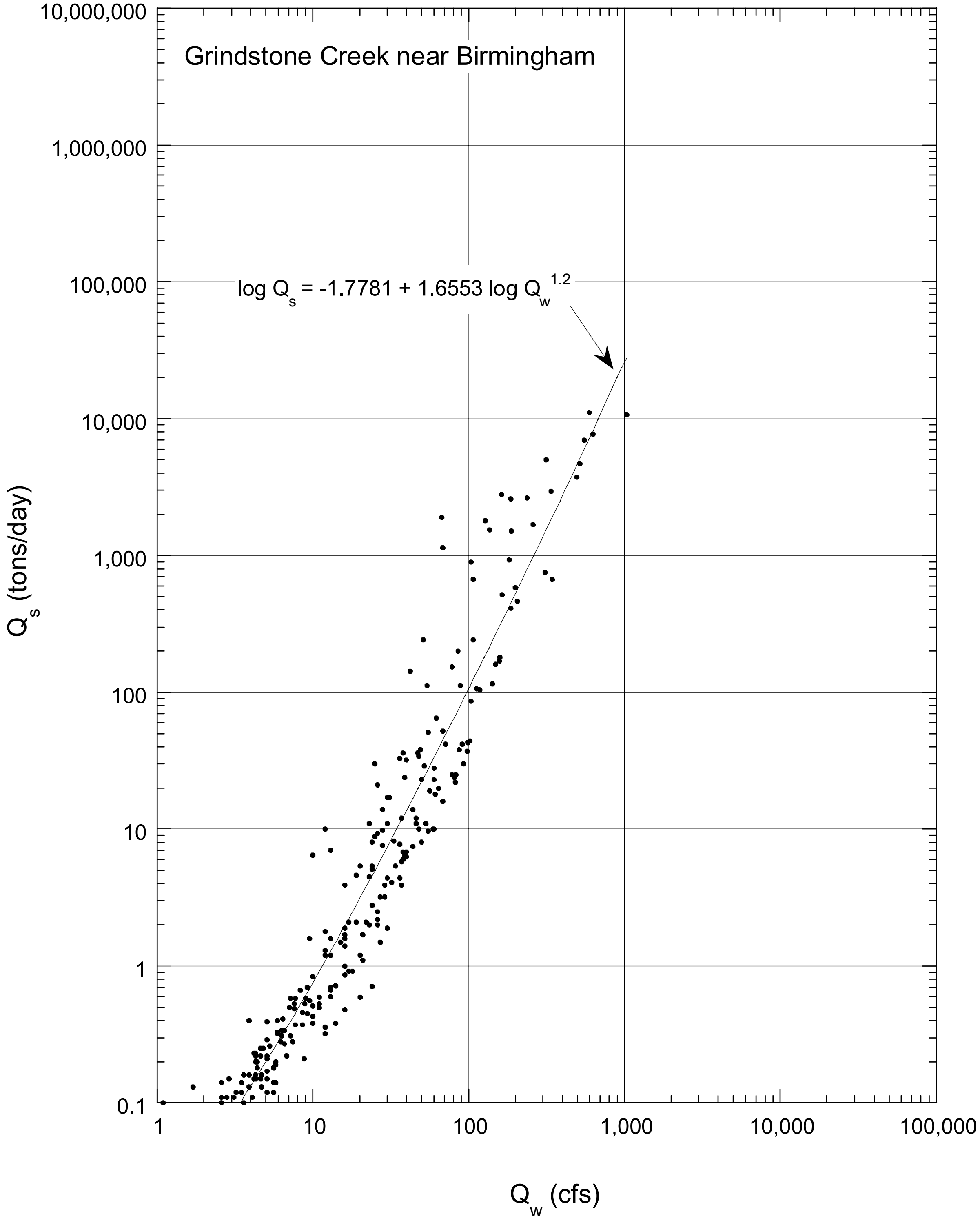

Figure B15. Comparison of multi-year sediment load curve with data for Grindstone Creek near Birmingham

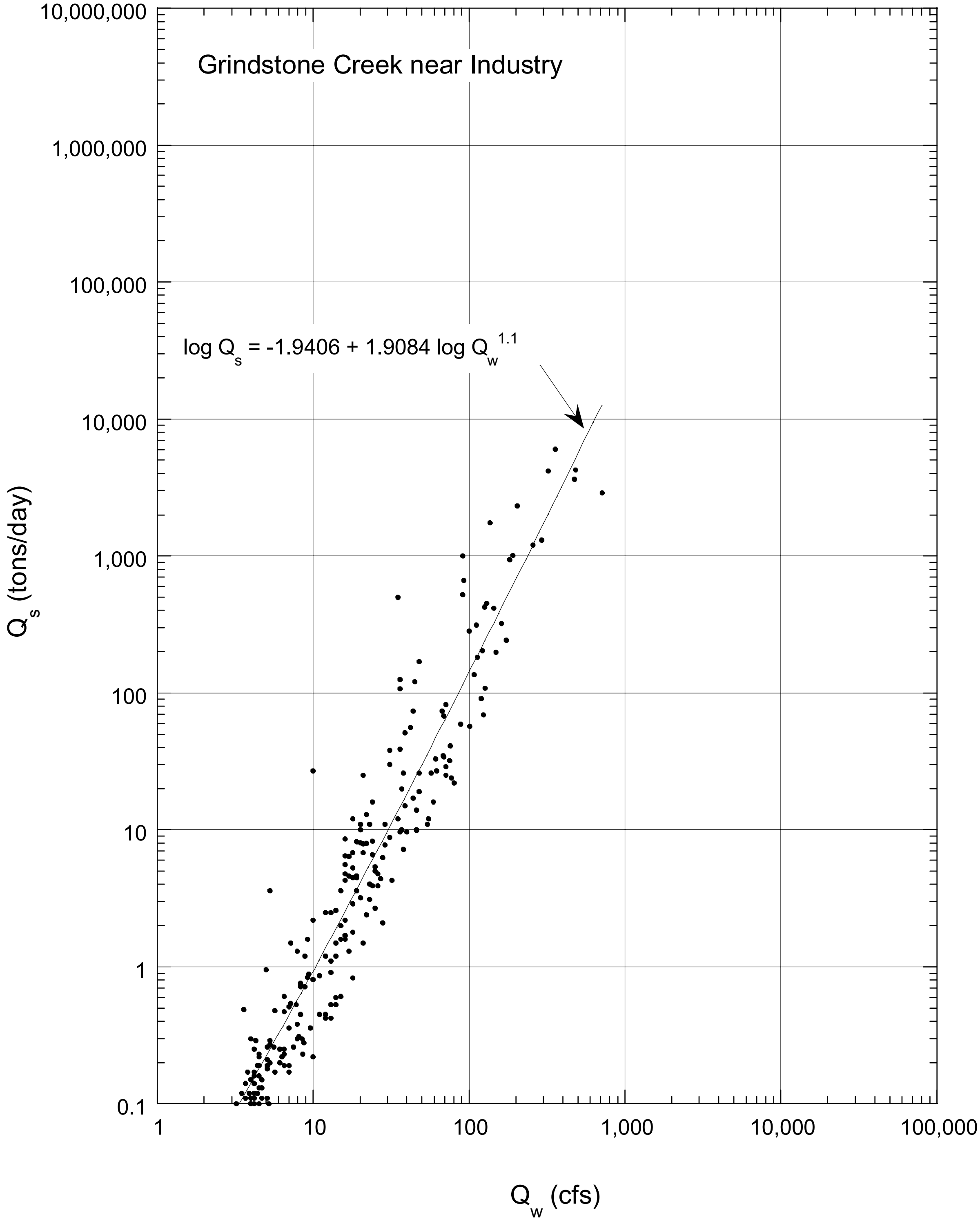

Figure B16. Comparison of multi-year sediment load curve with data for Grindstone Creek near Industry

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