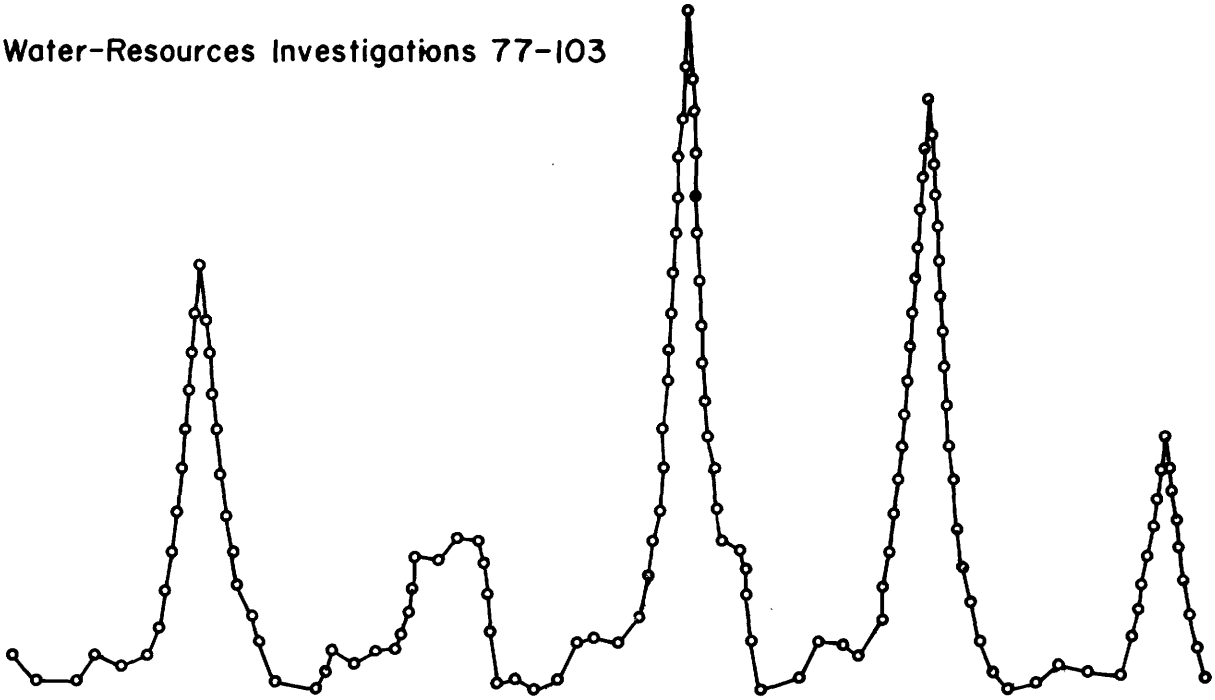
AN ANALYSIS OF SALINITY IN STREAMS OF THE GREEN RIVER BASIN, WYOMING

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-103



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Cheyenne, Wyoming 82001

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CONVERSION FACTORS

Multiply English units	By	To obtain metric units
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
tons per day	.9072	megagrams per day (Mg/d)

AN ANALYSIS OF SALINITY IN STREAMS OF THE GREEN RIVER BASIN, WYOMING

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ABSTRACT

Dissolved-solids concentrations and loads can be estimated from streamflow records using a regression model derived from chemical analyses of monthly samples. The model takes seasonal effects into account by the inclusion of simple-harmonic time functions. Monthly mean dissolved-solids loads simulated for a 6-year period at U.S. Geological Survey water-quality stations in the Green River Basin of Wyoming agree closely with corresponding loads estimated from daily specific-conductance records. In a demonstration of uses of the model, an average gain of 114,000 tons of dissolved solids per year was estimated for a 6-year period in a 70-mile reach of the Green River from Fontenelle Reservoir to the town of Green River, including the lower 30-mile reach of the Big Sandy River.

INTRODUCTION

Water demands in the Green River Basin of Wyoming (fig. 1) are increasing as a result of existing and potential development of extensive coal, oil, gas, uranium, and oil-shale resources. Planners need more useable information than is now available concerning the effects of proposed development alternatives on the water resources of the basin (Lowham and others, 1976). Water quality, specifically salinity, is an important factor in determining water use and in assessing possible impacts of those uses over time. Salinity data have been collected on the Green River and its major tributaries during the last 25 years, but use of the data in tabular form as published has been limited. A quantitative description of salinity in the Green River and its major tributaries is useful to the evaluation of alternative development plans.

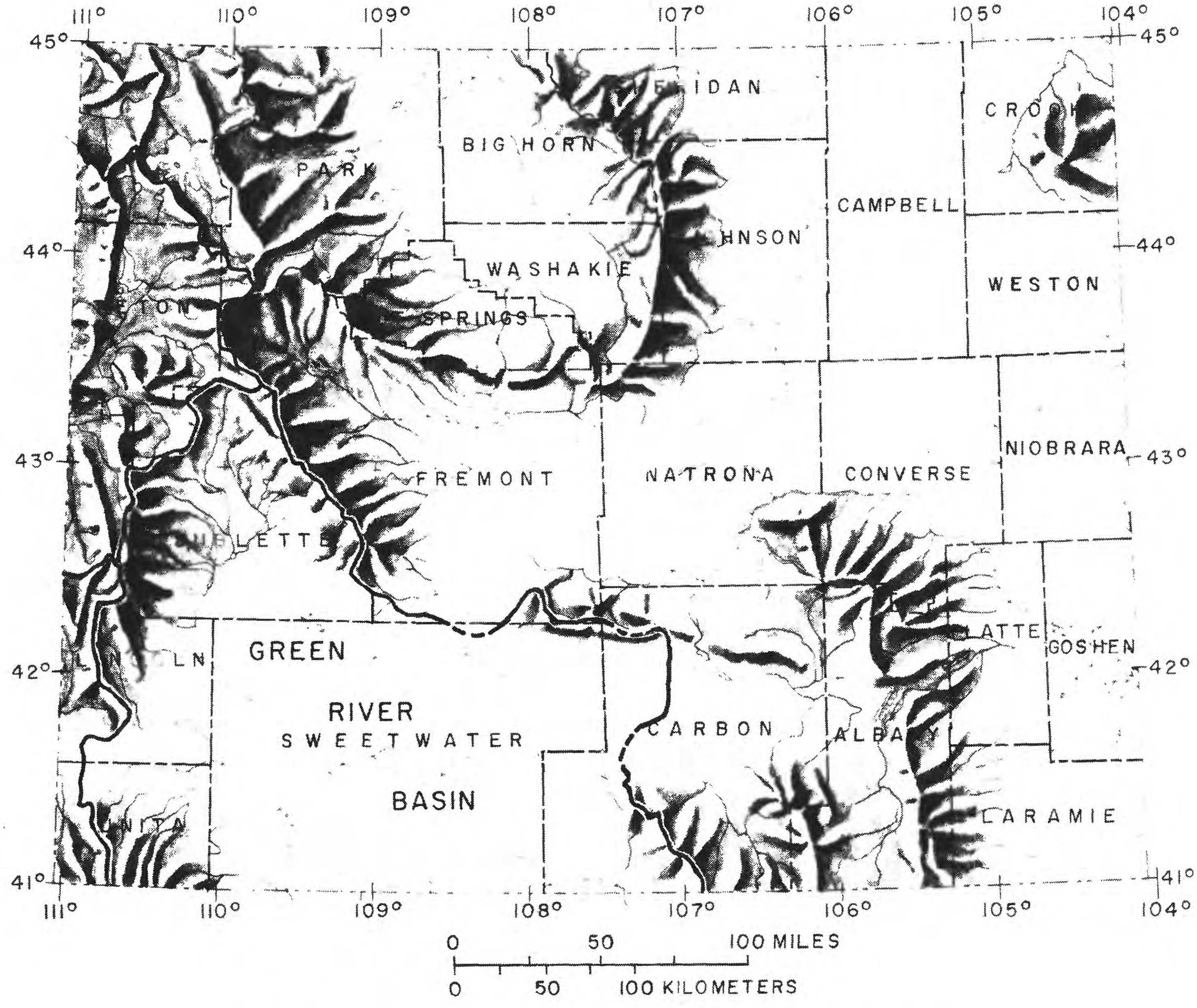

Figure 1.—Location of Green River Basin in Wyoming.

Purpose

The purpose of this report is to present a method for converting salinity data into more useable information. Specific objectives are to develop and demonstrate a regression model that would enable daily concentrations and monthly and annual mean loads of the major dissolved inorganic constituents to be estimated at streamflow stations where only monthly samples have been collected.

Data Analyzed

Data analyzed in this report are from streamflow and water-quality stations operated by the U.S. Geological Survey in cooperation with other Federal agencies and with the State of Wyoming. Station locations are shown in figure 2. Table 1 lists sampling stations and period of record for which data were analyzed. In general, the data include analyses of the major inorganic constituents from discrete samples collected before October 1975. Several of the stations have historical water-quality records available in addition to the data used for this study.

METHOD OF ANALYSIS

A quantitative description of the solutes transported in a stream system is useful to evaluate the impacts of proposed or past surface-water development projects (such as reservoirs, irrigation systems, and withdrawals for municipal or industrial use). Many published water-quality records consist of analyses of monthly samples. Natural variability of streamflow during a month reduces the value of a discrete sample to represent streamflow quality throughout the entire month. When daily streamflow records are available in addition to monthly water-quality records, an improved representation of streamflow quality throughout the month may be obtained from estimates that utilize functional relations between streamflow and solute concentration. Multiple-variable regression is used in this report to define the relation of solute concentration to streamflow and day of the year.

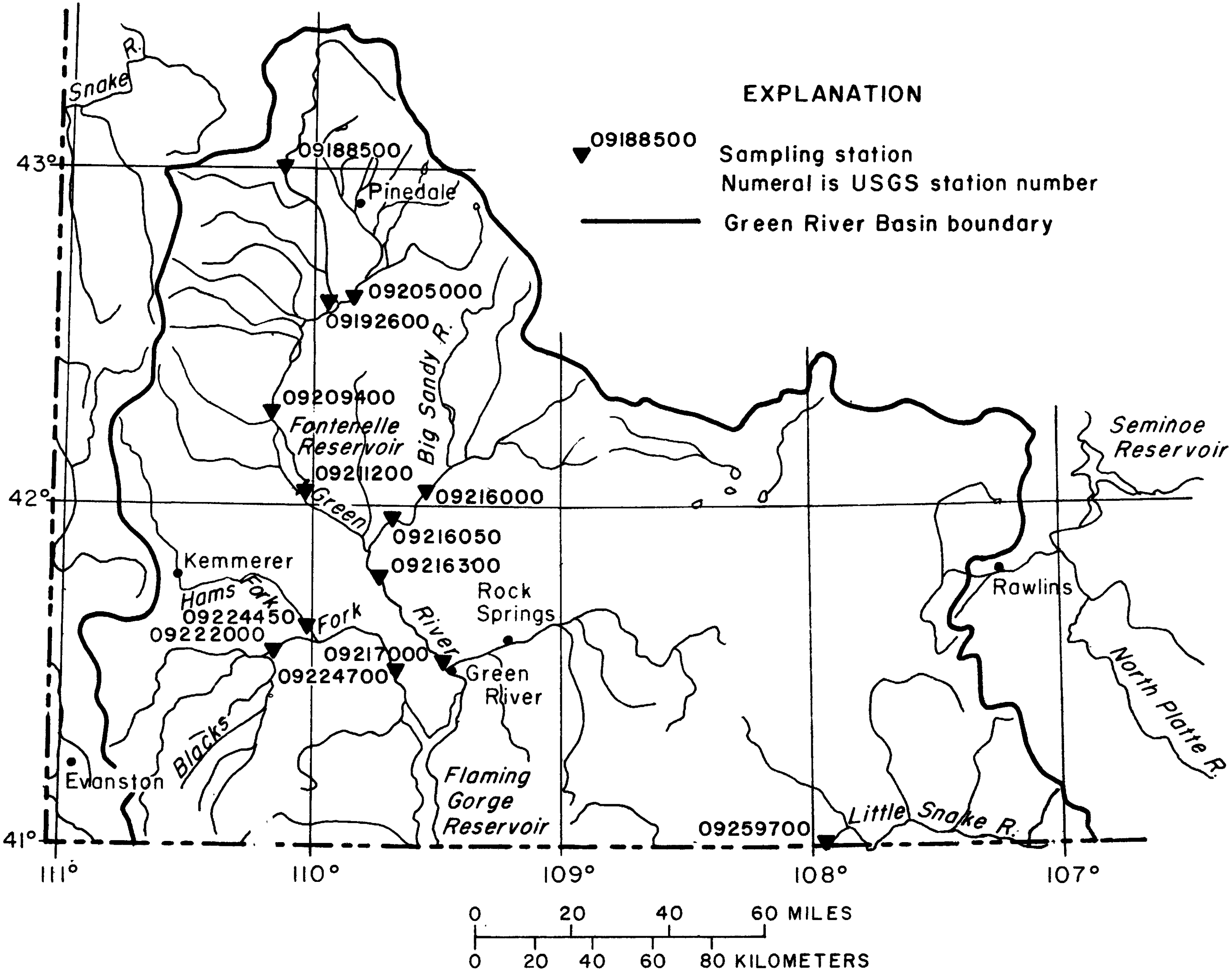

Figure 2.—Locations of quality-of-water sampling stations.

Table 1.--Chemical quality-of-water sampling stations[a/] in Wyoming

[See fig. 2 for locations.]

Station	Name	Water Years analyzed
09188500	Green River at Warren Bridge, near Daniel----	1968-75
09192600	Green River near Big Piney-------------------	1967-75
09205000	New Fork River near Big Piney----------------	1969-75
09209400	Green River near La Barge--------------------	1970-75
09211200	Green River below Fontenelle Reservoir-------	1970-75
09216000	Big Sandy River below Eden-------------------	1961-75
09216300	Green River at Big Island, near Green River--	1966-75
09217000	Green River near Green River-----------------	1969-75
09222000	Blacks Fork near Lyman-----------------------	1970-75
09224450	Hams Fork near Granger-----------------------	1969-75
09224700	Blacks Fork near Little America--------------	1970-75
09259700	Little Snake River near Baggs----------------	1965-74

a/ Cooperators: U.S. Bureau of Land Management.
Wyoming Department of Environmental Quality.
Wyoming Department of Agriculture.
U.S. Geological Survey.
U.S. Bureau of Reclamation.

Two-Variable Regression Model

Dissolved-solids concentration in a stream is related to many factors, but one of the most important is the volume of water available for dilution (Hem, 1970, p. 271). In general, higher concentrations occur at lower streamflows, and with increasing flows concentrations tend to decrease.

Concentration of the major dissolved inorganic constituents in a stream can be related to streamflow by the following two-variable regression equation (Steele, 1973 and 1976):

$$C = A\,Q^{B} \tag{1}$$

where
- C = concentration, in milligrams per liter,
- Q = streamflow, in cubic feet per second, and
- A and B = regression coefficients.

An example of this relation is shown in figure 3. Concentration residuals (differences between estimated and observed concentrations) shown in figure 4 are consistently positive during some periods and negative during other periods.

Seasonal shifts in the concentration-flow relation, as exemplified in figure 4, are typical of data for the stations analyzed in this report and, in general, limit the application of equation 1 to depict concentration-flow relations in the Green River Basin. The regression procedure, assuming a constant year-round relation, causes concentration residuals totaled over the entire regression period to approach zero. Positive residuals during one period are balanced against negative residuals during another period. Because streamflow is not evenly distributed over time, residuals from loads calculated from streamflow records and estimated concentrations will normally not approach zero. This leads to inaccuracies both in estimation of annual loads at a given site and seasonal distribution of the annual load over the year.

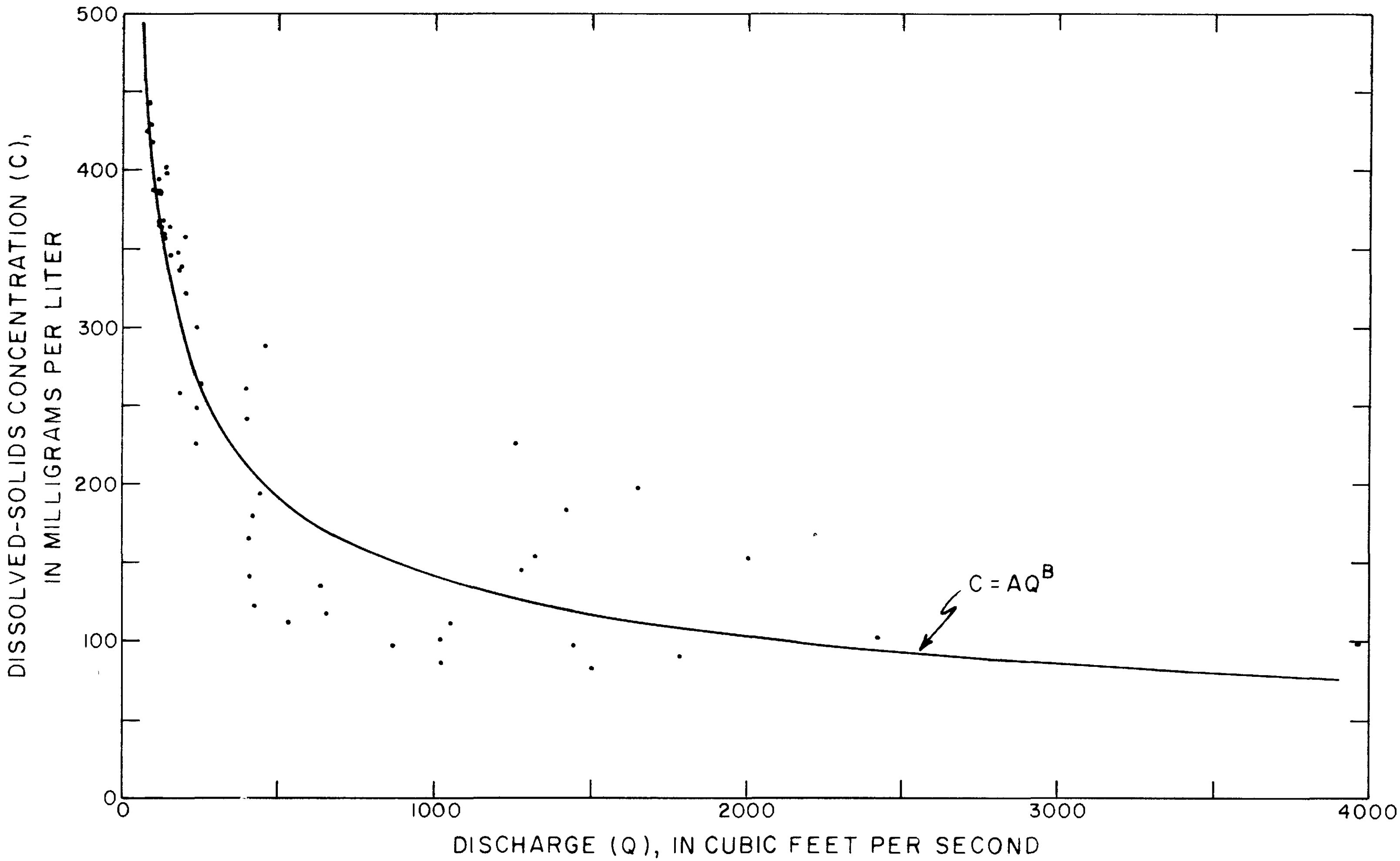

Figure 3 —Relation of dissolved solids to discharge at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

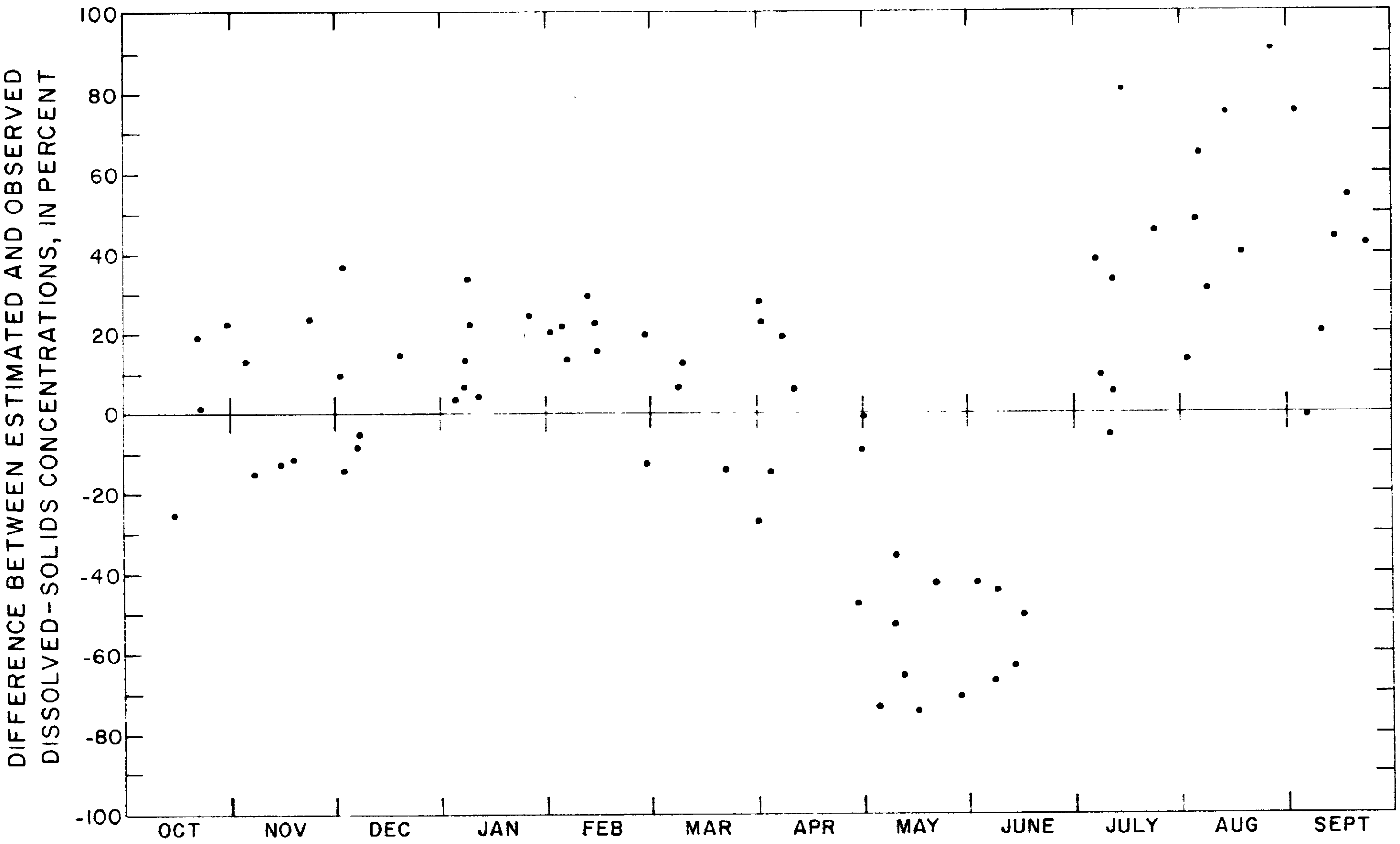

Figure 4.—Difference between dissolved-solids concentrations estimated from the two-varible-regression model and dissolved-solids concentrations observed at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

Multiple-Variable Regression Model

Seasonal effects were accounted for quantitatively by adding a season-related variable to the regression model. Water temperature would have been an obvious selection for this variable, but time, expressed as day of the water year (table 2), was used because it simplified later simulation efforts. Seasonal effects are incorporated into coefficients A and B in equation 1 by using the following functions:

$$\text{Log}_{10} A = B_o + B_1 \sin(\alpha t) + B_2 \cos(\alpha t) \text{ and} \tag{2}$$

$$B = B_3 + B_4 \sin(\alpha t) + B_5 \cos(\alpha t), \tag{3}$$

where t = day of the water year (table 2),
α = 0.987 degrees per day or 0.0172 radians per day, and
B_o through B_5 = regression coefficients (table 3).

Parameters B_o through B_5 were determined for the major dissolved inorganic constituents by a multiple-variable regression technique using a computer program developed by K. C. Glover (written commun., 1976). Regression-analysis results for the stations covered in this study are listed in table 3. To demonstrate the improved accuracy of the multiple-regression model in describing variability of dissolved-solids concentration, residuals of the model are plotted versus time in figure 5. This may be compared with the previous two-variable regression example (fig. 4). The same data for station 09188500 were used in both cases. Similar changes in terms of reduced magnitude and more random time-series distribution of residuals were found for other stations analyzed in this report. Hence, subsequent computations in this report utilize the model determined by the multiple-regression technique.

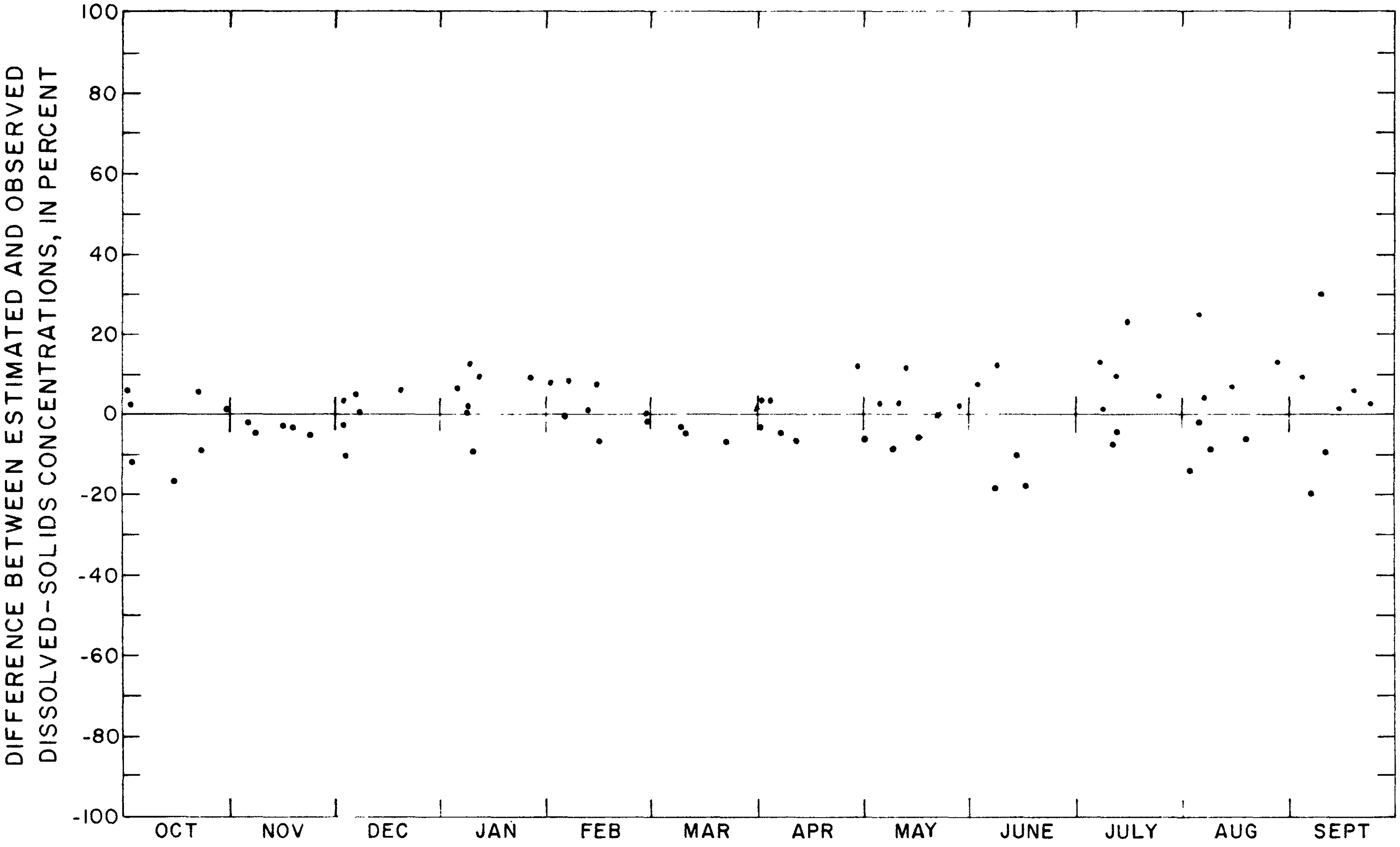

Figure 5.—Difference between dissolved-solids concentrations estimated from the multiple-variable-regression model and dissolved-solids concentrations observed at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

APPLICATION OF THE MULTIPLE-VARIABLE REGRESSION MODEL

Computation of Monthly Mean Dissolved-Solids Loads

Monthly mean dissolved-solids loads can be computed from daily streamflow records using the multiple-variable regression model previously described to estimate daily concentrations in the following relation:

$$\overline{L} = (b/d) \sum_{j=1}^{d} C_j Q_j \qquad (4)$$

where $\overline{L}$ = monthly mean load, in tons per day,
b = 0.0027 (tons per day (milligram) (cubic feet per second),
d = days per month,
j = day of month,
C_j = daily concentration, in milligrams per liter, and
Q_j = daily discharge, in cubic feet per second.

Daily dissolved-solids concentrations can be estimated by another method when daily specific conductance data are available. Dissolved-solids concentration can be related to specific conductance (fig. 6) by the following equation (Steele, 1973):

$$C_j = E + F K \qquad (5)$$

where C_j = daily dissolved-solids concentration, in milligrams per liter,
E and F = regression coefficients (table 4), and
K = specific conductance, in micromhos per centimeter at 25°C.

Because of the large number of calculations involved in estimating dissolved-solids loads, equations 1 through 5 were incorporated into a computer program developed by K. C. Glover (written commun., 1976). Card output from the program was used with an off-line card reader and X-Y plotter to produce solute-load hydrographs as exemplified for dissolved solids in figures 7-14. Individual constituent concentrations and loads (table 3) also can be estimated and plotted.

Semi-quantitative conclusions can be drawn from the dissolved-solids-load hydrographs (figs. 7-14). At stations 09209400, 09211200, 09217000, 09222000, and 09224700 (figs. 9, 10, 12, 13, and 14) where daily specific-conductance data are available, generally good agreement exists between loads computed from concentrations estimated by the two previously described methods. Because identical scales are used on the

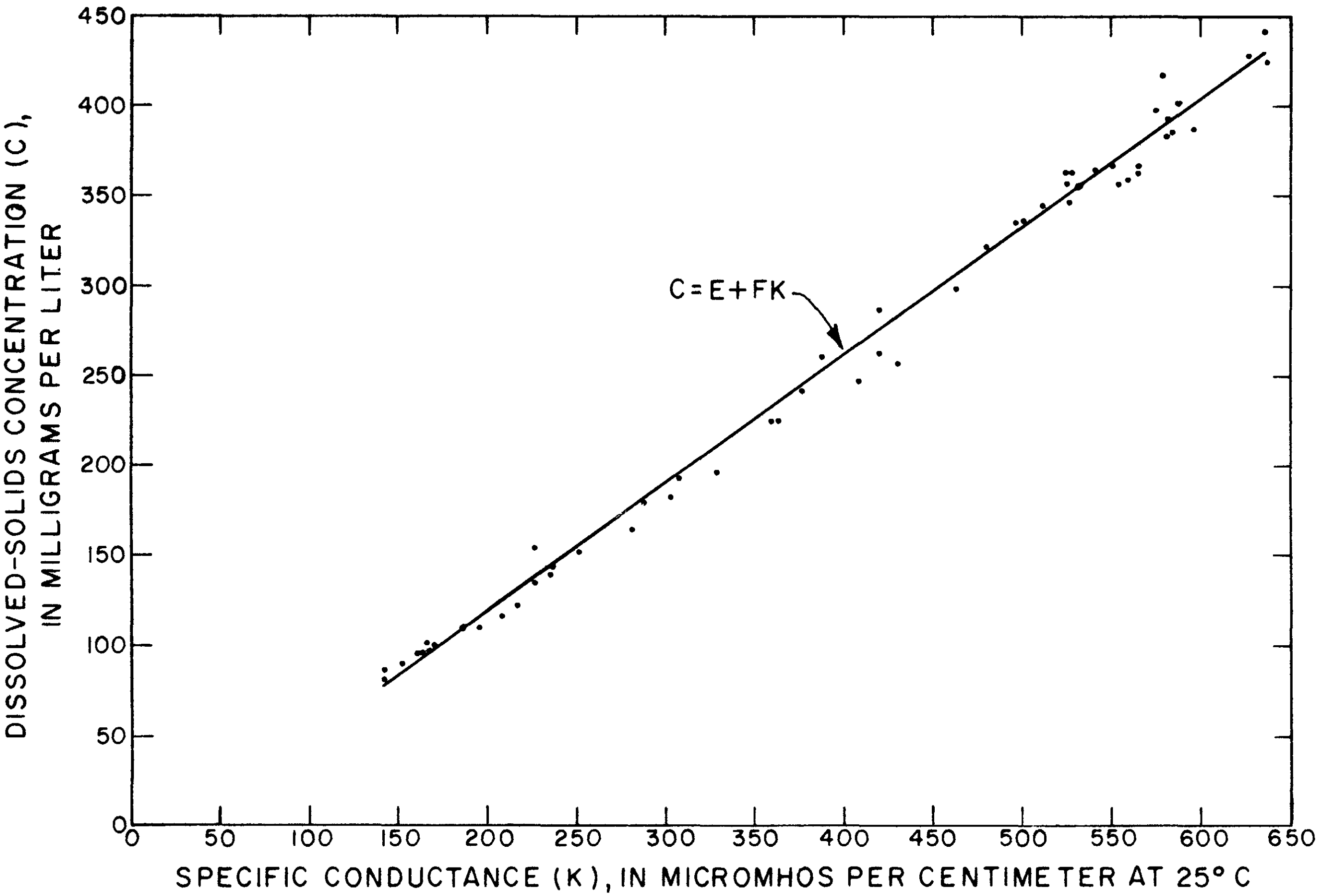

Figure 6.—Relation of dissolved-solids concentration to specific conductance at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

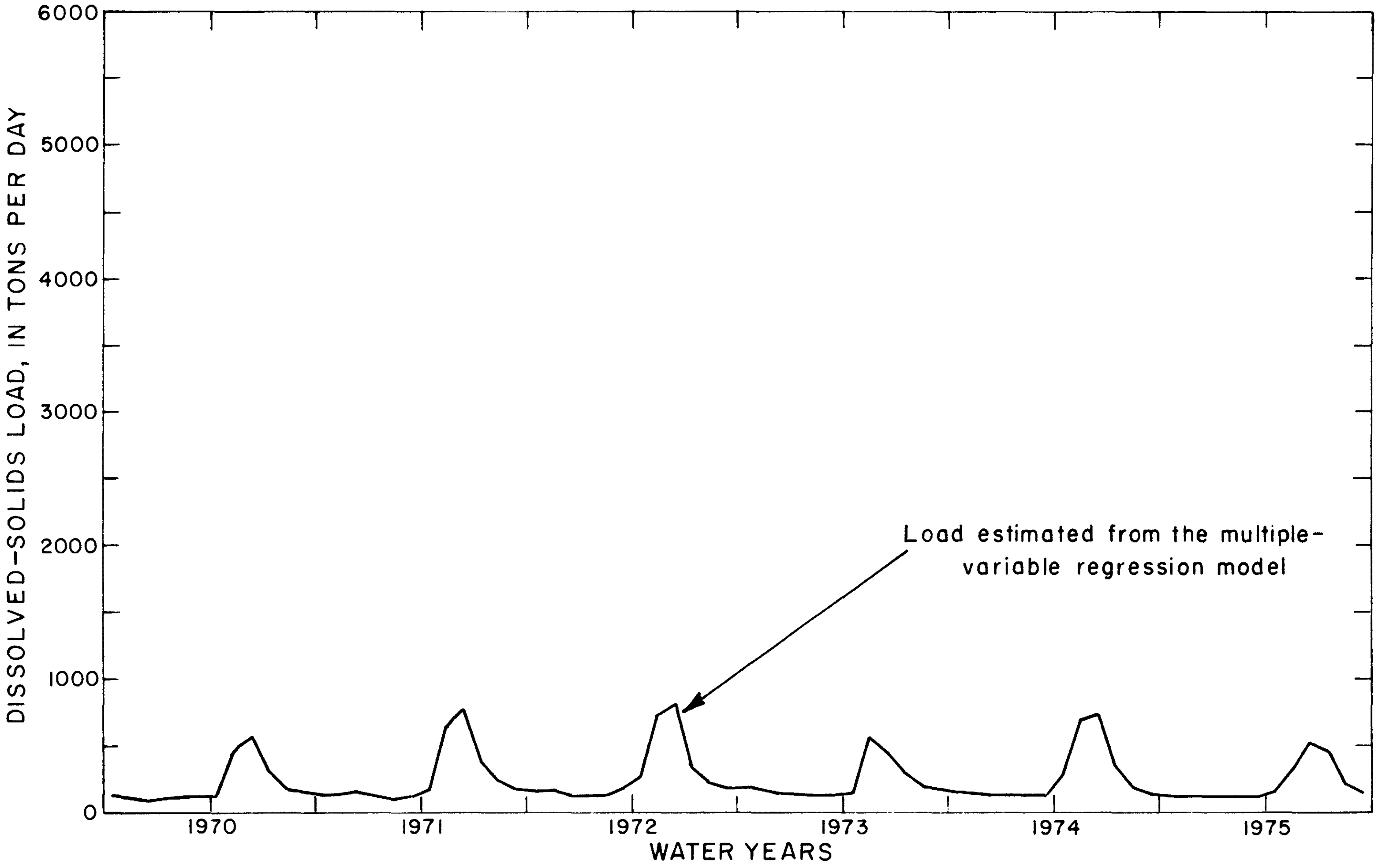

Figure 7.—Monthly mean dissolved-solids loads at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

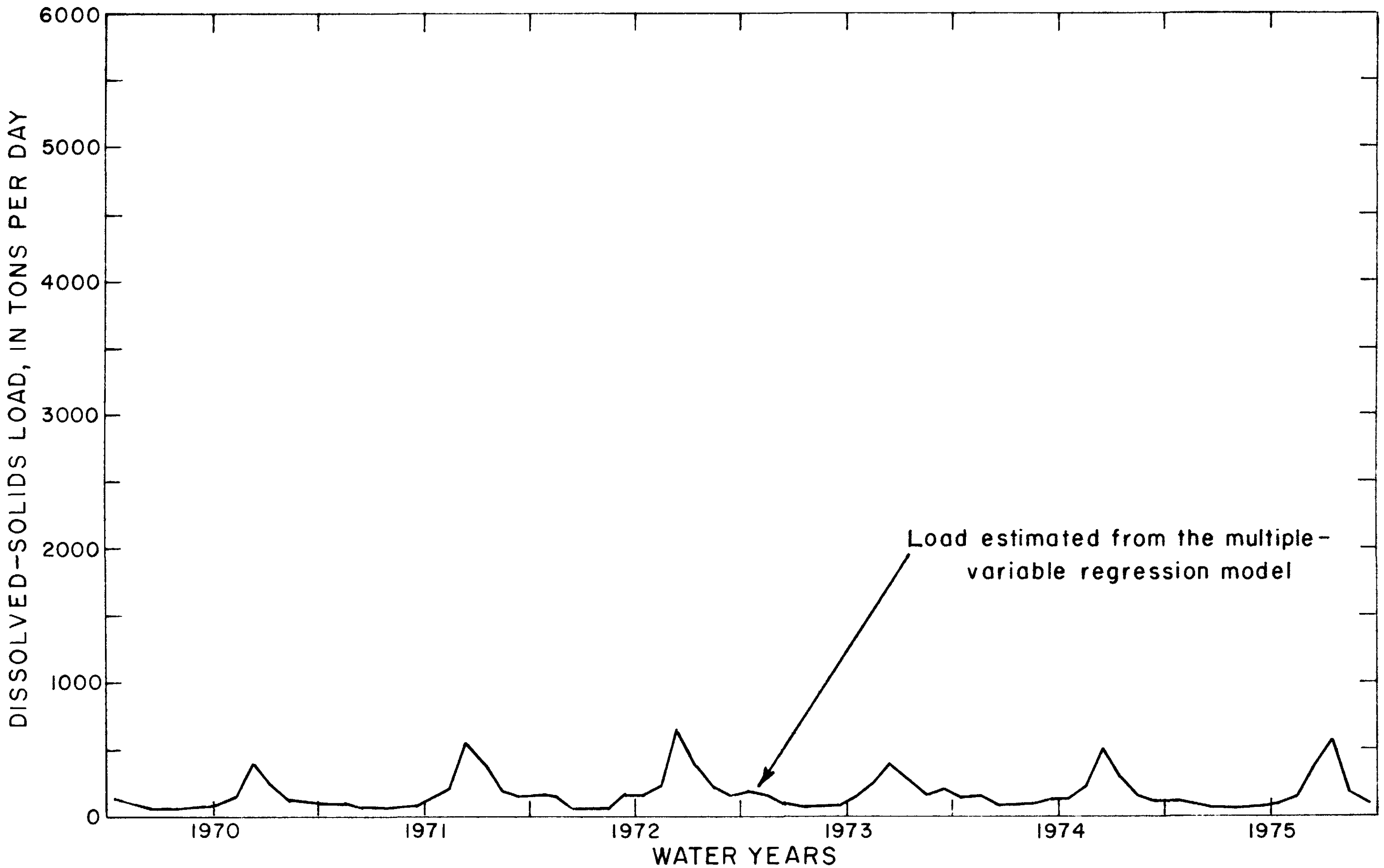

Figure 8.—Monthly mean dissolved-solids loads at station 09205000 New Fork River near Big Piney, Wyoming.

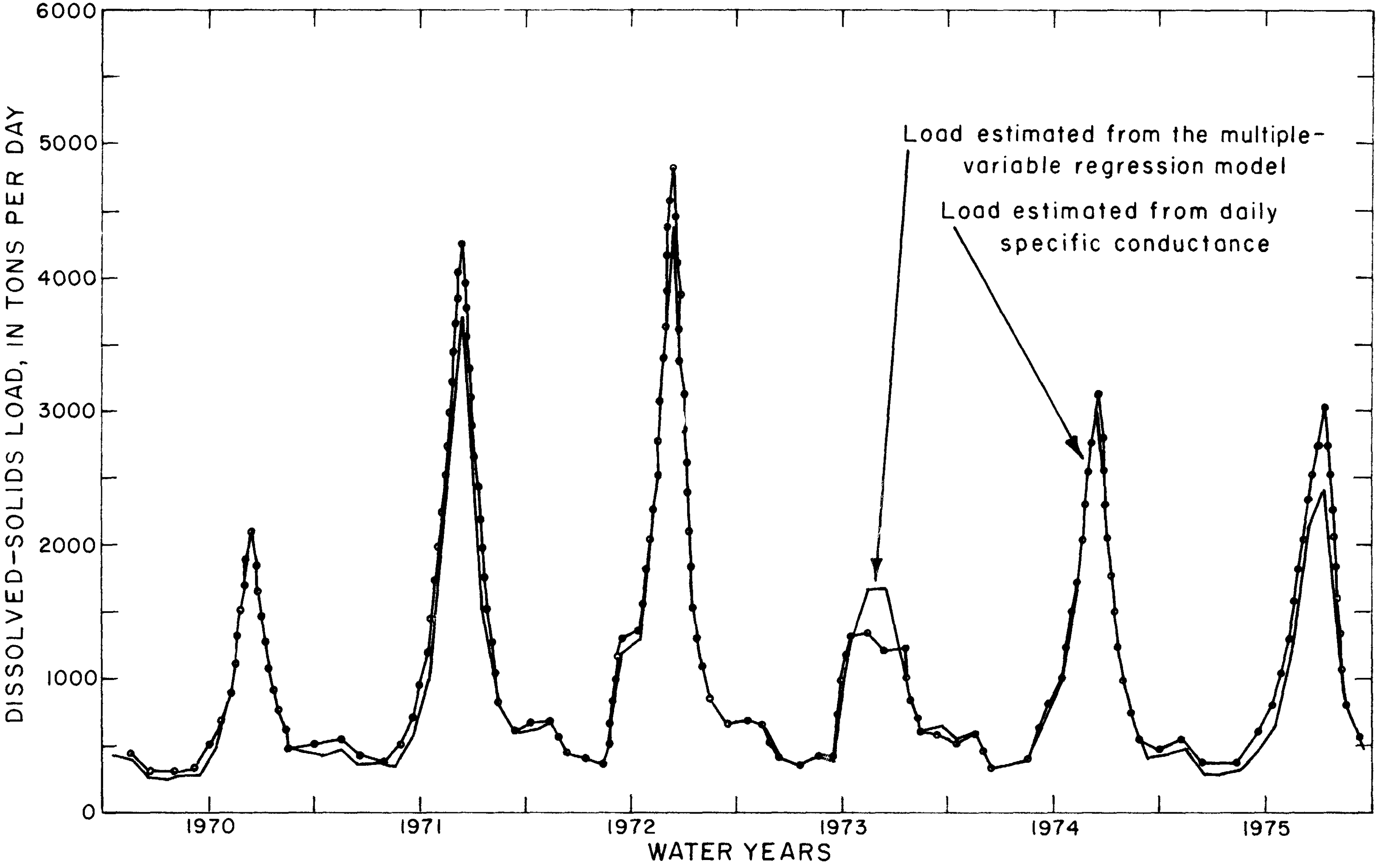

Figure 9.—Monthly mean dissolved-solids loads at station 09209400 Green River near La Barge, Wyoming.

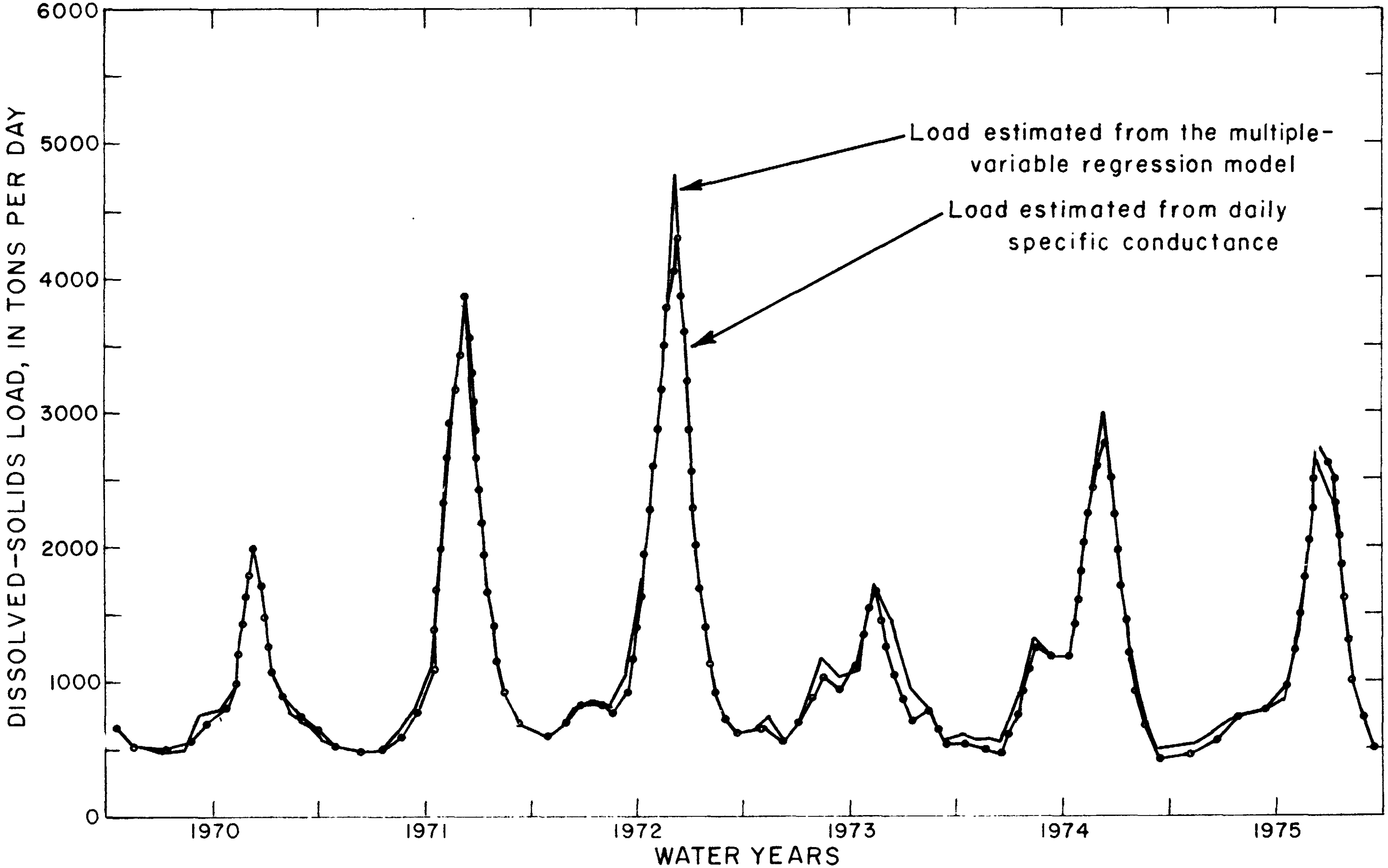

Figure 10.—Monthly mean dissolved-solids loads at station 09211200 Green River below Fontenelle Reservoir, Wyoming.

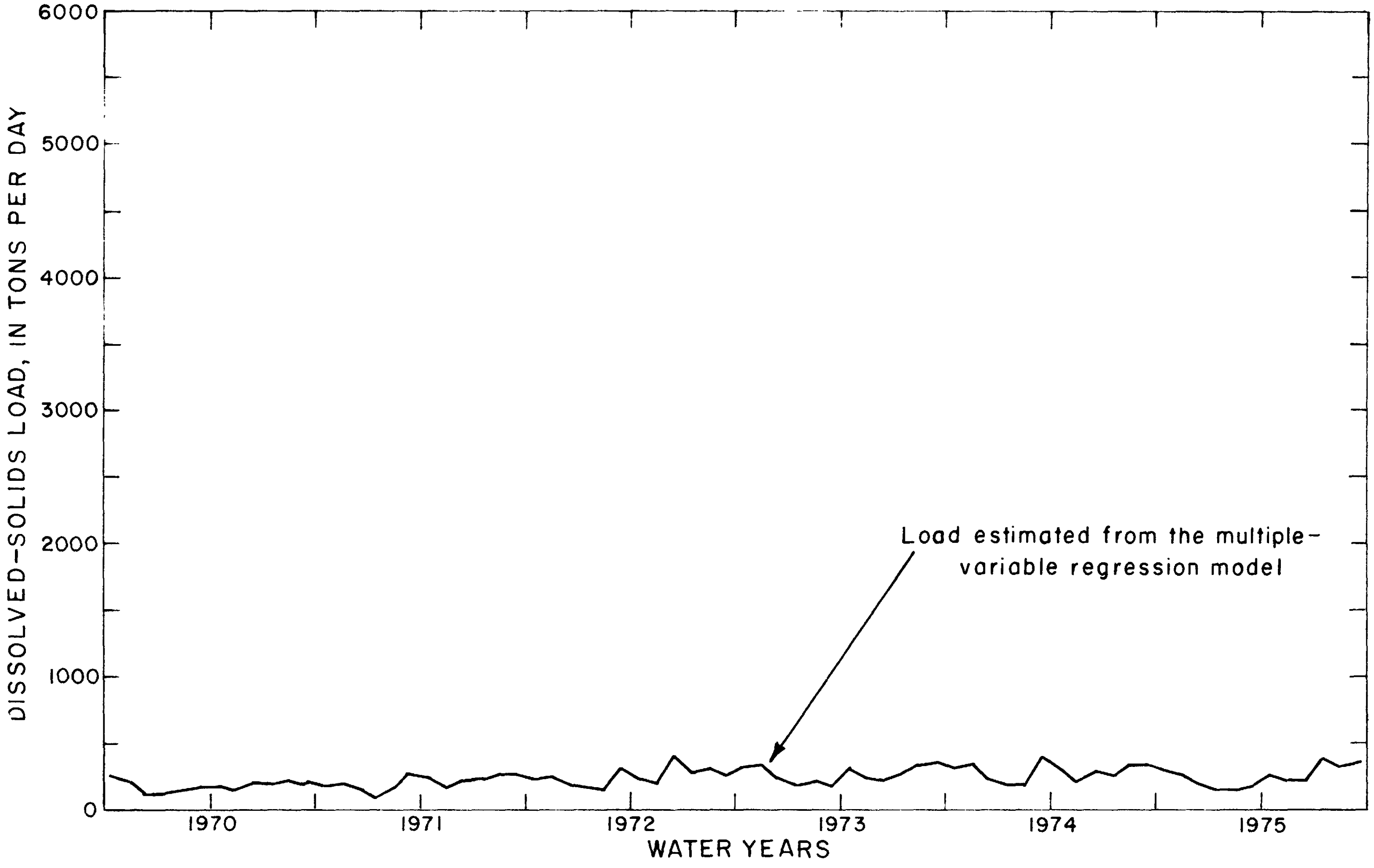

Figure 11.—Monthly mean dissolved-solids loads at station 09216000
Big Sandy River below Eden, Wyoming.

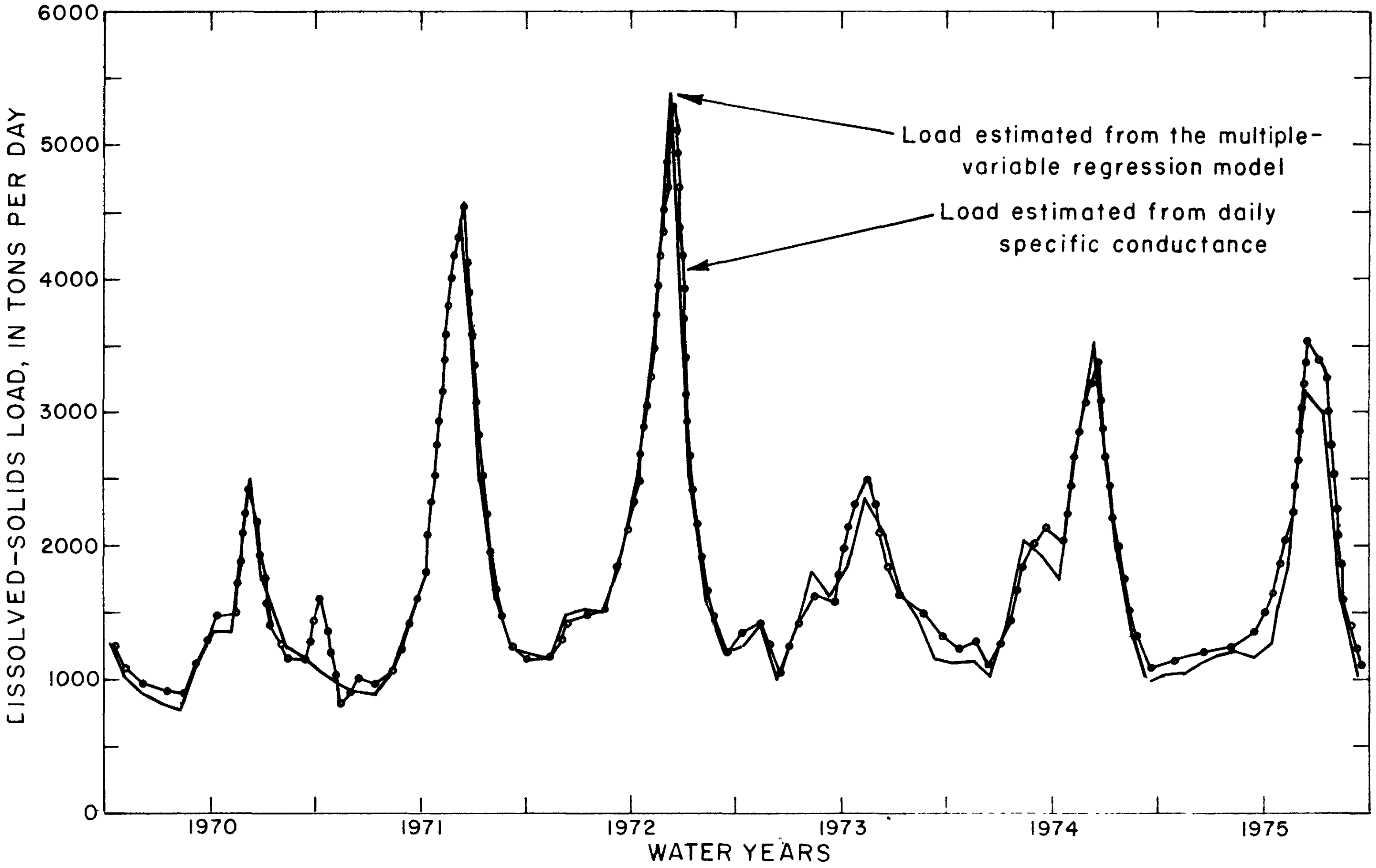

Figure 12.—Monthly mean dissolved-solids loads at station 09217000 Green River near Green River, Wyoming.

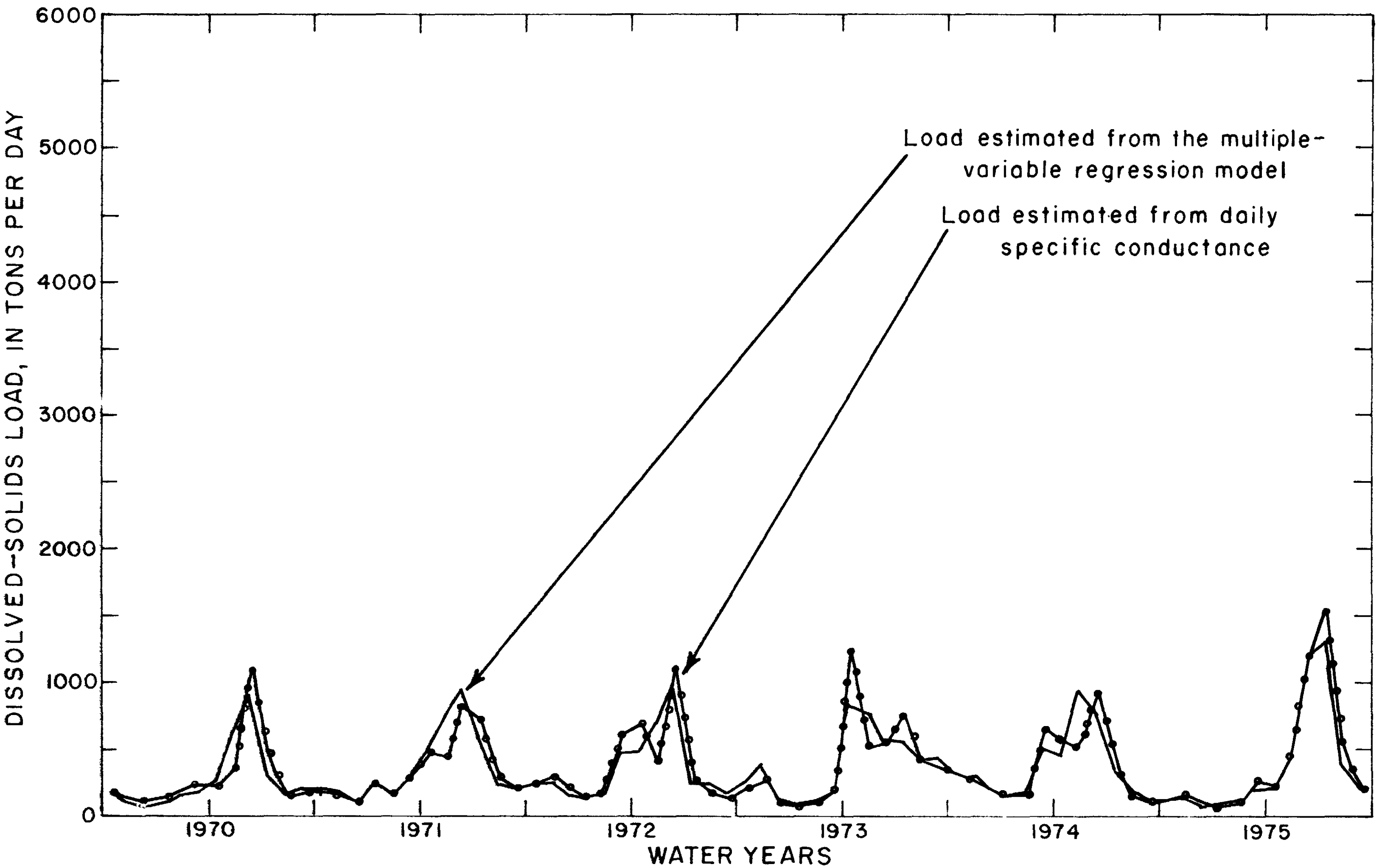

Figure 13.—Monthly mean dissolved-solids loads at station 09222000 Blacks Fork near Lyman, Wyoming.

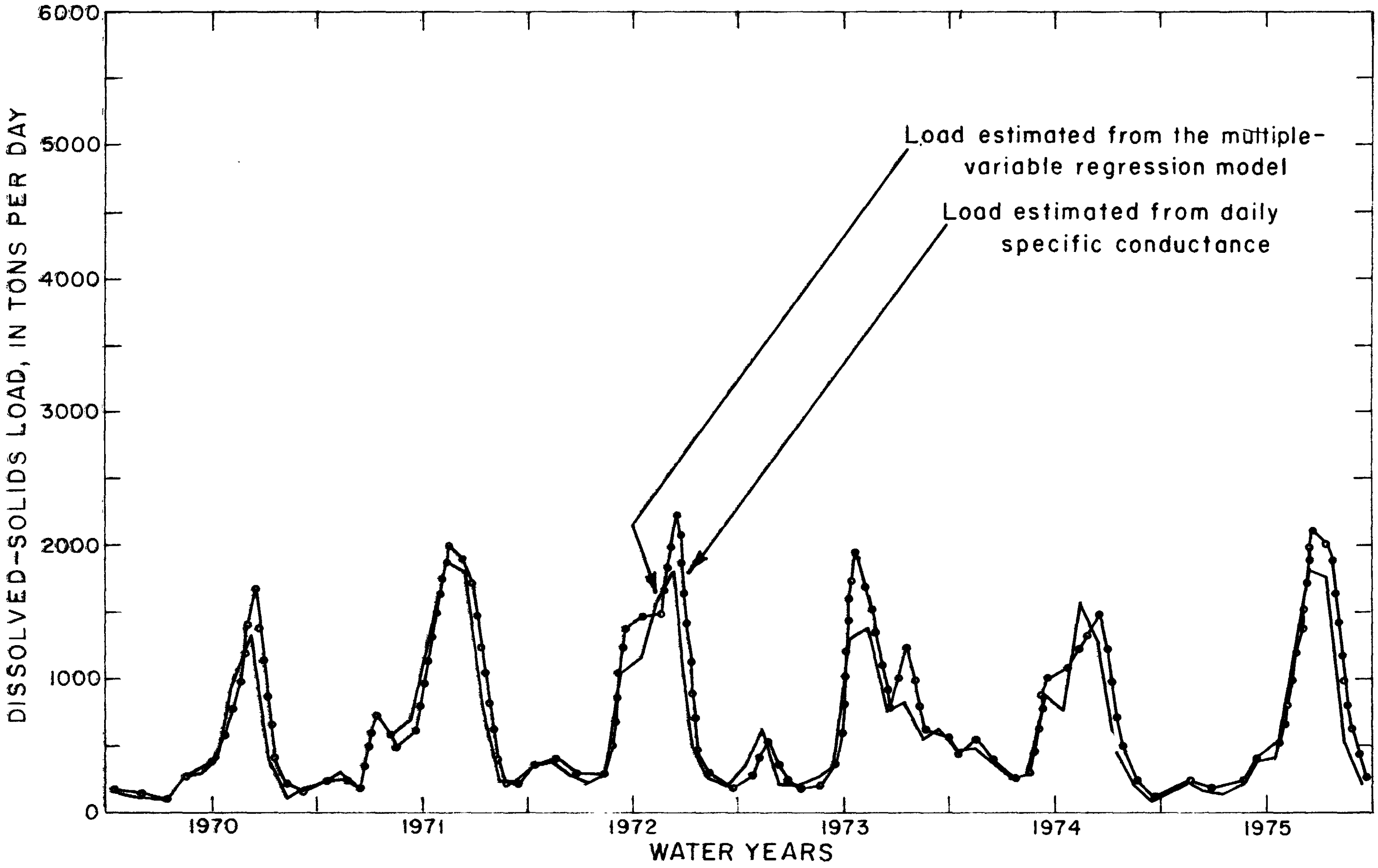

Figure 14.—Monthly mean dissolved-solids loads at station 09224700 Blacks Fork near Little America, Wyoming.

load hydrographs, comparison between stations of load magnitude and distribution with time can be made by visual inspection. For example, the base-flow loads at station 09211200 (fig. 10) increase in comparison to station 09209400 (fig. 9) without a corresponding increase in peak-flow loads. In contrast, comparisons between stations 09217000 (fig. 12) and 09211200 (fig. 10) indicate an increase of about 500 tons per day for both base-flow loads and peak-flow loads. While visual inspection of the example hydrographs aids in the evaluation of solute flow through a stream system, a more quantitative approach, as demonstrated in the following section, often is desirable.

Delineation of Sources of Salinity

Loads estimated at several points in a stream system collectively can provide quantitative information about the amount and chemical composition of dissolved solids gained in the intervening reaches.

For example, simulated dissolved-solids loads at stations 09211200 Green River below Fontenelle Reservoir and 09217000 Green River near Green River, Wyoming, show an average gain over the 1970-75 water years in the intervening reach of about 202,000 tons of dissolved solids per year. This gain represents about 33 percent of the load at station 09217000 and less than 5 percent of the streamflow. Big Sandy River is the major tributary to the Green River between stations 09211200 and 09217000. Simulated dissolved-solids loads averaged over the 1970-75 water years at station 09216000 Big Sandy River below Eden, Wyoming, 30 river miles upstream from the mouth, is 88,200 tons per year. The remaining increase of 114,000 tons per year is gained along the lower 30-mile reach of the Big Sandy River to the mouth and along the Green River between Fontenelle Reservoir and Green River, Wyoming. Cumulative dissolved-solids loads at stations 09211200, 09216000, and 09217000 are shown in figure 15 to illustrate the relative contribution of dissolved solids in the reaches between the stations.

More can be learned about the mean annual 114,000 ton-per-year dissolved-solids load by considering individual components of the load. Dissolved-sodium and dissolved-sulfate loads, plotted in figures 16 and 17, more than double in the Green River from below Fontenelle Reservoir to Green River, Wyoming. The average chemical composition of the 114,000 ton-per-year load is 84 percent sodium plus sulfate by weight compared to 31 and 72 percent sodium plus sulfate by weight in the loads at stations 09211200 and 09216000.

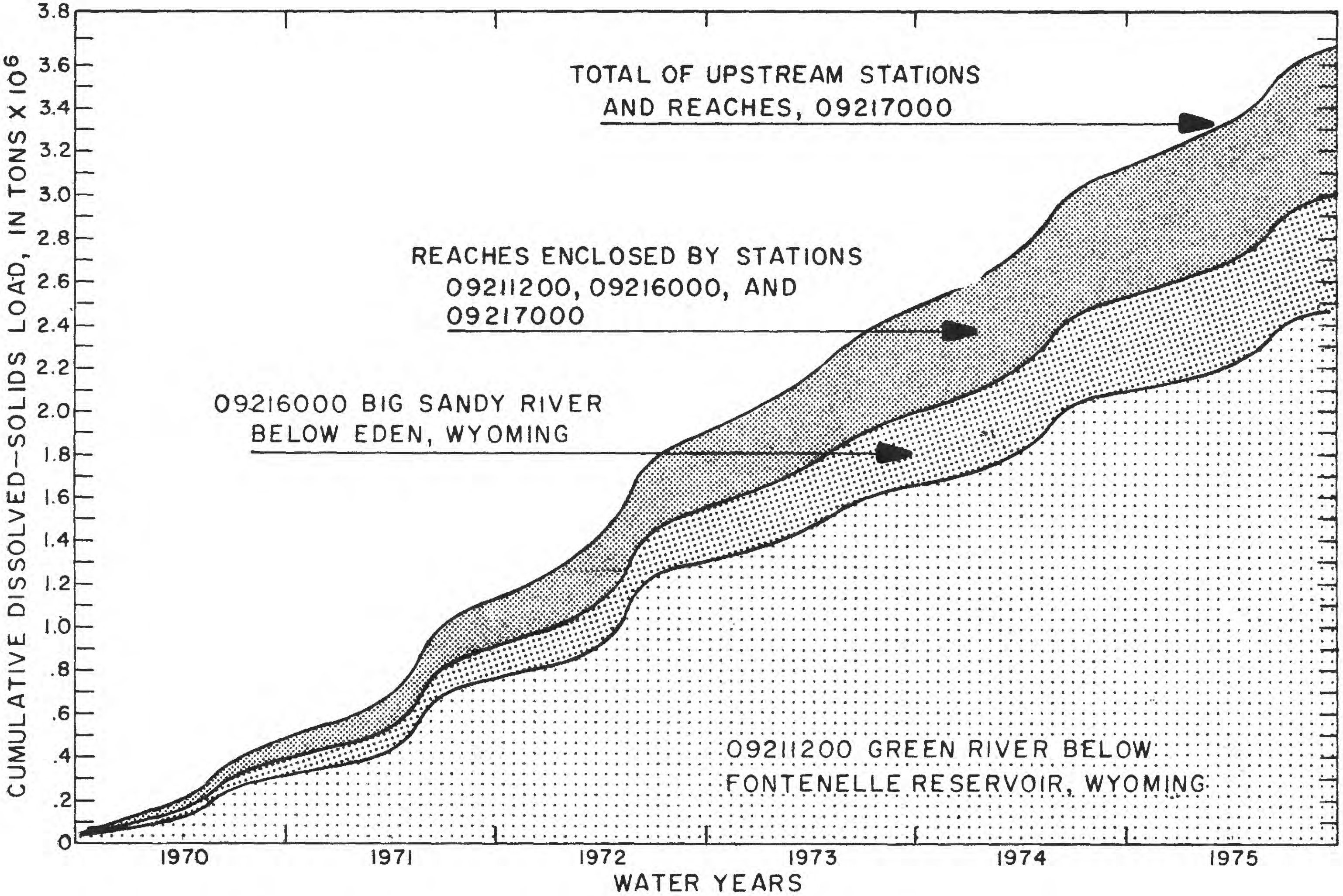

Figure 15.—Cumulative dissolved-solids loading in reaches enclosed by stations 09211200 Green River below Fontenelle Reservoir, Wyoming; 09216000 Big Sandy River below Eden, Wyoming; and 09217000 Green River near Green River, Wyoming.

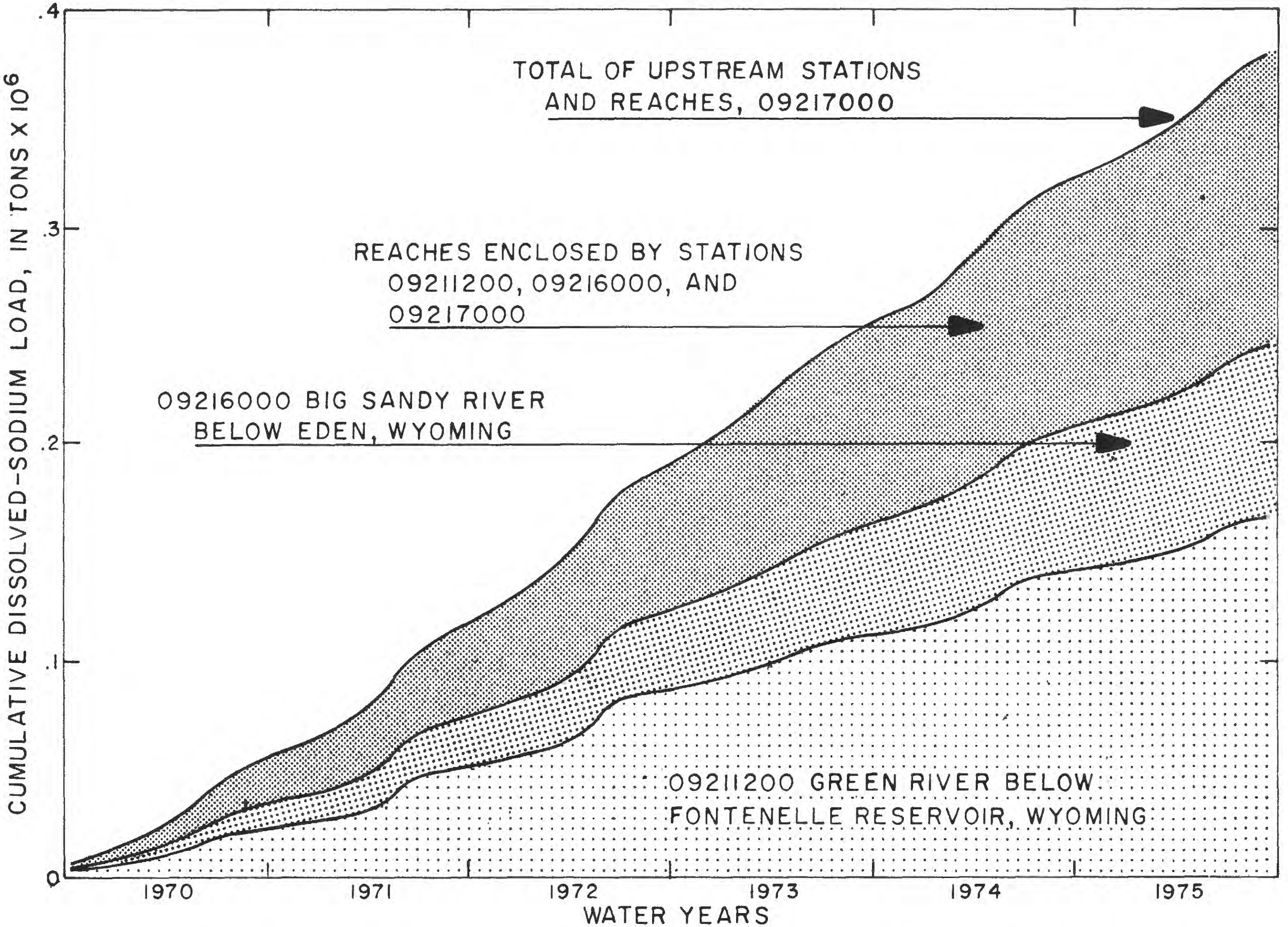

Figure 16.—Cumulative dissolved-sodium loading in reaches enclosed by stations 09211200 Green River below Fontenelle Reservoir, Wyoming; 09216000 Big Sandy River below Eden, Wyoming; and 09217000 Green River near Green River, Wyoming.

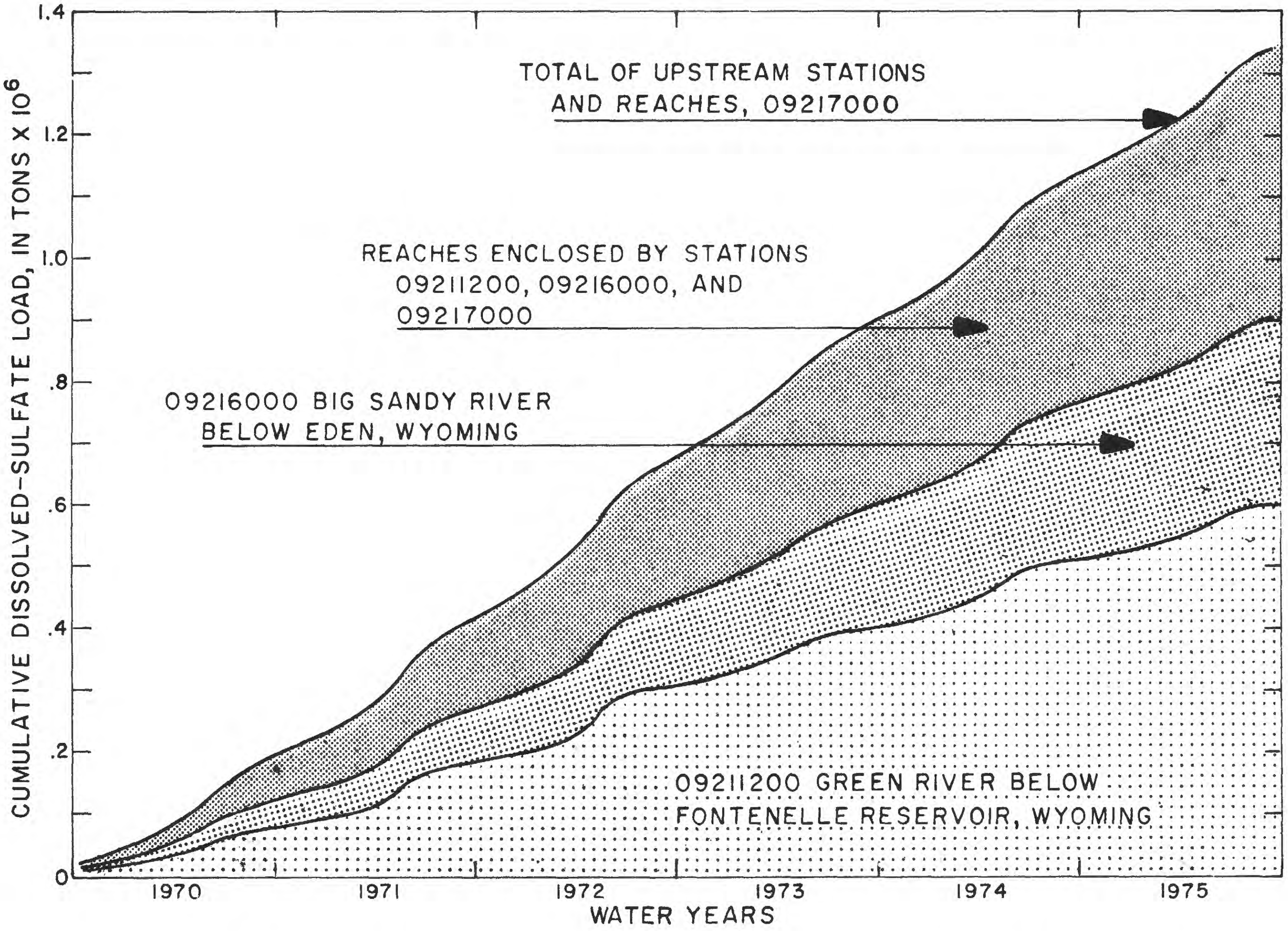

Figure 17.—Cumulative dissolved-sulfate loading in reaches enclosed by stations 09211200 Green River below Fontenelle Reservoir, Wyoming; 09216000 Big Sandy River below Eden, Wyoming; and 09217000 Green River near Green River, Wyoming.

The chemical character of the dissolved-solids gain serves as an indicator of sources. Samples from seeps along the Big Sandy River downstream from station 09216000 range from 3,800 to 6,800 milligrams per liter dissolved solids of which 84 percent is sodium plus sulfate by weight. Station 09216050 Big Sandy River at Gasson Bridge near Eden, Wyoming, (fig. 2) was established downstream from the seeps in May 1972 for the purpose of collecting streamflow records. Because water-quality sampling at the station was not initiated until February 1975, there are not yet enough data available to estimate dissolved-solids loads to quantitatively determine the dissolved-solids contribution of seeps along the Big Sandy River between stations 09216000 and 09216050. Discharge from the seeps has not been measured directly, but streamflow records at the two stations indicate a mean discharge gain of about 20 cubic feet per second in October when there is less evapotranspiration and negligible surface-water gain. Based on an average flow from the seeps of 20 cubic feet per second at a concentration of 5,000 milligrams per liter dissolved solids, the annual discharge from the seeps would average about 100,000 tons of dissolved solids which would account for about 88 percent of the load gained in the Green River and Big Sandy reaches enclosed by stations 09211200 and 09216000 upstream, and 09217000 downstream. To demonstrate how the amount and chemical character collectively aid in delineating sources of salinity, the sum of sodium and sulfate loads versus total dissolved-solids load is plotted for this example in figure 18. The close proximity of points representing the sum of the estimated seepage load and upstream stations to points representing loads at station 09217000 indicates good agreement both in amount and chemical character of the load gained in the intervening reaches despite a relatively large variation in loads at stations 09211200 and 09216000. Analyses similar to this example can be used in many other reaches where discrete monthly samples and daily streamflow records are available. This type of analysis would be difficult based on discrete monthly samples alone.

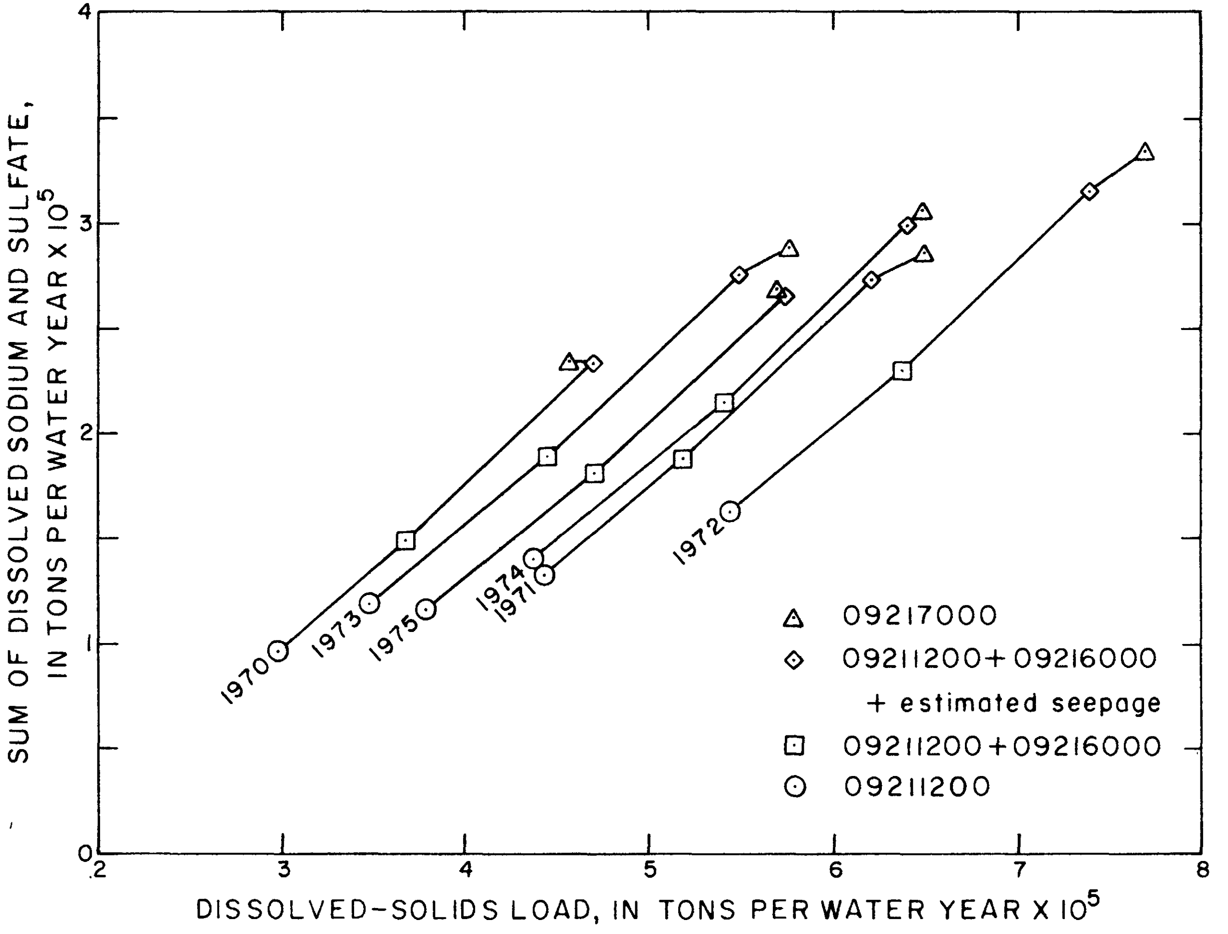

Figure 18.—Sum of dissolved-sodium and dissolved-sulfate annual loads versus dissolved-solids annual loads for estimated seepage and stations 09211200 Green River below Fontenelle Reservoir, Wyoming; 09216000 Big Sandy River below Eden, Wyoming; and 09217000 Green River near Green River, Wyoming.

SUMMARY

Daily concentration of dissolved solids in a stream may be estimated from daily streamflow records using a multiple-variable regression model developed from chemical analyses of samples collected on a monthly basis. The model relates dissolved-solids concentration of the stream to streamflow. Seasonal variation of dissolved solids not directly related to streamflow are accounted for in the model by the incorporation of harmonic functions of time. Because of the variability in streamflow and dissolved-solids concentration of streams in the Green River Basin, monthly mean loads and concentrations computed from daily estimates from the model provide a better representation of overall dissolved-solids concentration of the streams than do discrete monthly samples. Consequently, estimates from the model of dissolved-solids concentrations provide information useful to water planners and managers concerned with the evaluation of impacts of proposed and past water-development projects (such as reservoirs irrigation systems, and withdrawals for municipal and industrial use). The model may also be utilized in assessing the feasibility of reduced sampling frequencies for providing continuing information on long-term trends in salinity-streamflow relations and shifts in sampling locations for providing additional information on sources of salinity. An overall reduction in the data collection effort allocated to salinity in the streams of the Green River Basin would allow greater emphasis to be applied to other equally important water-quality factors for which few data are presently available.

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Table 2.--Sequence number conversion, date to water-year day

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1	1	32	62	93	124	152	183	213	244	274	305	336
2	2	33	63	94	125	153	184	214	245	275	306	337
3	3	34	64	95	126	154	185	215	246	276	307	338
4	4	35	65	96	127	155	186	216	247	277	308	339
5	5	36	66	97	128	156	187	217	248	278	309	340
6	6	37	67	98	128	157	188	218	249	279	310	341
7	7	38	68	99	130	158	189	219	250	280	311	342
8	8	39	69	100	131	159	190	220	251	281	312	343
9	9	40	70	101	132	160	191	221	252	282	313	344
10	10	41	71	102	133	161	192	222	253	283	314	345
11	11	42	72	103	134	162	193	223	254	284	315	346
12	12	43	73	104	135	163	194	224	255	285	316	347
13	13	44	74	105	136	164	195	225	256	286	317	348
14	14	45	75	106	137	165	196	226	257	287	318	349
15	15	46	76	107	138	166	197	227	258	288	319	350
16	16	47	77	108	139	167	198	228	259	289	320	351
17	17	48	78	109	140	168	199	229	260	290	321	352
18	18	49	79	110	141	169	200	230	261	291	322	353
19	19	50	80	111	142	170	201	231	262	292	323	354
20	20	51	81	112	143	171	202	232	263	293	324	355
21	21	52	82	113	144	172	203	233	264	294	325	356
22	22	53	83	114	145	173	204	234	265	295	326	357
23	23	54	84	115	146	174	205	235	266	296	327	358
24	24	55	85	116	147	175	206	236	267	297	328	359
25	25	56	86	117	148	176	207	237	268	298	329	360
26	26	57	87	118	149	177	208	238	269	299	330	361
27	27	58	88	119	150	178	209	239	270	300	331	362
28	28	59	89	120	151	179	210	240	271	301	332	363
29	29	60	90	121	(152)	180	211	241	272	302	333	364
30	30	61	91	122	---	181	212	242	273	303	334	365
31	31	--	92	123	---	182	---	243	---	304	335	---

Note: For months of March through September add one (1) to number in table for sequence conversion of days for leap years.

Table 3.--Regression results, concentration versus discharge and time

$$C = 10^{[B_o + B_1\sin(\alpha t) + B_2\cos(\alpha t)]}\, Q^{[B_3 + B_4\sin(\alpha t) + B_5 \cos(\alpha t)]}$$

where

C = Constituent concentration, in milligrams per Liter.
Q = Discharge, in cubic feet per second.
B_o through B_5 = Regression coefficients.
α = 0.987 degrees per day or 0.0172 radians per day.
t = Day of water year.

r = Correlation coefficient.
SE = Standard error of estimate, log units.
N = Number of samples.

Constituents (concentrations are in milligrams per liter):
Ca = calcium
Mg = magnesium
Na = sodium
K = potasium
HCO_3 = bicarbonate
SO_4 = sulfate
CL = chloride
TDS = dissolved solids

Constitu-ent	B_o	B_1	B_2	B_3	B_4	B_5	r	SE (log units)	N
09188500 Green River at Warren Bridge, near Daniel, Wyo., 1968-75 water years									
Ca	2.4454	-0.3368	0.5140	-0.2555	0.1819	-0.2513	0.981	0.045	78
Mg	1.8932	- .3916	.6109	- .3043	.2072	- .3014	.949	.086	78
Na	.8680	- .4383	.5463	- .1274	.2191	- .2654	.829	.116	78
K	.0586	- .4819	.2751	$.9698X10^{-2}$	.2265	- .1690	.695	.128	78
HCO_3	2.4140	- .2260	.6311	- .1248	.1293	- .3068	.965	.044	78
SO_4	3.0835	- .5370	.3708	- .4159	.2739	- .1863	.986	.055	77
Cl	.3870	- .3415	.6011	- $.8663X10^{-1}$	.1641	- .2640	.415	.250	77
TDS	3.0855	- .3275	.4789	- .2617	.1814	- .2407	.985	.041	78
09192600 Green River near Big Piney, Wyo., 1967-75 water years									
Ca	1.7843	$0.9890X10^{-1}$	$0.9982X10^{-1}$	$-0.3792X10^{-2}$	$0.2161X10^{-1}$	$-0.5733X10^{-1}$	0.910	0.056	89
Mg	1.0344	- $.7263X10^{-1}$	$.5276X10^{-1}$	$.5451X10^{-1}$	$.9910X10^{-1}$	- $.5017X10^{-1}$	.825	.095	89
Na	.4995	- .9178	.3005	.1697	.3824	- .1512	.569	.164	89
K	.2784	- .3790	.3183	.1800	.1863	- .1610	.712	.102	89
HCO_3	1.9968	$.9484X10^{-1}$	.1246	$.8842X10^{-1}$	$.1397X10^{-1}$	- $.7213X10^{-1}$	.852	.053	89
SO_4	2.2344	- .4376	$.4258X10^{-1}$	- .1120	.2469	- $.4056X10^{-1}$	.945	.080	89
Cl	.9049	- .2238	.6090	- .1906	$.7529X10^{-1}$	- .2718	.314	.339	85
TDS	2.4224	- $.7516X10^{-1}$	.1077	$.5206X10^{-2}$	$.8699X10^{-1}$	- $.6815X10^{-1}$	.927	.052	89
09205000 New Fork River near Big Piney, Wyo., 1969-75 water year									
Ca	2.1925	-0.4160	-0.4160	-0.2947	0.1498	0.1200	0.893	0.078	71
Mg	.7144	- .5475	- .5633	- $.1464X10^{-1}$	.2410	.2187	.564	.186	70
Na	1.4866	- .8208	- .2626	- .1899	.3111	.1078	.858	.098	71
K	.3708	- .6029	- $.8019X10^{-1}$	- $.4406X10^{-1}$	.2294	$.2738X10^{-1}$	.567	.120	70
HCO_3	2.7188	- .4023	- .5371	- .2641	.1458	.2191	.879	.083	71
SO_4	1.5564	- .7377	.3968	- .1672	.2992	- .1518	.631	.196	70
Cl	.7356	- .7806	.3370	- $.8435X10^{-1}$	.3120	- .1411	.532	.200	68
TDS	2.6440	- .4413	- .2889	- .2109	.1687	.1254	.851	.087	70
09209400 Green River near La Barge, Wyo., 1970-75 water years									
Ca	1.9262	-0.1408	0.4260	$-0.8631X10^{-1}$	$0.6860X10^{-1}$	-0.1532	0.857	0.051	59
Mg	1.4935	- .1518	.1662	- .1294	$.6249X10^{-1}$	- $.7216X10^{-1}$	.644	.100	59
Na	1.3806	-1.150	.6504	- $.6527X10^{-1}$	.4034	- .2239	.786	.107	59
K	.1218	- .6747	.7754	$.4045X10^{-1}$	.2318	- .2802	.613	.104	59
HCO	2.5069	- .1116	.3261	- $.9231X10^{-1}$	$.4692X10^{-1}$	- .1192	.784	.049	58
SO	2.2587	- .7708	.4432	- .1699	.2946	- .1665	.926	.075	58
Cl	.2396	-1.028	.3341	.1219	.3955	- .1445	.620	.187	59
TDS	2.5593	- .4033	.3956	- $.6532X10^{-1}$	.1555	- .1459	.864	.053	59
09211200 Green River below Fontenelle Reservoir, Wyo., 1970-75 water years									
Ca	1.8813	$-0.7463X10^{-1}$	0.1242	$-0.6576X10^{-1}$	$0.3601X10^{-1}$	$-0.6532X10^{-1}$	0.858	0.044	59
Mg	2.1434	.3819	- $.9552X10^{-1}$	- .3400	- .1351	- $.8903X10^{-3}$	.582	.118	59
Na	2.1664	- $.7561X10^{-1}$	.5277	- .2969	$.3505X10^{-1}$	- .1969	.838	.079	59
K	.2186	.1826	- .2944	- $.7194X10^{-2}$	- $.6705X10^{-2}$	$.7906X10^{-1}$	.494	.081	59
HCO_3	2.3076	$.1433X10^{-2}$	- $.7979X10^{-1}$	- $.3280X10^{-1}$	$.4625X10^{-2}$	$.5705X10^{-2}$	.785	.039	59
SO_4	2.8633	- .2999	.8828	- .3392	.1028	- .3247	.897	.074	56
Cl	1.1211	$.9124X10^{-1}$	- .4148	- .1548	- $.9964X10^{-2}$	$.7716X10^{-1}$	.660	.172	58
TDS	2.9542	$.4108X10^{-1}$	.2386	- .1848	- $.8943X10^{-2}$	- .1036	.904	.038	59

Table 3.--Regression results--continued

Constituent	B_0	B_1	B_2	B_3	B_4	B_5	r	SE (log units)	N
09216000 Big Sandy River below Eden, Wyo., 1961-75 water years									
Ca	2.8308	-0.2819	-0.3118	-0.3193	0.2238	0.2298	0.930	0.065	135
Mg	2.5163	- .4769	- .4435	- .3962	.3409	.2906	.763	.170	133
Na	3.1705	- .5360	- .1425	- .4107	.3546	.9222X10^{-1}	.921	.075	136
K	.8432	- .2324	- .1871	- .1831	.1371	.1271	.747	.070	134
HCO_3	2.6226	- .2080	- .2263	- .1526	.1509	.1526	.856	.052	136
SO_4	3.7132	- .4768	- .3024	- .3867	.3453	.2078	.939	.071	132
Cl	2.6059	- .6753	- .5450X10^{-1}	- .5222	.3899	.5756X10^{-1}	.911	.090	134
TDS	3.9191	- .4373	- .2577	- .3697	.3102	.1791	.938	.065	134
09216300 Green River at Big Island, near Green River, Wyo., 1966-75 water years									
Ca	2.3985	0.9136X10^{-1}	0.1184	-0.2114	-0.1983X10^{-1}	-0.5649X10^{-1}	0.906	0.042	102
Mg	2.3717	.1850	.118	- .3557	- .5387X10^{-1}	- .5183X10^{-1}	.789	.097	102
Na	3.5144	- .1151	.4623	- .6195	.3199X10^{-1}	- .1610	.900	.094	102
K	.4599	.4617X10^{-1}	.1556	- .7425X10^{-1}	- .2488X10^{-1}	- .6086X10^{-1}	.298	.092	102
HCO_3	2.4754	.2112	- .8044X10^{-2}	- .8492X10^{-1}	- .5954X10^{-1}	- .1613X10^{-1}	.843	.038	102
SO_4	4.1100	- .2129	.3763	- .6234	.7070X10^{-1}	- .1364	.921	.088	101
Cl	2.7664	- .6385	.6583	- .6096	.1907	- .2426	.804	.141	101
TDS	2.4358	.1564X10^{-1}	.5281X10^{-1}	- .6429X10^{-1}	.8525X10^{-3}	- .2016X10^{-1}	.981	.026	90
09217000 Green River near Green River, Wyo., 1969-75 water years									
Ca	2.3422	.7921X10^{-1}	.3339	- .3339	- .1773X10^{-1}	- .1223	.914	.031	79
Mg	2.0169	- .6733X10^{-1}	.5429X10^{-1}	- .2299	.3125X10^{-1}	- .3226X10^{-1}	.849	.053	79
Na	2.9491	- .7523	.1445	- .4147	.2477	- .5830X10^{-1}	.833	.105	79
K	.1949	- .3300	.1001	.2950X10^{-1}	.1050	- .4980X10^{-1}	.373	.114	68
HCO_3	2.4509	.1540	.1388	- .7179X10^{-1}	- .4039X10^{-1}	- .6137X10^{-1}	.866	.029	79
SO_4	3.7297	- .4682	.4333	- .4920	.1560	- .1485	.934	.065	68
Cl	1.8550	- .4853	.3897	- .3137	.1587	- .1463	.802	.089	68
TDS	3.4821	- .1001	.3078	- .2910	.4131X10^{-1}	- .1087	.935	.039	68
09222000 Blacks Fork near Lyman, Wyo., 1970-75 water years									
Ca	2.6737	-0.1666	0.2548X10^{-1}	-0.3078	0.2669X10^{-1}	0.3359X10^{-1}	0.951	0.062	53
Mg	2.2836	- .3277	- .3364X10^{-1}	- .3487	.1007	.7367X10^{-1}	.934	.089	54
Na	2.6877	- .6437	.3100	- .2599	.2574	- .9781X10^{-1}	.884	.126	53
K	.5752	- .4374	.2794	- .4799X10^{-1}	.1716	- .1409	.775	.082	54
HCO_3	2.5942	- .9595X10^{-3}	- .2064	- .1076	- .1372X10^{-1}	.9670X10^{-1}	.679	.053	54
SO_4	3.3881	- .4991	.1929	- .3596	.1776	- .1158X10^{-1}	.931	.113	54
Cl	1.9935	- .7167	.2139	- .1367	.3011	- .8693X10^{-1}	.710	.167	54
TDS	3.5611	- .4165	.1823	- .2872	.1476	- .3277X10^{-1}	.930	.087	54
09224450 Hams Fork near Granger, Wyo., 1969-75 water years									
Ca	1.9122	0.1702	-0.1251	-0.3613X10^{-1}	-0.6055X10^{-1}	0.5120X10^{-1}	0.771	0.069	88
Mg	1.6777	.1173	- .1355	- .1912	- .7256X10^{-1}	.6406X10^{-1}	.815	0.084	88
Na	1.9557	.1579X10^{-1}	- .1859	- .2271	- .5991X10^{-2}	.1140	.832	.116	88
K	.2819	.9825X10^{-1}	.1170X10^{-1}	- .2305X10^{-1}	- .5176X10^{-1}	- .3552X10^{-1}	.476	.082	88
HCO_3	2.4167	.1674	- .9874X10^{-1}	- .5596X10^{-1}	- .1046	.4351X10^{-1}	.658	.057	88
SO_4	2.5180	.2888X10^{-1}	- .2209	- .2006	.3031X10^{-1}	.1248	.890	.103	86
Cl	1.4965	.5568X10^{-1}	- .2590	- .1467	.4525X10^{-1}	.1355	.845	.127	88
TDS	2.8561	.1368	- .1227	- .1392	- .5930X10^{-1}	.5637X10^{-1}	.855	.066	88
09224700 Blacks Fork near Little America, Wyo., 1970-75 water years									
Ca	2.1897	-0.3005X10^{-1}	-0.2452	-0.8708X10^{-1}	0.1222X10^{-1}	0.1432	0.778	0.087	61
Mg	1.9720	- .3323	- .3435	- .1506	.1459	.1844	.894	.082	62
Na	2.5947	- .6160	- .4195	- .1768	.2907	.2250	.817	.168	62
K	.7172	- .3418	- .3822	- .3461X10^{-1}	.1374	.1560	.661	.078	55
HCO_3	2.5747	.2151	- .3399	- .7689X10^{-1}	- .8641X10^{-1}	.1328	.759	.061	62
SO_4	3.2412	- .4122	- .2117	- .2758	.1868	.1505	.903	.115	54
Cl	2.1541	- .5409	- .3045	- .1707	.2657	.1348	.770	.153	55
TDS	3.4221	- .2466	- .1394	- .2064	.1164	.9722X10^{-1}	.886	.092	55
09259700 Little Snake River near Baggs, Wyo., 1965-74 water years									
Ca	1.6052	-0.3896	-0.4413X10^{-1}	0.8984X10^{-2}	0.2174	0.2892X10^{-1}	0.895	0.078	81
Mg	1.1950	- .7907	- .1716	- .4597X10^{-1}	.3869	.7229X10^{-1}	.844	.177	81
Na	1.9928	- .8096	.1733	- .2087	.3709	- .5973X10^{-1}	.952	.134	81
K	.4759	- .4543	.6136X10^{-1}	- .5436X10^{-1}	.2002	- .3844X10^{-1}	.792	.126	80
HCO_3	2.4537	- .2912	- .1615	- .8414X10^{-1}	.1598	.8360X10^{-1}	.952	.061	81
SO_4	1.9059	-1.027	.3184	- .4803X10^{-1}	.4940	- .1370	.920	.156	80
Cl	1.7546	- .6815	.2016	- .3413	.2858	- .5831X10^{-1}	.924	.203	79
TDS	2.704	- .5203	.1653	- .1190	.2498	- .7013X10^{-1}	.961	.075	80

Table 4.--Regression results, concentration versus specific conductance

[S. J. Rucker IV, written commun., 1977]

$$TDS = E+FK$$

where

TDS = Dissolved solids, in milligrams per liter,

E = Intercept, in milligrams per liter,

F = Slope, and

K = Specific conductance, in micromhos per centimeter at 25°C.

Station	E	F	r	SE	N
09209400	-12.9	0.645	0.987	9.6	129
09211200	-23.6	.657	.942	10.4	83
09217000	-57.5	.760	.993	21.1	149
09222000	-18.4	.856	.993	86.3	150
09224700	-88.8	.772	.995	52.6	154

r = Correlation coefficient.

SE = Standard error of estimate, in milligrams per liter.

N = Number of paired values.

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