TREND ANALYSIS OF SALT LOAD AND EVALUATION OF THE FREQUENCY OF WATER-QUALITY MEASUREMENTS FOR THE GUNNISON, THE COLORADO, AND THE DOLORES RIVERS IN COLORADO AND UTAH

By James E. Kircher, Richard S. Dinicola, and Robert F. Middelburg

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WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Colorado District Chief
U.S. Geological Survey, MS 415
Box 25046, Denver Federal Center
Lakewood, CO 80225

For sale by:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey, MS 306
Box 25425, Federal Center
Denver, CO 80225
Telephone (303) 234-5888

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CONVERSION FACTORS

Inch-pound units used in this report may be converted to SI (International System) units by using the following conversion factors:

Multiply inch-pound units	*by*	*To obtain SI units*
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
degree Fahrenheit (°F)	°C=5/9(°F-32)	degree Celsius (°C)
micromho per centimeter at 25° Celsius (µmhos/cm at 25°C)	1.000	microsciemens per centimeter at 25° Celsius
pound (lb)	0.4536	kilogram
square mile (mi^2)	2.590	square kilometer
ton (short)	0.9072	ton
ton per day per year	0.9072	ton per day per year

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ABSTRACT

Monthly loads were computed for water-quality constituents at four streamflow gaging stations in the Upper Colorado River Basin for the determination of trends. Seasonal regression and seasonal Kendall trend-analysis techniques were applied to two monthly data sets at each station for four different time periods. A recently developed method for determining optimal water-discharge data-collection frequency was also applied to the monthly water-quality data.

Trend-analysis results varied with each monthly load-computational method, period of record, and trend-detection model used. No conclusions could be reached regarding which computational method was best to use in trend analysis. Time-period selection for analysis was found to be important with regard to intended use of the results. Seasonal-Kendall procedures were found to be applicable to most data sets. Seasonal-regression models were more difficult to apply and were sometimes of questionable validity; however, those results were more informative than seasonal-Kendall results. The best model to use depends upon the characteristics of the data and the amount of trend information needed. The measurement-frequency optimization method has potential for application to water-quality data, but refinements are needed.

INTRODUCTION

The Colorado River basin is an important source of water for more than 12 million people, industrial users, and approximately 2.5 million acres of irrigated agricultural land (Mueller and Moody, 1983). As the Colorado River and its tributaries flow from their headwaters to their mouths, the concentrations of dissolved solids increase; this increase in concentration causes millions of dollars damage annually to agricultural, industrial, and municipal users (U.S. Bureau of Reclamation, 1983). Dissolved solids and salinity as used in this report are synonomous and refer to the amount of dissolved minerals in water that is used as an indicator of inorganic water quality. To address this basinwide problem, Congress passed the Colorado River Basin Salinity Control Act in 1974, which authorized construction of 4 salinity-control projects and planning studies on 12 other salinity-control units. Also, in response to the Federal Water Pollution Control Act Amendments of 1972, the seven Colorado River basin States in 1976 adopted salinity standards at three locations on the lower main stem of the Colorado River. These standards shown below reflect 1972 flow-weighted concentrations at these locations.

Flow-weighted concentrations are computed by multiplying the discharge for a sampling period by the concentrations of individual constituents for the corresponding period and dividing the sum of the products by the sum of the discharges.

Dissolved-solids standards for the Colorado River

Location	Annual Flow Weighted Average (measured as mg/L)
Below Hoover Dam------------------	723
Below Parker Dam------------------	747
At Imperial Dam-------------------	877

To maintain these standards while the basin States continue to develop their compact-apportioned waters, it has been estimated that over 2.2 million tons of dissolved solids must be removed from the system by the year 2010.

Computational methods were developed at this time to predict the effects of planned water-resources development. Early projections showed that dissolved-solids increases observed at Imperial Dam in Arizona between 1949 and 1970 would continue, with dissolved-solids concentration eventually reaching 1,200 mg/L (milligrams per liter) by the year 2000, compared to the established 1972 regulatory level of 879 mg/L; however, dissolved-solids concentration actually has been decreasing since 1970 (fig. 1). A decrease in dissolved-solids concentration from some upper basin areas is indicated, but definitive causes for the decreases are not readily apparent. Trends in dissolved solids at a particular site may be caused by (1) Natural changes in dissolved-solids input above the site; (2) climatic trends affecting streamflow; (3) man-induced changes in dissolved-solids input from changes in agricultural or industrial activities or from implementation of salinity-control projects; and (4) changes in streamflow patterns from increased water use or from construction of reservoirs above the site.

The uncertainty of the dissolved-solids concentration measured at each monitoring site, measured in terms of standard error of the dissolved solids, needs to be estimated as a function of the frequency of data collection. This would assist managers and planners in determining how often to collect data to adequately define the dissolved-solids load in the study area.

Purpose and Scope

A study to investigate methods for the analysis of trends in solute concentrations and loads at four stations in the Colorado River basin (fig. 2) was conducted by the U.S. Geological Survey in cooperation with the U.S. Bureau of Reclamation. The purpose of this study was to (1) Present two methods for computing mean monthly dissolved-solids loads and comparing the results; (2) present various methods used for trend analysis; (3) present and compare results of different trend-analysis techniques; (4) use these results to explore the suitability of various trend tests; and (5) describe and apply to dissolved-solids data a recently developed method for determining an optimal frequency of water-discharge data collection to be used as a focus for developing a more refined tool for determining dissolved-solids sampling frequency.

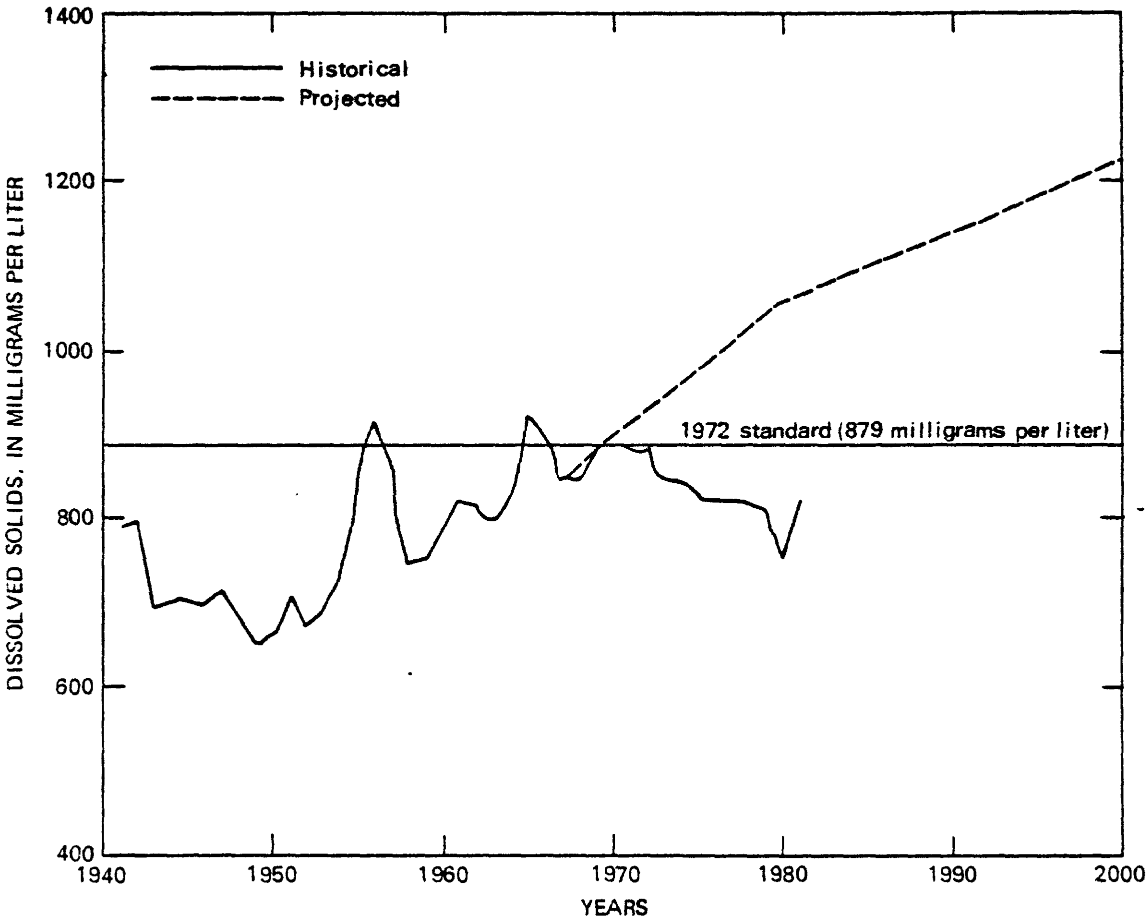

Figure 1.--Historical versus projected dissolved solids at Imperial Dam, Ariz. without salinity control. (From Mueller and Moody, 1983.)

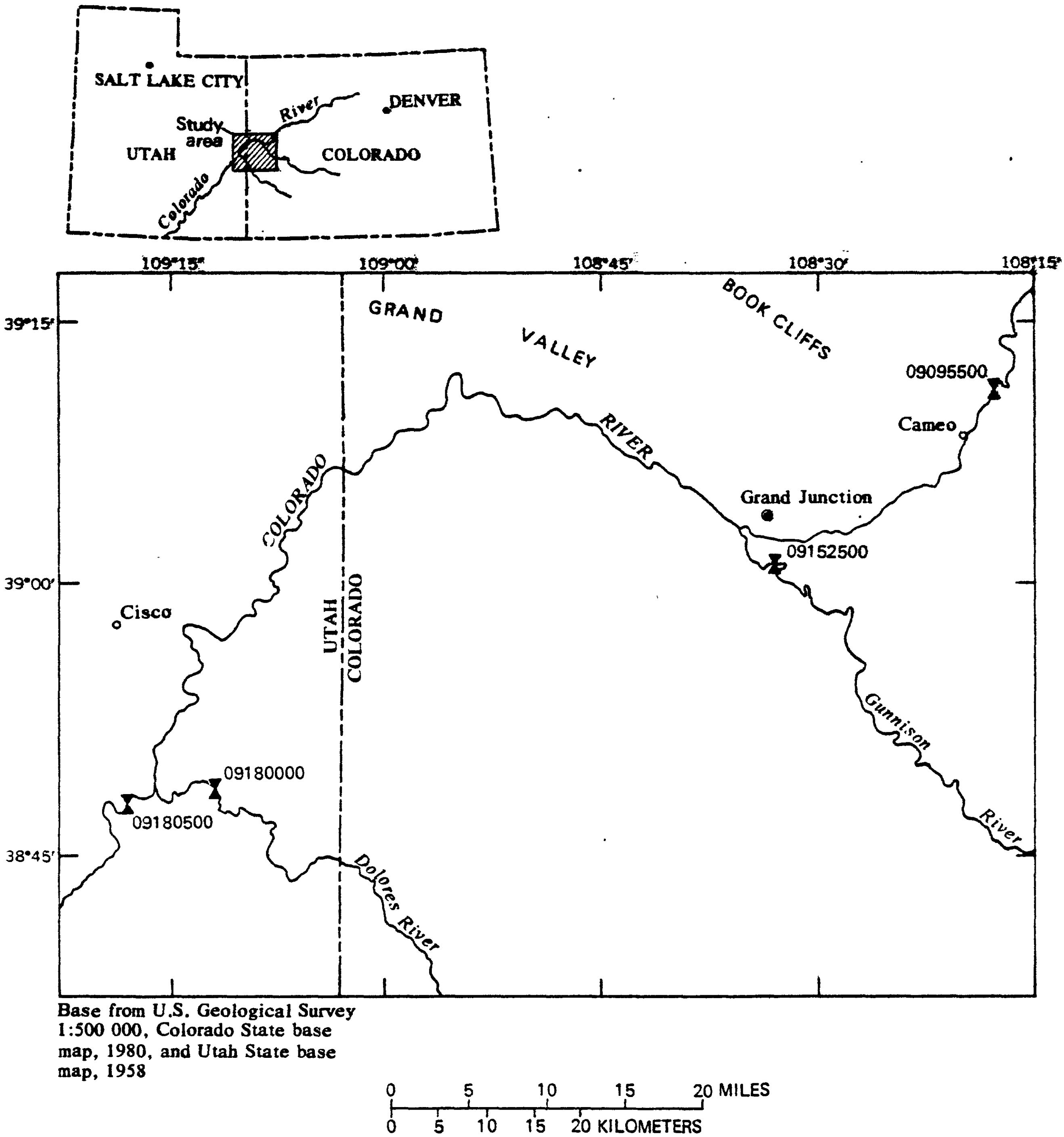

Figure 2.--Location of streamflow and water-quality stations used in this study.

Four U.S. Geological Survey stations in the Upper Colorado River Basin (fig. 2) were selected for evaluation: (1) 09095500 Colorado River near Cameo, Colo.; (2) 09152500 Gunnison River near Grand Junction, Colo.; (3) 09180000 Dolores River near Cisco, Utah; and (4) 09180500 the Colorado River near Cisco, Utah. Study sites were selected based on their importance for monitoring dissolved-solids input into the Colorado River above Cisco, Utah. The specific-conductance uncertainty evaluation was made at station 09180500 Colorado River near Cisco, Utah. This site was selected because it represents the outflow from the Upper Colorado River Basin.

METHOD OF COMPUTATION OF MONTHLY SALT LOADS

All data used for this project were taken from the U.S. Geological Survey WATSTORE (U.S. Geological Survey, 1979) data base. Computer routines were developed using the Statistical Analysis System (SAS Institute, 1982) procedures to check for errors in the data and to compute mean monthly discharge and the concentrations and loads of dissolved solids and six chemical constituents. The solutes were: calcium, magnesium, sodium, chloride, sulfate, and carbonate. These six constituents account for more than 95 percent of the dissolved-solids load at the gaging stations in the study area. Data retrieved from WATSTORE for the study included daily water discharge, daily specific conductance, and periodic chemical analyses.

Daily loads, in tons per day, were computed for each of the constituents, including dissolved solids. These data were accumulated to determine monthly loads. A discharge-weighted concentration for each month was computed using the monthly load and mean monthly discharge.

Daily loads were determined using two different methods. Method 1, used by the U.S. Bureau of Reclamation to compute daily solute concentration, is explained by Mueller and Moody (1983) as follows:

Single, missing solute concentrations in any chemical analysis were computed by setting net charge to zero. If two or more values were missing from a single analysis, no estimation was attempted. For such instances, the sum of constituents, necessary to compute mass fraction, was estimated from regression on evaporation-residue dissolved-solids concentration. The water-quality data, including missing-value estimates, then were combined with daily water discharge and conductance data, to estimate solute concentrations for unsampled days.

Composite sample analyses were assigned to each day of the composite period; instantaneous sample analyses were assigned only to the day of collection. To avoid masking temporal trends, missing daily values were generated by interpolation. A hierarchical process was used in which discharge was estimated first, followed by conductance, and finally, solute concentrations. This hierarchy was necessary, because discharge was used to weight interpolation of conductance, and conductance in turn, to weight interpolation of concentration. The general formula used was:

$$X_k = \left\{ W_{k_o} X_{k_o} + \frac{k - k_o}{k_n - k_o} (W_{k_n} X_{k_n} - W_{k_o} X_{k_o}) \quad W_k^{-1} \right\} \tag{1}$$

where x=Discharge, conductance, or solute concentration,
k=Julian date with period of missing record,
W=a weighting factor,
k_o=last Julian date with observed data prior to period of missing record,
k_n=first Julian date with observed data following the period of missing record.

Weighting factors are defined as follows:

1. Discharge: W_k=1, for all k.
2. Conductance: $W_k=1/Q_k^B$, where B is the slope of the log-log regression of conductance on discharge (Q) for the entire period of record.
3. Solute concentrations: $W_k=1/_{Lk}$, where L is specific conductance on day k.

In equation 1, discharge interpolation is linear with respect to time, which is considered adequate because missing values rarely occur in the discharge record. Conductance and concentration are transformed by the weighting factors into parameters (a and b) that are expected to be relatively constant over a short time period. The equation for interpolation of conductance thus becomes:

$$L_k=aQ_k^B \cdot \tag{2}$$

Lane (1975) found this type of relationship to be generally applicable to natural streams in the Western United States. Interpolation of solute concentration is of the form:

$$C_k=bL_k, \tag{3}$$

where: L_k=specific conductance in µmhos/cm (micromhos per centimeter) at 25°C (degrees Celsius) on day k,
C_k=constituent concentration in mg/L, on day k,
Q_k=water discharge, in ft³/s (cubic feet per second), on day k, and
a,b, and B=regression constants.

Over small ranges of conductance, such a linear relationship is reasonable for predicting concentration (Hem, 1970).

Interpolations were constrained to maximum intervals of 20 days for discharge and conductance and 60 days for solute concentrations. Conductance interpolation was not attempted if the missing value period included days of zero discharge.

Monthly mean discharge and discharge-weighted concentrations were then computed from daily values. If measured or estimated values were unavailable for more than 25 percent of the days in a month, that month was dropped from further analysis.

Method 2, developed by the U.S. Geological Survey for this report, is a regression technique for computing monthly loads. This approach determines daily load as a function of daily specific conductance and daily water discharge. The general form of the logarithmic relation is:

$$\ln L = A + b(\ln(SC)) + c(\ln(Q)) \qquad (4)$$

where ln=natural logarithm,
L=average daily load of the constituent of interest, in tons per day,
A,b,c=regression coefficients,
SC=average daily specific conductance in μmhos/cm at 25°C, and
Q=average daily water discharge, in ft^3/s.

By taking antilogs, equation 4 becomes:

$$L = aSC^{b}Q^{c} \qquad (5)$$

where L, SC, Q, b, and c are as defined above, and
$a=e^{A}$.

Logarithmic transformations of the data were used to approximate more closely a normal distribution and to satisfy the assumptions of regression analysis. Specific conductance was chosen as an independent variable because of the physical relationship between it and the concentration of major dissolved constituents in natural waters. Discharge was included in the model because it explains much of the data variability.

The regression equation was derived from the regression analysis of instantaneous loads versus instantaneous specific conductance and water discharge; it is assumed that this relation also will represent mean daily values. The data base was divided into a series of overlapping 3-year periods to not remove any existing time trend. Regression relationships were developed for each successive 3-year period and used to compute monthly loads for the center year of the 3 years. For example, the first 3-year period might be the 1965, 1966, and 1967 water years; results used would be for 1966. The next 3-year period would be 1966, 1967, and 1968; results used would be for 1967, and so on.

The following equation is suggested if a concentration regression equation is preferred:

$$C=aSC^{b}Q^{c}, \tag{6}$$

where C=concentration, in milligrams per liter,
a,b,c=regression constants,
SC=specific conductance, in µmhos/cm at 25°C, and
Q=water discharge, in ft^3/s.

Estimated daily concentration is multiplied by 0.0027, the unit's constant, and the daily average water discharge to obtain daily load. Loads from equation 5 and equation 6, multiplied by the discharge and unit's constant, are equivalent.

An additional equation is necessary when the specific-conductance record is missing. Rather than estimating specific conductance for periods of missing record, the daily load is estimated from discharge as follows:

$$L=aQ^{b}, \tag{7}$$

where L=daily load of selected constituent, in tons per day,
a,b=regression constants, and
Q=daily water discharge, in ft^3/s.

Monthly constituent loads computed by the two methods were compared by plotting the monthly dissolved-solids loads estimated by Method 2 (eqs. 5 and 7) and Method 1 (eqs. 1, 2, and 3) versus time (figs. 3-6). Absolute differences in monthly loads, as computed by the two methods, also is shown.

Plots of monthly constituent loads showed that differences occurred between the two estimates of monthly loads. The data base was examined to determine possible reasons for the differences between the estimated loads. In most instances, it was determined that significant flow variations had occurred between discrete water-quality samples. Interpolated estimates of monthly loads were usually higher than regression estimations when the average flow between the discrete samples was higher than the flow at the time when the discrete samples were taken. Analogous reverse results were found for the loads during periods of lower flow.

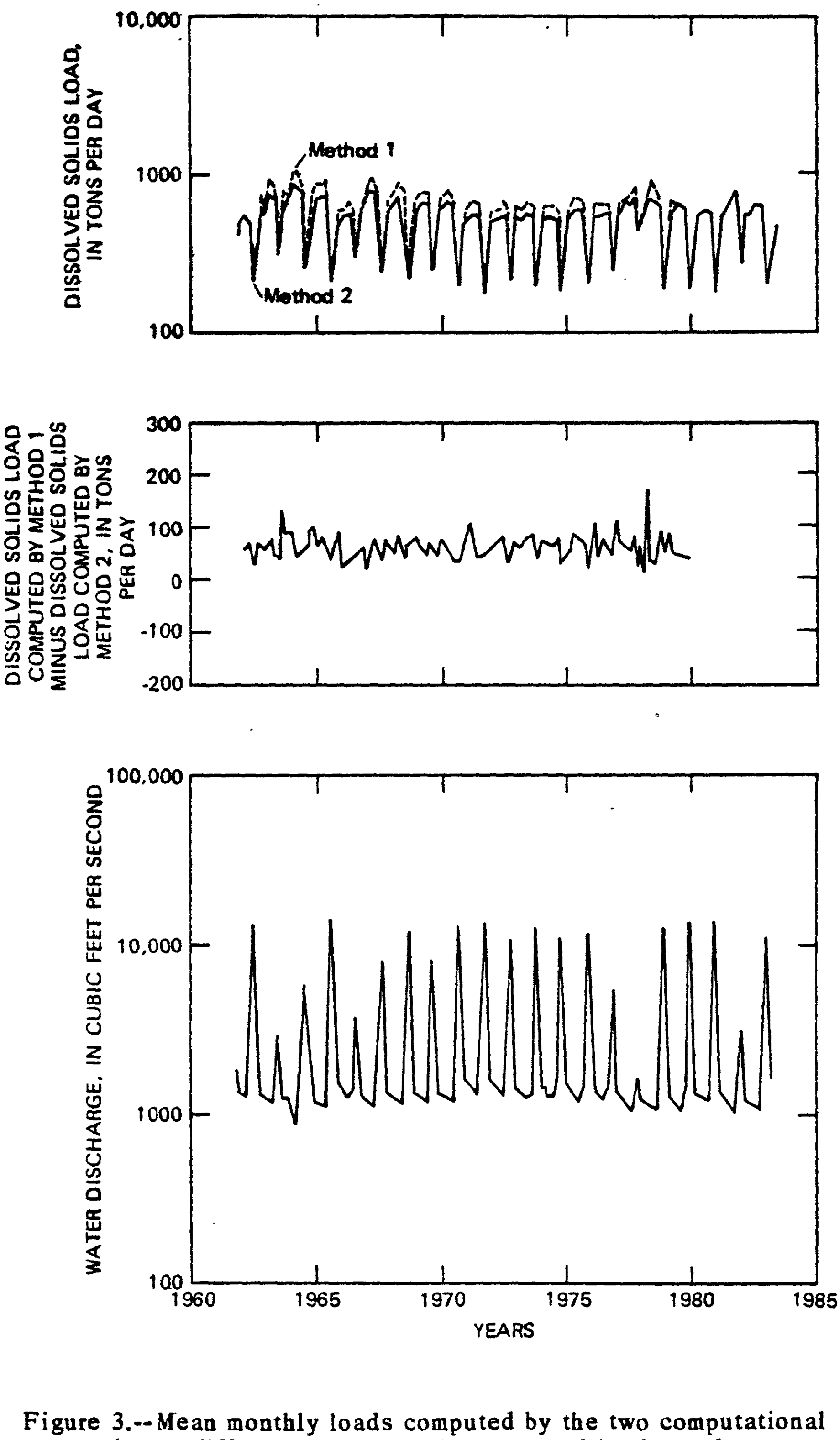

Figure 3.--Mean monthly loads computed by the two computational procedures, difference between the computed loads, and mean monthly water discharge versus time for station 09095500, Colorado River near Cameo, Colo.

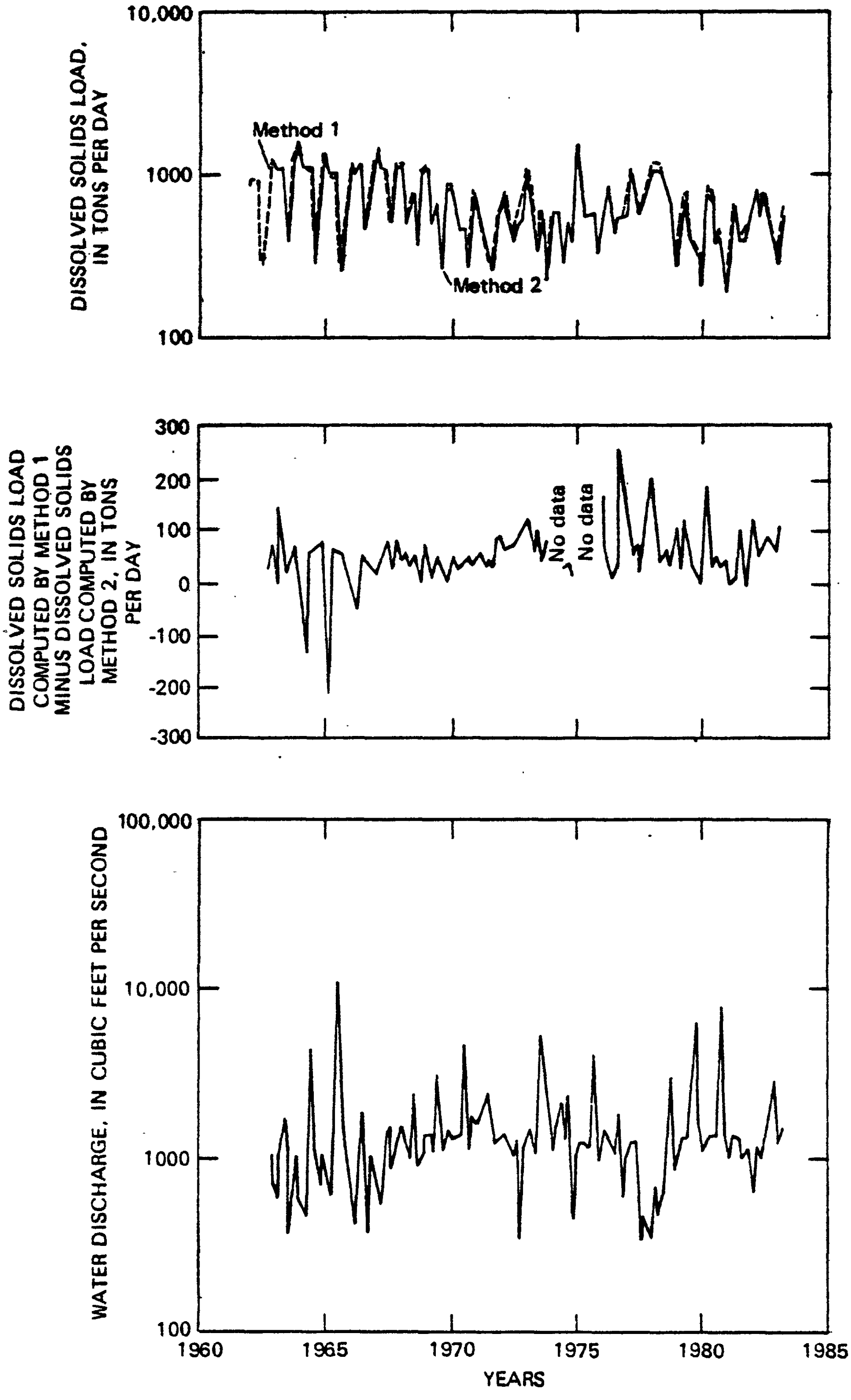

Figure 4.—Mean monthly loads computed by the two computational procedures, difference between the computed loads, and mean monthly water discharge versus time for station 09152500, Gunnison River near Grand Junction, Colo.

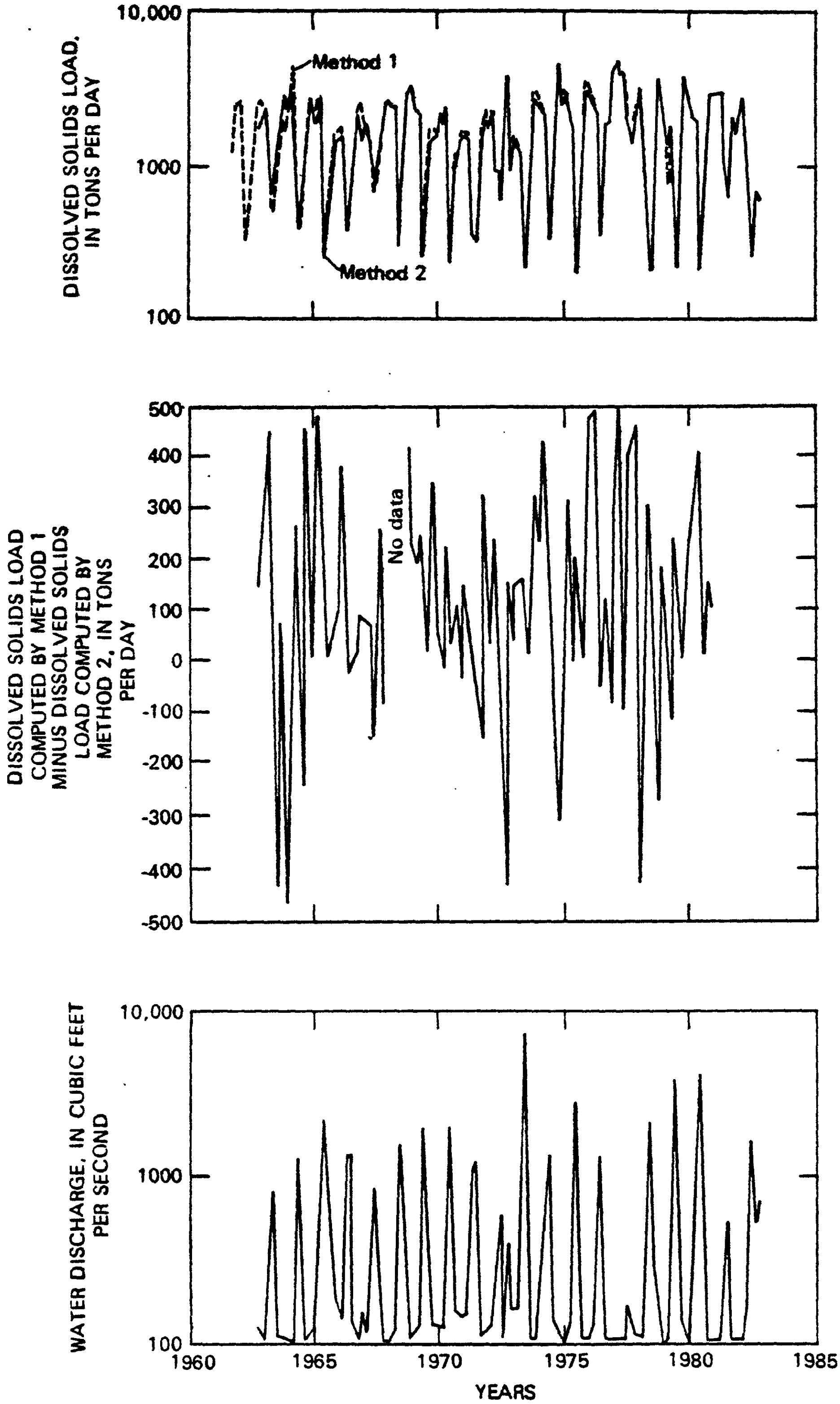

Figure 5.--Mean monthly loads computed by the two computational procedures, difference between the computed loads, and mean monthly water discharge versus time for station 09180000, Dolores River near Cisco, Utah.

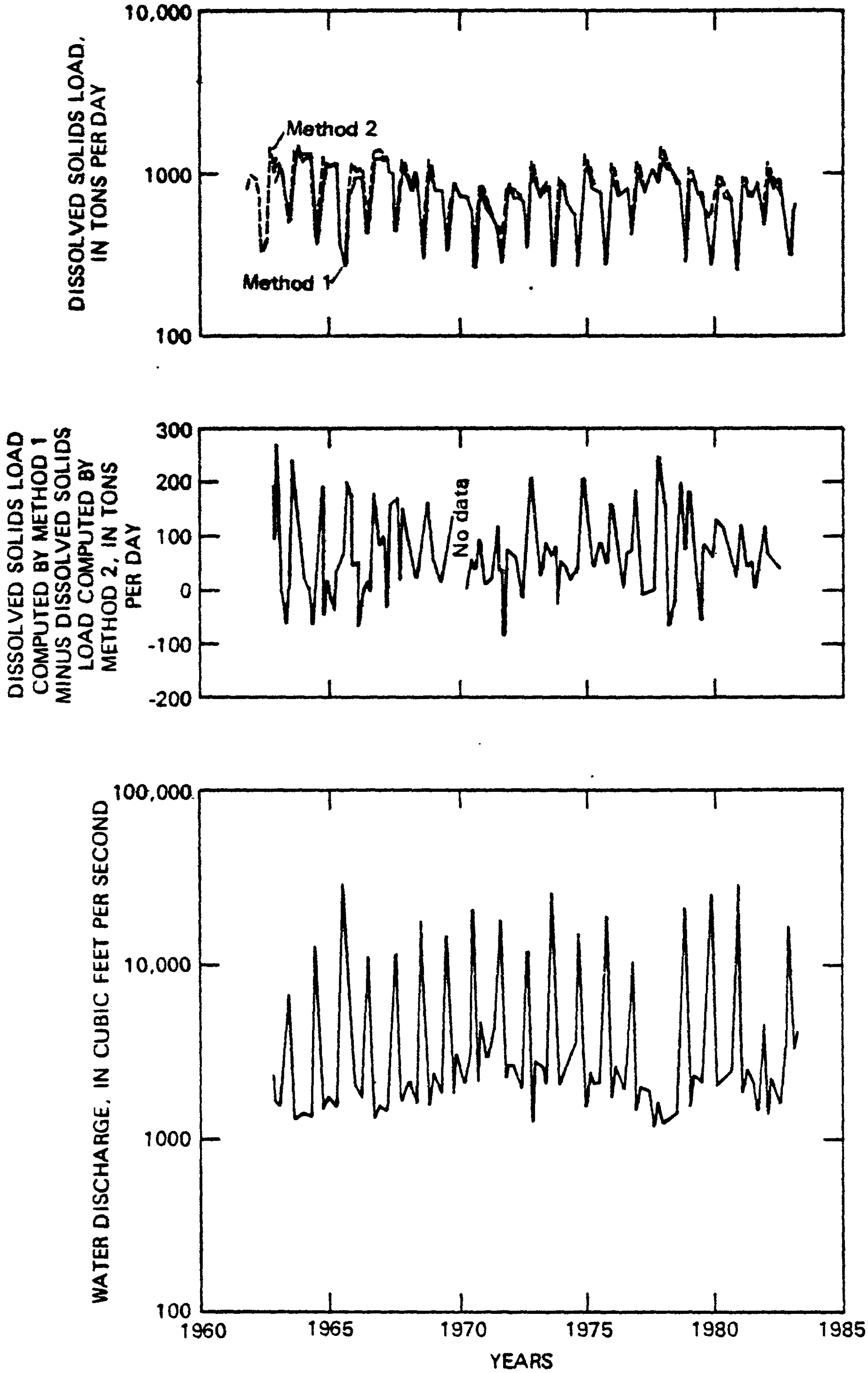

Figure 6.--Mean monthly loads computed by the two computational procedures, difference between the computed loads, and mean monthly water discharge versus time for station 09180500, Colorado River near Cisco, Utah.

DISSOLVED-SOLIDS TREND ANALYSIS

General Considerations

Trends in a time series of data are typically evaluated by using statistical techniques to test hypotheses at specified levels of significance. Hypothesis testing for trend detection consists of the following steps (Smith and others, 1982):

1. State the null hypothesis and background assumptions for the test; (an example of a null hypothesis might be: the random variable and and its time of observation are independent; an example of background assumptions might be that the random variable is serially independent and normally distributed).
2. Calculate an appropriate test statistic from the data.
3. Interpret the value of the statistic in light of the known probability distribution of the statistic.
4. If the value of the test statistic is within preselected limits on the distribution, do not reject the null hypothesis.
5. If the value of the test statistic is outside the preselected limits, reject the null hypothesis and claim a statistically significant trend.

For this study, the preselected significance level is 0.05. If the null hypothesis is not rejected, then one could say that a trend is not statistically significant at the 5-percent level; if the null hypothesis is rejected, then one could say that the trend is significant at the 5-percent level. Another way to say this is that, in 95 percent of the cases, this test will correctly decide there is no trend when there actually is no trend.

The probability distribution of the test statistic needs to be known. For some hypothesis tests, this distribution is not generally known because it depends on the distribution of the random variable, which is itself unknown. This leaves a choice between using a test that is very powerful under very restrictive assumptions about the underlying distribution or a less powerful test under more relaxed assumptions that may correspond better to the problem.

A common test for trend is based on linear regression of the variable of interest against time. In this instance, the null hypothesis is that the variable is uncorrelated with time, and the background assumptions are that the regression residuals are normal, independent, and identically distributed over time. If the slope of the line is found to be significant, a trend is said to exist. However, several of the assumptions underlying the probability distribution needed to make the test are not met with natural data. Water-quality data generally are skewed, seasonal, and serially correlated. These features violate the assumptions of normality, independence, and stationarity needed for computing the probability distribution of the test statistic in the regression test for trend. Any one of these violations can render the test invalid. To circumvent these shortcomings, one could use a logarithmic transform of the variable to remove the skewness, look at separate seasons to avoid seasonality effects, and possibly use annual values instead of monthly values to avoid serial correlation. However, removing all three defects is extremely difficult, if not impossible.

Another test that has been used recently and is largely unaffected by the aforementioned defects is the seasonal-Kendall test for trend (Hirsch and others, 1982; Smith and others, 1982; and Crawford and others, 1983). This test has less restrictive assumptions than classical regression techniques, so it is less sensitive to the distribution of water-quality time series. The null hypothesis for this test is that the variable of interest is independent of time; the only background assumption is that the random variables are independent and identically distributed within each season.

When all assumptions for the regression test are met, the regression test is the most powerful test for linear trend (Kendall and Stuart, 1968). Based on a series of Monte Carlo experiments, Hirsch and others (1982) found that the seasonal Kendall test was almost as powerful. They also found that when skewness or seasonality were introduced, the seasonal-Kendall test was better than the test based on linear regression. When serial correlation was introduced, its effect on the seasonal Kendall test was no more severe than its effect on linear regression.

In this report, both techniques (regression and the seasonal Kendall) were used, and attempts were made to adjust for defects in the assumptions where possible. These methods and trend results are presented in the next two sections.

Determination of Time Periods

The long-term record for each station was divided based on development in the upper basin. The history of development in the upper basin indicates that either the 1965 or the 1969 water year could be used as a divisional year for the record. Trend analysis was run on the data sets for the pre-1965 period, the post-1965 period, the post-1969 period, and the entire period of record. The pre-1965 time period is the time frame from the beginning of record collection for each site, through and including the 1964 water year. The post-1965 period includes the 1965 water year through the end of the record. The post-1969 time period includes the 1969 water year through the end of the record. The period of record for each station used in this study is given in table 1.

Table 1.--*Periods of record for each of the four gaging stations in the study area*

Station number and name		Period of record (water years)
09095500	Colorado River near Cameo, Colo----------------	1934 through 1979
09152500	Gunnison River near Grand Junction, Colo-------	1932 through 1982
09180000	Dolores River near Cisco, Utah-----------------	1951 through 1982
09180500	Colorado River near Cisco, Utah----------------	1929 through 1983

The selection of a time period for a data set is a function of the specific objectives of a study; for example: Is the investigation interested in specific short-term trends or in general long-term trends? The trend-analysis methods presented in this study discern average temporal trends in a data set. A series of shorter term positive and negative trends in a data set covering a long time span could possibly be masked by this averaging.

Regression Analysis

The first trend-examination method used was the regression-analysis technique. Several variations were used to satisfy background assumptions. A residual analysis was made to detect any variations from these assumptions.

The data were first analyzed for seasonal variability by looking at the monthly means and variances of both water discharge and dissolved solids. Three distinct seasons were identified, based on variation in dissolved-solids means and variances at station 09095500 Colorado River near Cameo, Colo.; station 09152500 Gunnison River near Grand Junction, Colo.; and station 09180500 Colorado River near Cisco, Utah. The seasons were called base flow for December through March, peak flow for May and June, and return flow for August through November. April and July were variable-transition months. Two seasons were identified at station 09180000 Dolores River near Cisco, Utah. These seasons were base flow for July through February and peak flow from April and May. March and June were transition months. Therefore, the annual cycle was divided into either two or three seasons for the study sites.

Seasonality was accounted for in the linear-regression analysis by using dummy variables. The term dummy means that the values (usually zero or 1) taken on by such variables were not measured, but only indicated a category of interest; for example, seasons in which the data fall (Kircher and Von Guerard, 1982; and Kircher and Karlinger, 1983). Through the use of dummy variables, regression analysis assumes a broad range of application. In particular, the use of dummy variables enables using regression analysis to produce the same information that is obtained by such procedures as analysis of variance and analysis of covariance. The use of dummy variables also enables comparison of regression equations for several categories by use of a single multiple-regression model.

Separate regressions were made at each station for mean monthly loads and concentrations in real and log space for post-1969, pre-1965, and post-1965 data. The seasonal-regression model used for stations with three seasons was:

$$Y=B0+B1(Z1)+B2(Z2)+B3(T)+B4(Z1*T)+B5(Z2*T), \qquad (8)$$

where Y=discharge solute load, concentration or the natural logarithm of these variables,
B0, B1, B2, B3, B4, and B5=regression coefficients,
Z1 and Z2=dummy variables, and
T=time, in years.

The variables Z1 and Z2 were defined as:

SEASON	MONTHS	Z1	Z2
Base flow----------	December through March---	0	0
Peak flow----------	May and June-------------	0	1
Return flow--------	August through November--	1	0

Data from the transition months, April and July, were omitted from the analyses. The seasonal-regression model used at the Dolores River station (two seasons) was:

$$Y=B0+B1(Z1)+B2(T)+B3(Z1*T), \quad (9)$$

where all the terms are defined as for equation 8, but the dummy variable Z1 is either zero for base flow (July through February) or 1 for peak flow (April and May). March and June data were omitted from these analyses.

The following null hypotheses were tested for the three-season seasonal-regression model to analyze the various trend characteristics:

NULL HYPOTHESIS	TREND CHARACTERISTIC TESTED
B3=0	Trend in base flow
B3+B5=0	Trend in peak flow
B3+B4=0	Trend in return flow
B5=0	Difference between base and peak trends
B4=0	Difference between base and return trends
B5-B4=0	Difference between peak and return trends

Hypotheses tested for the two-season seasonal-regression model include:

B2=0	Trend in base flow
B2+B3=0	Trend in peak flow
B3=0	Difference between base and peak trends

As mentioned, these seasonal-regression models were analyzed with and without a natural logarithmic transformation. Residuals of the untransformed regressions were plotted to see if they met the regression assumptions. In some instances, the residuals exhibited a normal scatter, but this was not true for all cases (figs. 7-10). A primary objective of this study was to find one method that could be used for all stations, so the next step was to transform the data to a logarithmic form that better met the assumptions of linear regression. The residuals of the logarithmic regressions were plotted to see if they met the regression assumptions (figs. 11-14). The regressions with logarithms of loads as the dependent variable resulted in more nearly homoscedastic residuals.

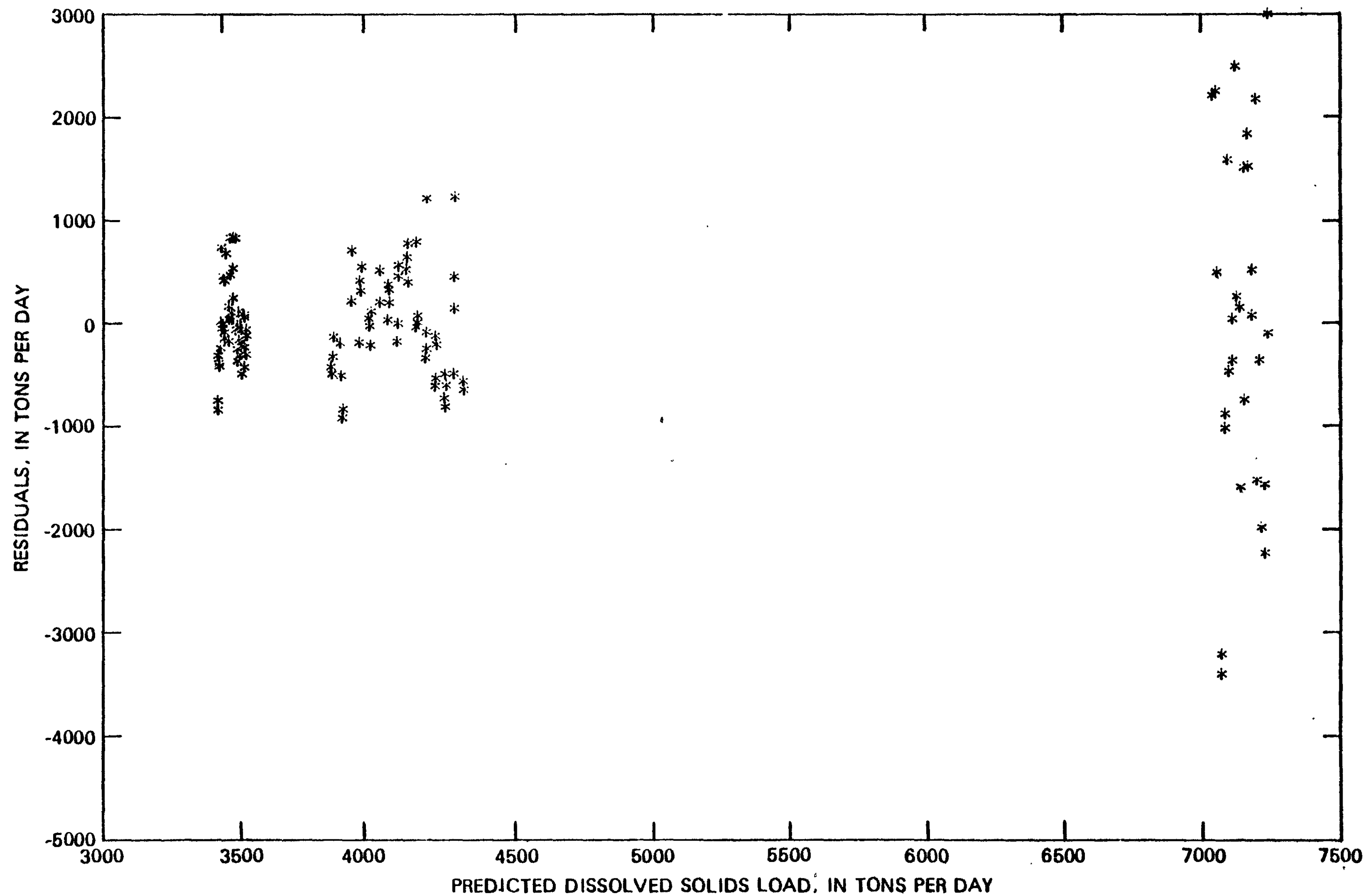

Figure 7.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation DS = *f* (time), for station 09095500, Colorado River near Cameo, Colo.

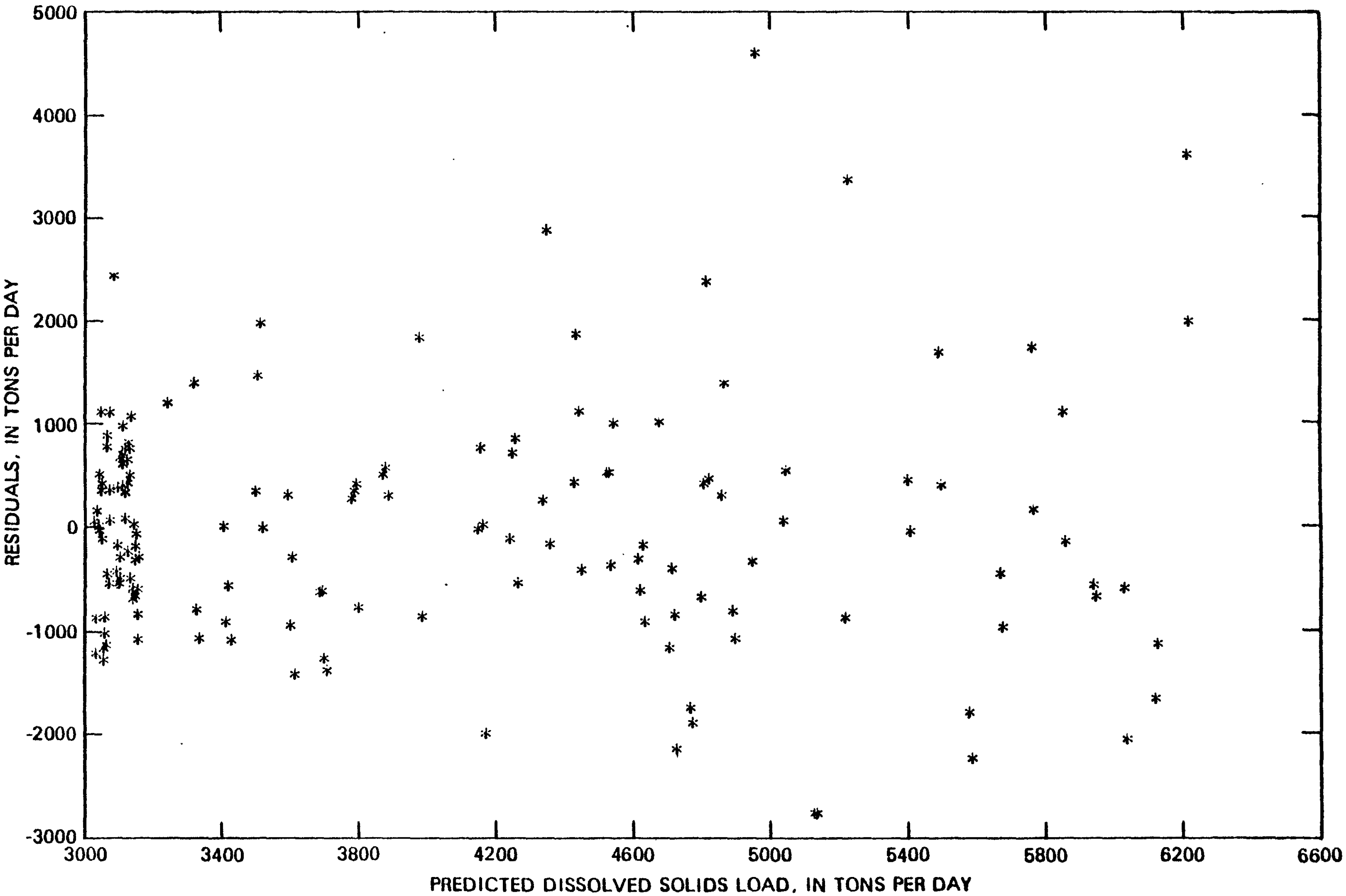

Figure 8.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation DS = f (time), for station 09152500, Gunnison River near Grand Junction, Colo.

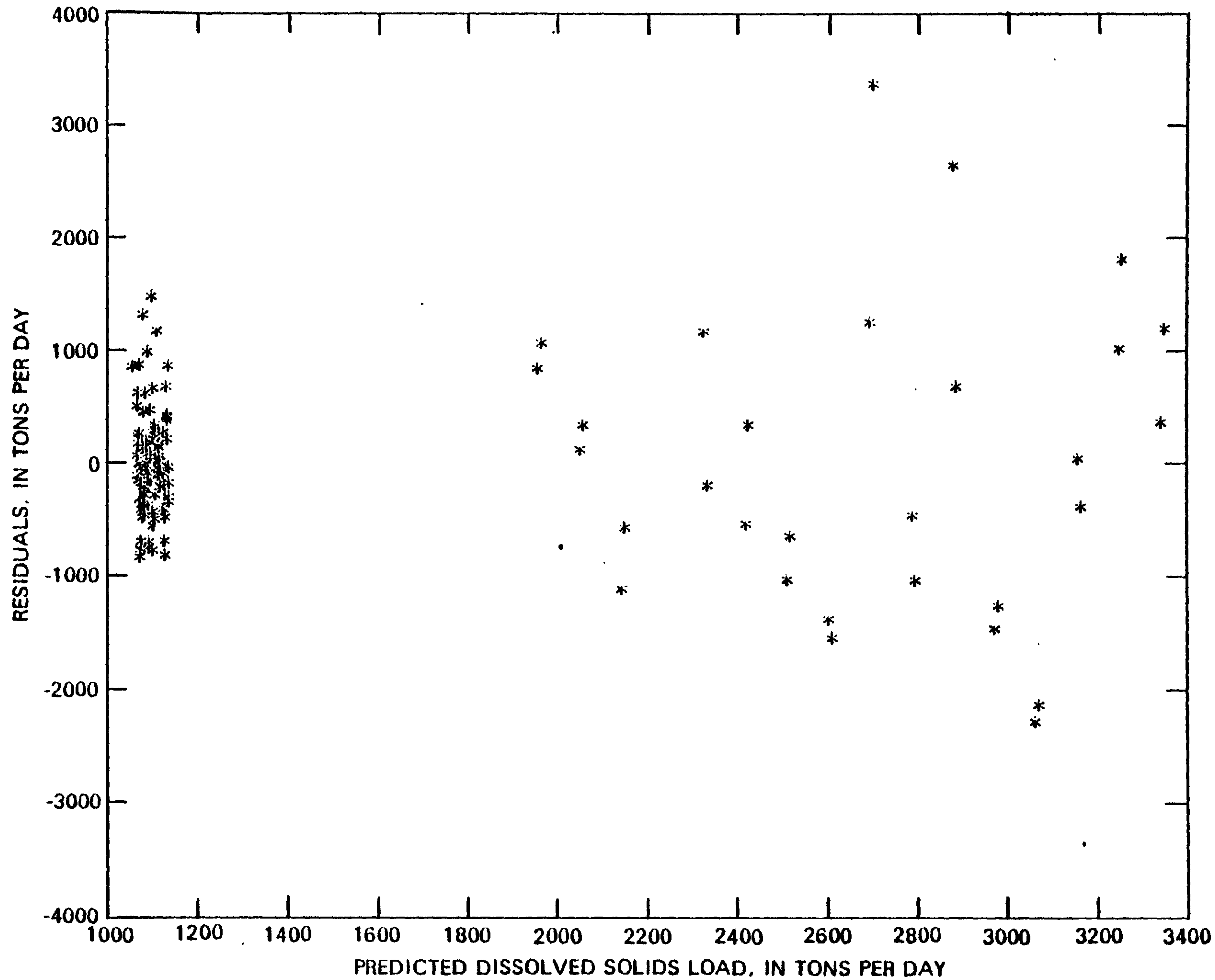

Figure 9.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation DS = f(time), for station 09180000, Dolores River near Cisco, Utah.

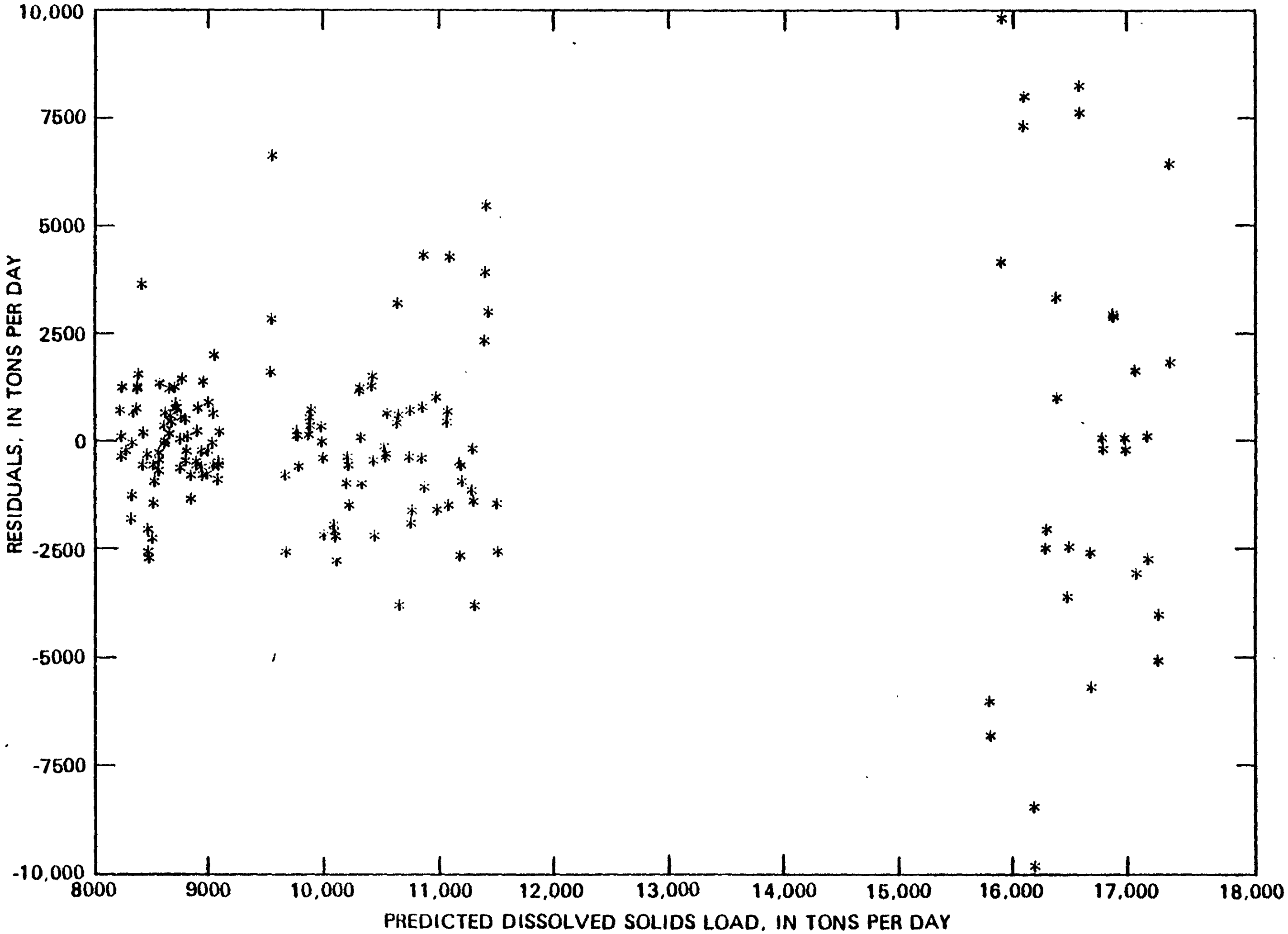

Figure 10.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation DS = f(time), for station 09180500, Colorado River near Cisco, Colo.

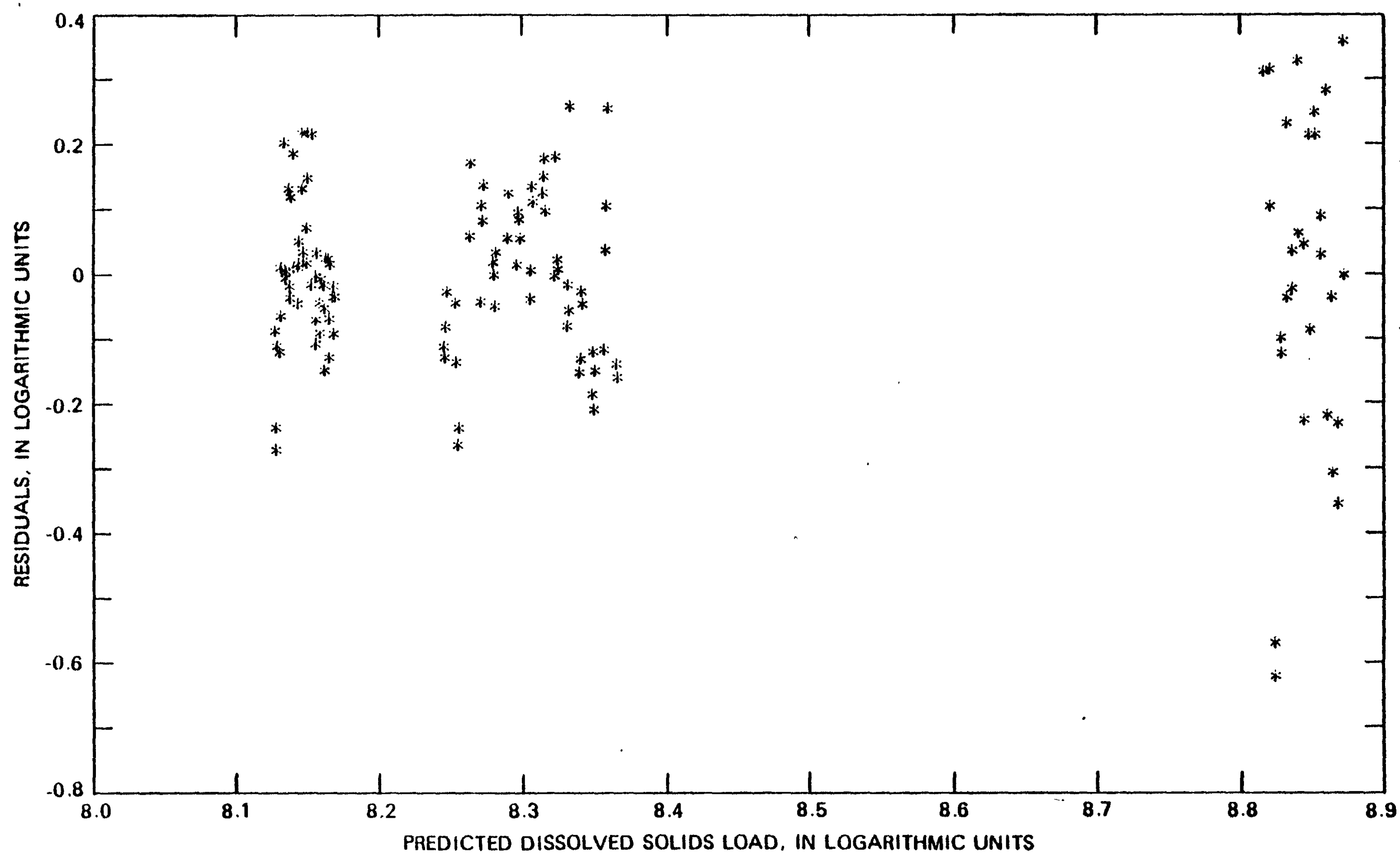

Figure 11.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation ln(DS) = *f* (time), for station 09095500, Colorado River near Cameo, Colo.

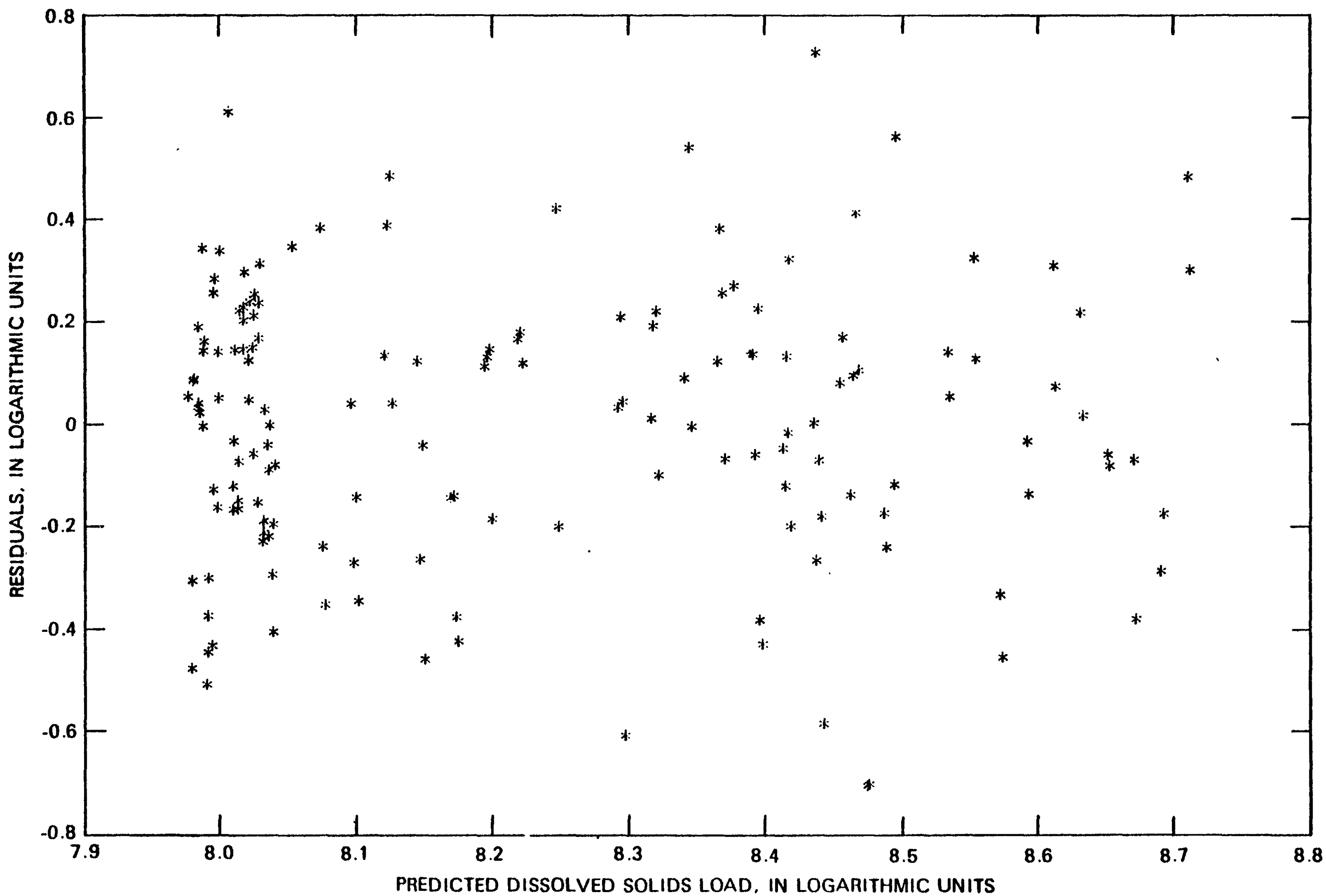

Figure 12.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids for the regression relation ln(DS) = f(time), for station 09152500, Gunnison River near Grand Junction, Colo.

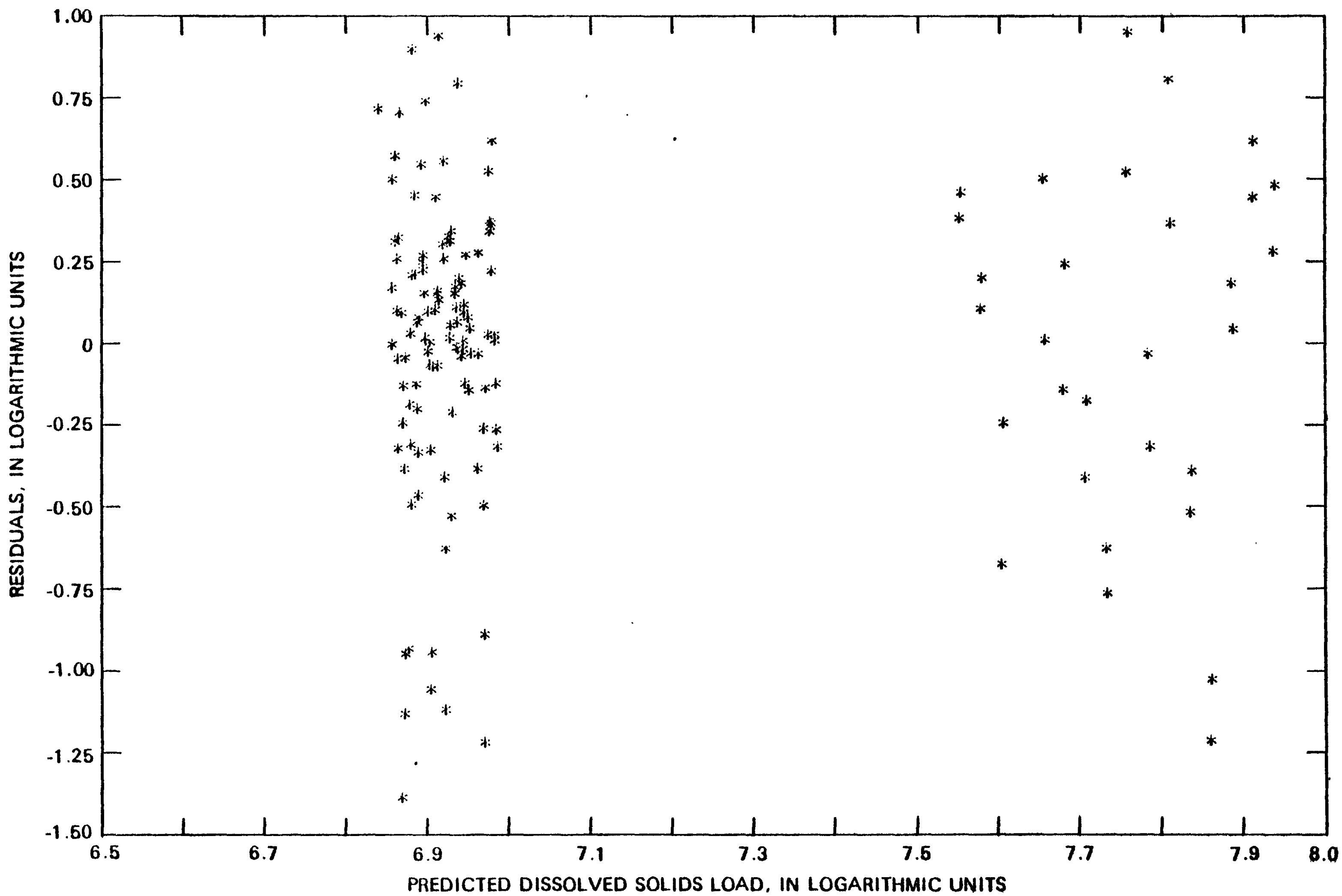

Figure 13.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation ln(DS) = *f*(time), for station 09180000, Dolores River near Cisco, Utah.

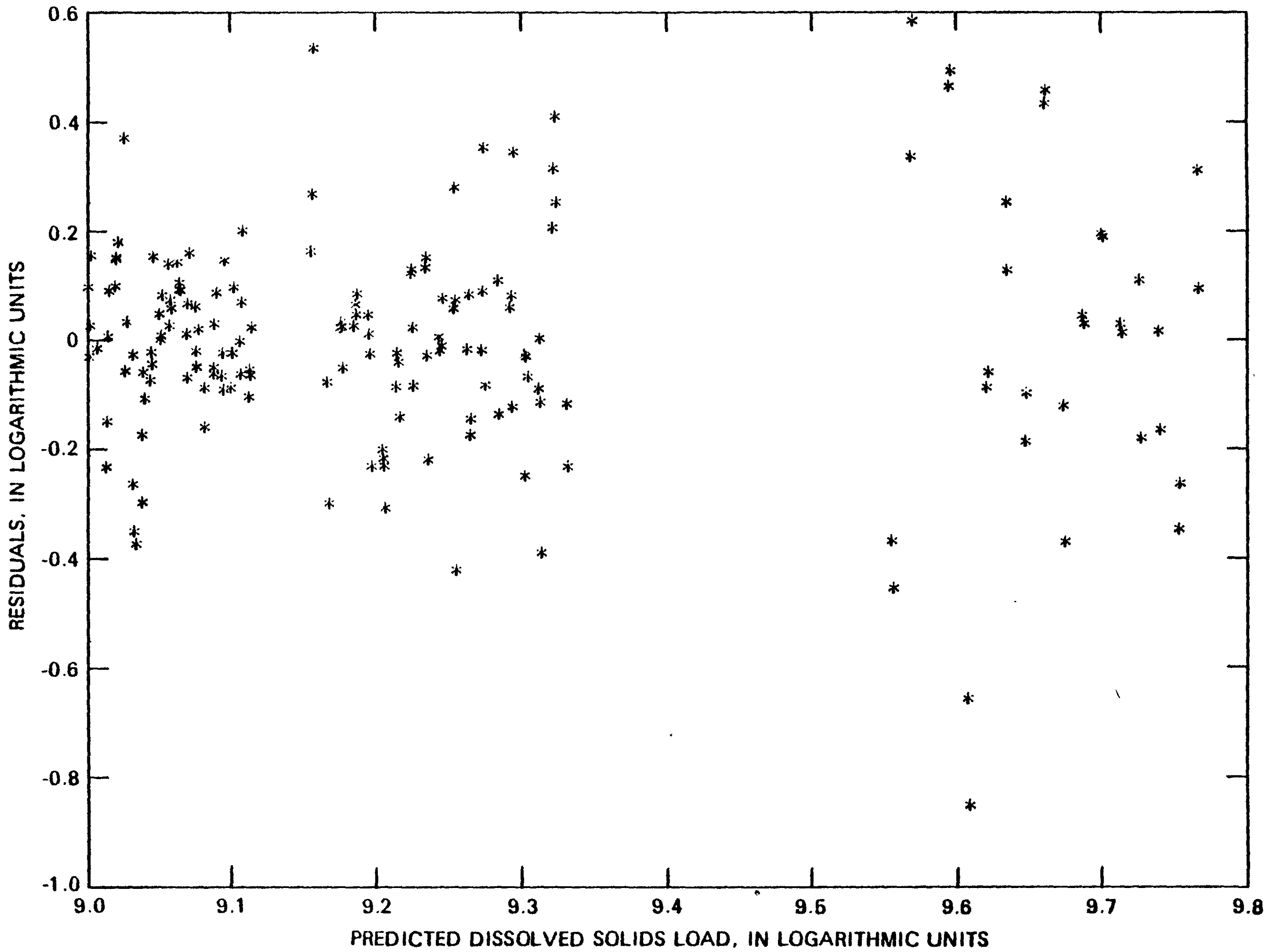

Figure 14.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation ln(DS) = ƒ(time), for station 09180500, Colorado River near Cisco, Utah.

In many instances, solute loads and concentrations are correlated highly with stream discharge. If this is the situation, and discharge shows a temporal trend, then the trend in solute loads or concentrations may be a result of the particular discharge history, rather than an underlying change in the processes by which the solute enters and is carried by the river. Therefore, adding water discharge to the regression reduces the variance in the solute loads and concentrations and makes any existing trends more detectable.

Water-discharge-related variation in the regression analysis was removed by including discharge as an independent variable in the seasonal-regression models (eqs. 8 and 9). The addition of discharge to equations 8 and 9 resulted in the following models:

$$Y=B0+B2(Z2)+B3(T)+B4(Z1*T)+B5(Z2*T)+B6(Q)+B7(Z1*Q)+B8(Z2*Q). \qquad (10)$$

$$Y=B0+B1(Z1)+B2(T)+B3(Z1*T)+B4(Q)+B5(Z1*Q), \qquad (11)$$

where Y=solute load, concentration, or the natural logarithm of these variables,
B0, B1, B2, B3, B4, B5, B6, B7, and B8=regression constants,
Z1 and Z2=dummy variables,
T=time, in years, and
Q=water discharge or the natural log of water discharge.

The residual plots (figs. 15 to 18) show that after eliminating discharge-related variability, the seasonal-regression models more closely approximate a normal distribution of residuals. Variation in the residuals also was substantially reduced. The inclusion of log discharge as an explanation variable in the logarithmic model reduced the variance of the residuals down to 19 to 35 percent of the variance of the model without log discharge.

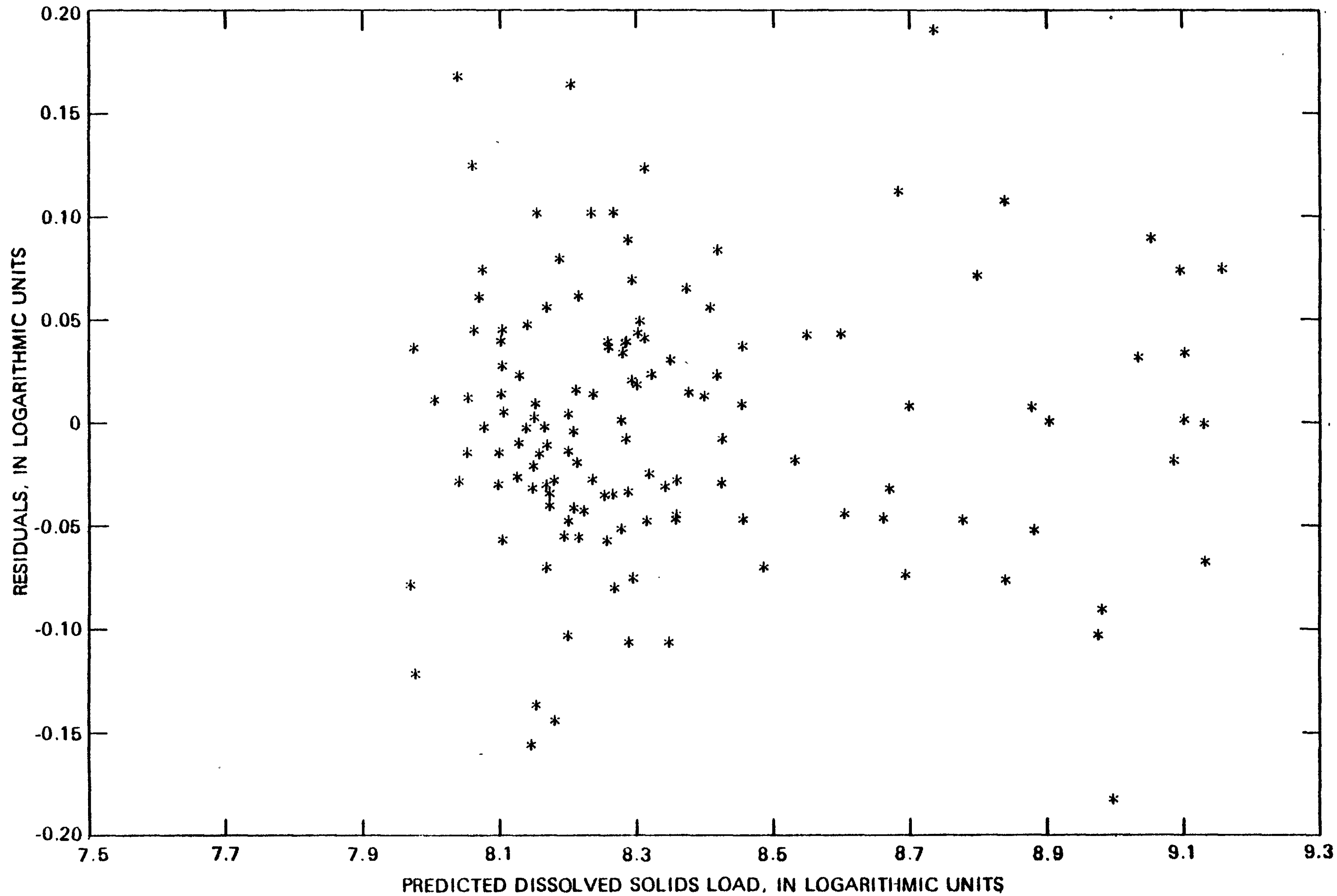

Figure 15.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation $\ln(DS) = f(\text{time}, \ln(Q))$, for station 09095500, Colorado River near Cameo, Colo.

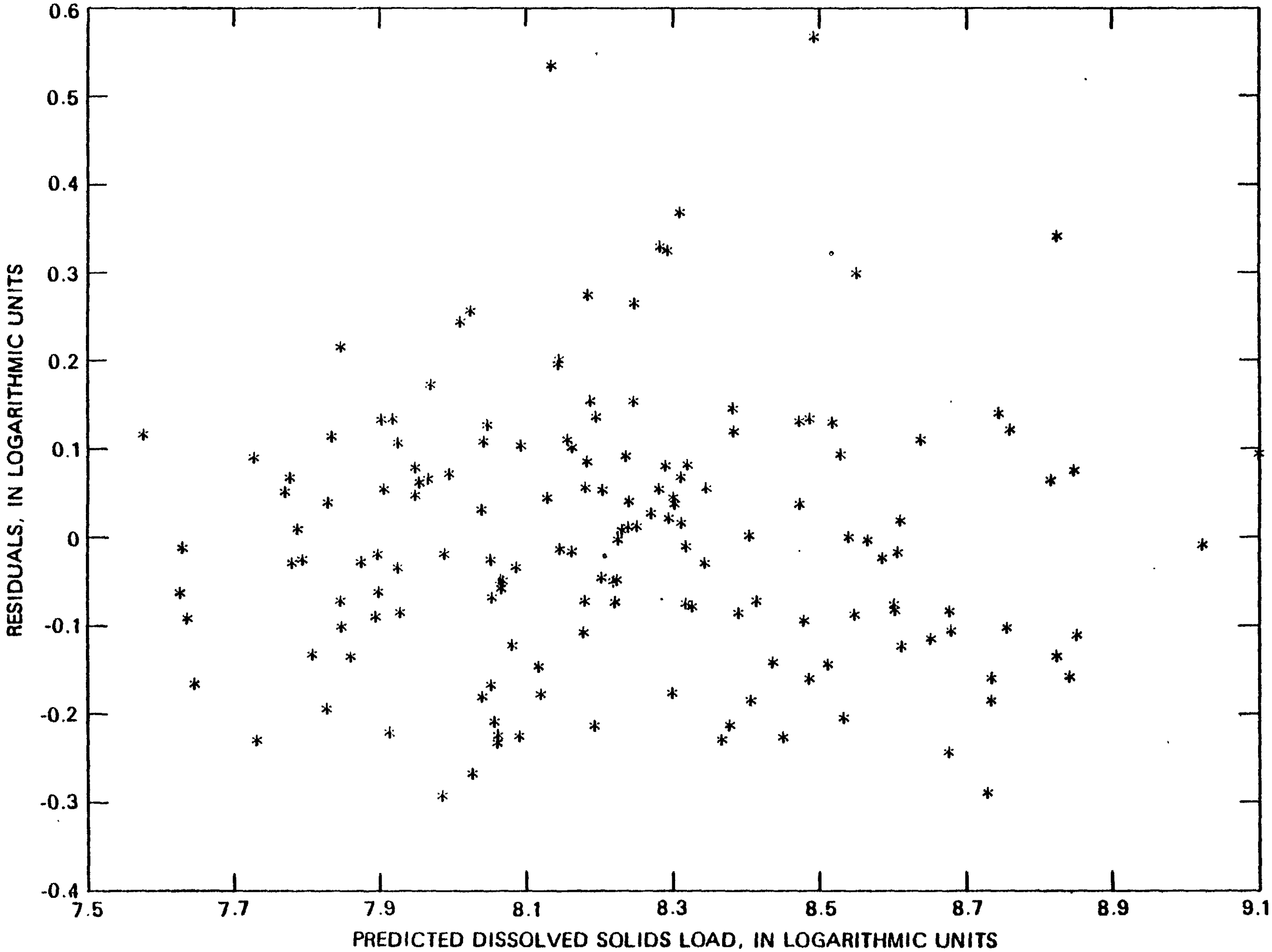

Figure 16.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation $\ln(DS) = f\,(\text{time}, \ln(Q))$, for station 09152500, Gunnison River near Grand Junction, Colo.

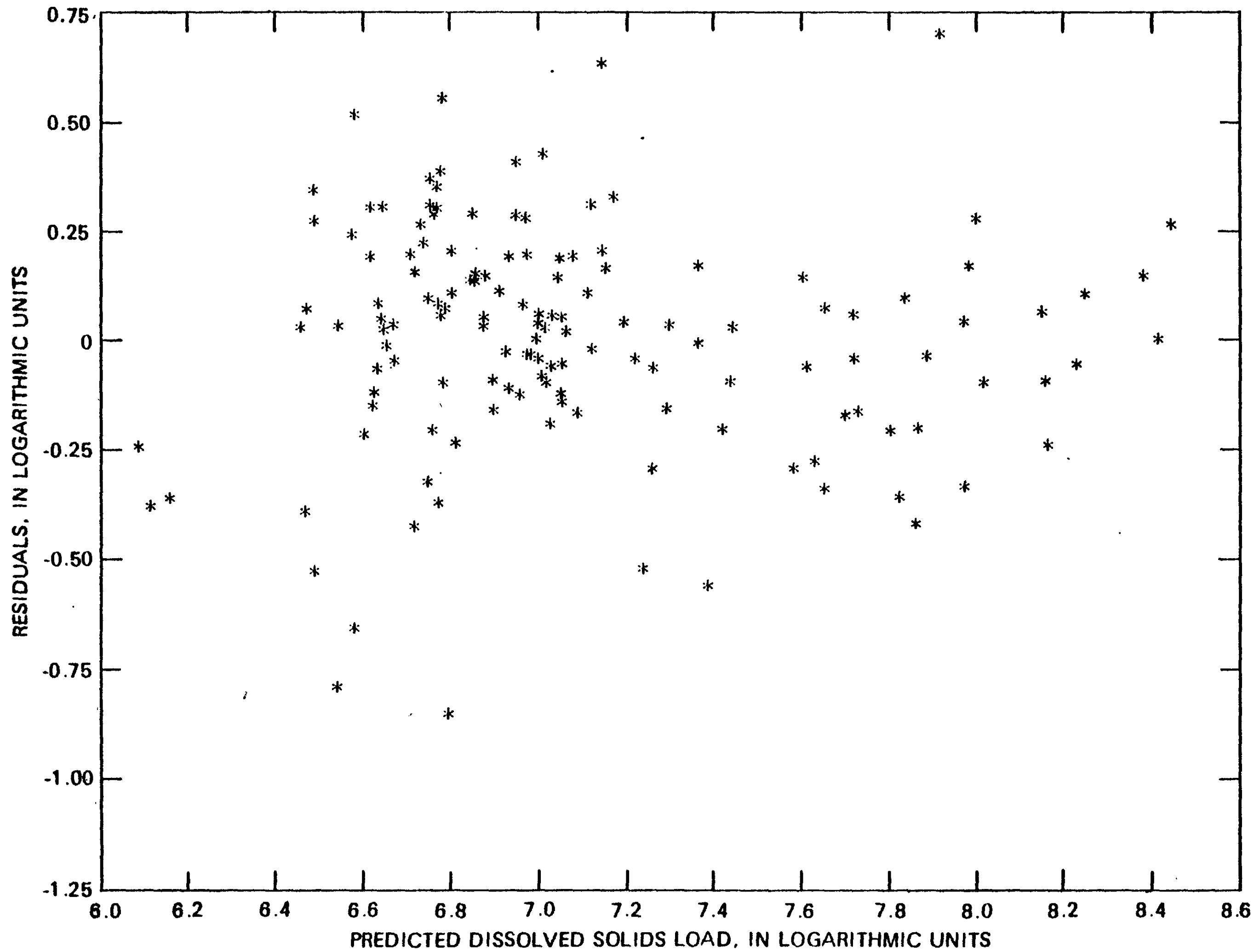

Figure 17.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation ln(DS) = *f* (time, ln(*Q*)), for station 09180000, Dolores River near Cisco, Utah.

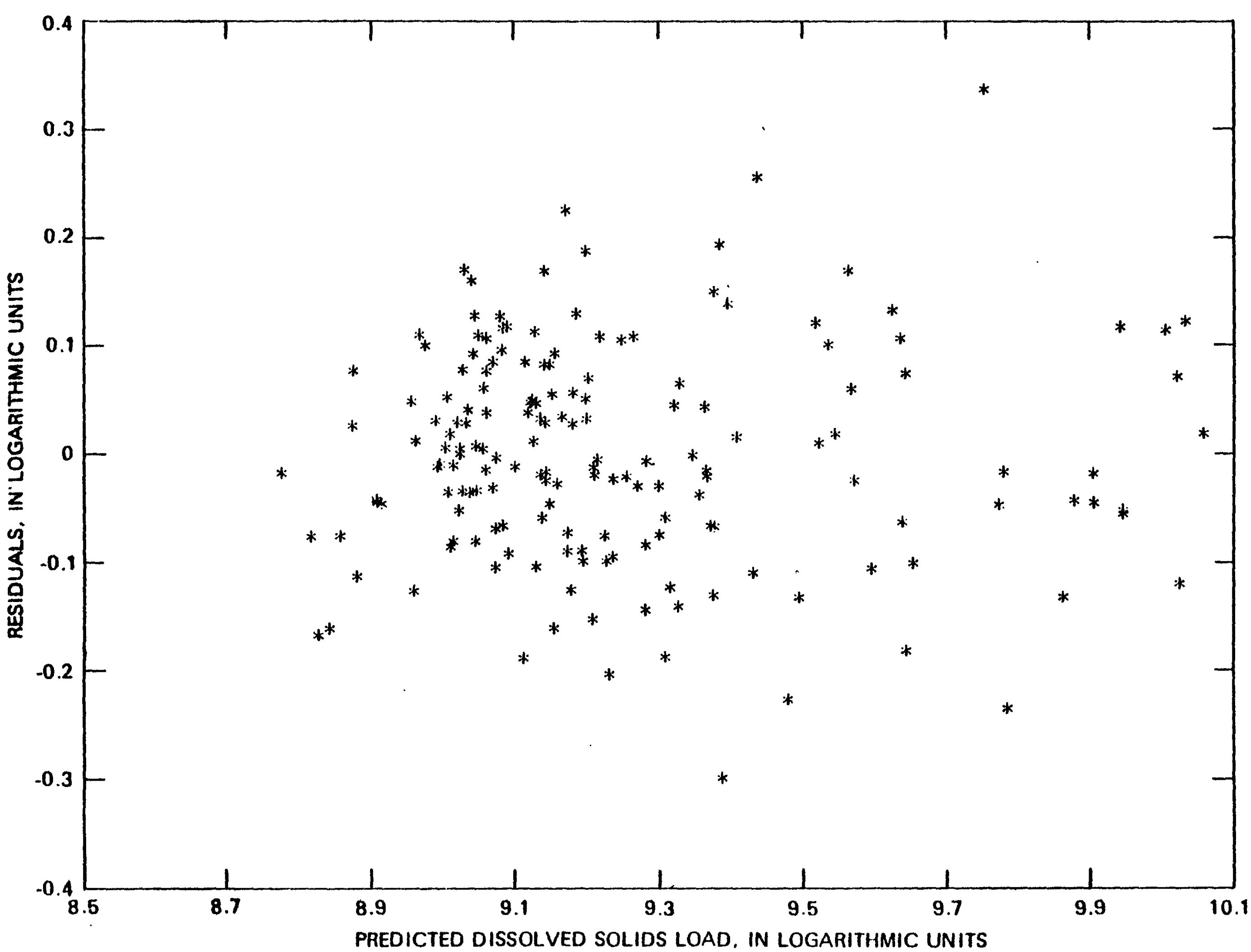

Figure 18.--Residuals (observed dissolved solids-predicted dissolved solids) versus predicted dissolved-solids load from the regression relation $\ln(DS) = f(\text{time}, \ln(Q))$, for the station 09180500, Colorado River near Cisco, Utah.

Results from the seasonal-regression analysis (table 2) for post-1965 data show the effects of logarithmic transformations and discharge-variation removal on trend slopes. The previous discussion on residual analysis indicated that the assumptions behind the real-space models are most likely violated. However, these results are useful for showing the effect that discharge, as an independent variable, had on the trends. Real-space seasonal-regression results also are directly compared to real-space nonparametric results in a later section of this report. Logarithmic seasonal-regression results are valid for this data set, so the actual effects from discharge-variation removal can be quantified from these trend estimates. Results in table 2 show that inclusion of the logarithm of discharge decreases the probability level of the model that does not include logarithm of discharge. In other words, the removal of variance by inclusion of the logarithm of discharge has made the trends more evident. However, there is no particular pattern to the magnitude of the trend slopes. Removal of variance makes the trends more detectable, but has no particular effect on the trend magnitude. However, logarithmic results are difficult to interpret in terms of actual increases or decreases in tons per year of dissolved solids passing a station. Additional seasonal-regression results can be found in tables 5 through 9 and 12 through 15 in the Supplemental Data section at the end of this report. These results are discussed in detail in the Comparison of Trend Results section of this report.

Nonparametric Analysis

The seasonal-Kendall analysis also was used to study temporal trends in the water-quality data. This modified form of Kendall's tau (Kendall, 1975) is applicable to daily, monthly, or annual data sets, with or without seasonality. The procedure tests the significance of a trend and estimates the magnitude of the slope. The hypotheses were tested using the statistic S:

$$S_i = \sum_{k=1}^{m-1} \sum_{j=k+1}^{n_j} \mathrm{sgn}(X_{ij} - X_{ik}), \tag{12}$$

where n_j=number of annual values for season i,

X_{ij}=solute load for season i and year j,

X_{ik}=solute load for season i and year k,

$$\mathrm{sgn}(\theta) = \begin{cases} 1 \text{ if } \theta > 0 \\ 0 \text{ if } \theta = 0 \\ -1 \text{ if } \theta < 0 \end{cases}$$

where $\theta=(X_{ij}-X_{ik})$

Table 2.--*Trend magnitudes of monthly loads determined by seasonal-regression procedures for the post-1965 time period*

[t=time; p=significance probability; R^2=coefficient of determination; SE=standard error, in percent; DS=dissolved solids; Q=water discharge; ln=natural logarithm; N/A=not available]

Station name and number	Seasonal regression method	Trends in monthly loads						R^2	SE in percent
		Base		Season Peak		Return			
		Trend magnitude	p	Trend magnitude	p	Trend magnitude	p		
09095500 Colorado River near Cameo, Colo------	DS=f(time)	-8.0	0.792	-14.5	0.714	-34.3	0.236	0.72	20
	DS=f(time,Q)	-11.8	.335	-17.0	.299	-19.6	.093	.96	8
	lnDS=f(t)	-.003	.572	-.004	.574	-.009	.096	.74	16
	lnDS=f(t,lnQ)	-.006	.016	-.001	.753	-.005	.014	.96	7
09152500 Gunnison River near Grand Juncion, Colo----	DS=f(time)	-7.6	.785	-90.5	.020	-92.8	.0008	.43	29
	DS=f(time,Q)	-27.0	.138	-55.6	.028	-78.2	.0001	.77	18
	lnDS=f(t)	-.004	.574	-.020	.033	-.024	.0002	.42	28
	lnDS=f(t,lnQ)	-.015	.0002	-.010	.051	-.021	.0001	.81	16
09180000 Dolores River near Cisco, Utah------	DS=f(time)	-4.5	.754	92.2	.002	N/A	N/A	.47	51
	DS=f(time,Q)	-2.32	.787	10.9	.553	N/A	N/A	.81	30
	lnDS=f(t)	-.008	.380	.026	.165	N/A	N/A	.36	.49
	lnDS=f(t,lnQ)	.004	.497	.014	.201	N/A	N/A	.77	29
09180500 Colorado River near Cisco, Utah------	DS=f(time)	-47.4	.424	-98.0	.063	-110	.076	.55	24
	DS=f(time,Q)	-63.5	.029	7.55	.880	-90.9	.003	.90	12
	lnDS=f(t)	-.006	.178	-.013	.082	-.010	.041	.55	21
	lnDS=f(t,lnQ)	-.009	.0001	-.001	.875	-.008	.0006	.89	10

The magnitude of the slope was estimated by computing

$$b_{ijk}=(x_{ij}-x_{ik})/(j-k)$$

for all (x_{ij}, x_{ik}) pairs and finding the median of these values,
where d_{ijk}=slope between seasonal values for season i, year j, and
season i, year k, with j>k.

The seasonal-Kendall test gave combined overall results only, based on mean monthly or mean annual data. The procedure did not enable the user to divide the annual cycle into seasons of unequal duration. Therefore, rather than the two or three seasons used in the seasonal-Kendall models, each month was considered a separate season in the seasonal-Kendall procedure. Flow-adjusted concentrations were used as dependent variables in the seasonal-Kendall model to remove discharge-related variation. Flow-adjusted concentrations are the residuals of the regression between the constituent concentration and water discharge.

The flow-adjustment procedure is performed as follows:

1. Find the "best fit" regression relationship for c=f(Q), where c is the estimated concentration and f(Q) is a function of discharge. The function used in this analysis is ln(c)=a+b(ln(Q)).
2. Compute a time series of flow-adjusted concentrations (FAC), using $W_{ij}=C_{ij}-\hat{C}_{ij}$ as the FAC for month i and year j, where C_{ij} is the actual concentration.

Results from the seasonal-Kendall analysis (table 3) for post-1965 data show that log transformations have no effect on the significance of the trend. This is characteristic of seasonal-Kendall computational procedures. However, the trend magnitudes for logarithmic data cannot be converted to real values by exponentiation of the slope estimates.

The worth of logarithmic transformations for the seasonal-Kendall procedure is that logarithmic-slope estimates can be directly compared to FAC-slope estimates to determine the amount of discharge-related variation removed. Additional seasonal-Kendall results can be found in tables 10 and 11 in the Supplemental Data section at the end of the report. Seasonal-Kendall results are discussed in detail in the following section of this report.

Table 3.--*Trend magnitudes of monthly loads determined by the seasonal-Kendall procedure for post-1965 time period*

[T/d=ton per day; yr=year; ln=natural logarithm; mg/L=milligram per liter; FAC=flow adjusted concentration]

Station number	Station name		Trend magnitude	Significance probability
09095500	Colorado River near Cameo, Colo---------	Monthly load, (T/d)/yr------------	-6.00	0.547
		Monthly load, ln(T/d)/yr----------	-.001	.547
		Monthly concentration, (mg/L)/yr--	-1.6	.323
		Monthly concentration, ln(mg/L)/yr	-.003	.323
		FAC, ln(mg/L)--------------------	-.004	.0001
09152500	Gunnison River near Grand Junction, Colo---------	Monthly load, (T/d)/yr------------	-41.6	.005
		Monthly load, ln(T/d)/yr----------	-.011	.005
		Monthly concentration, (mg/L)/yr--	-14.5	.0001
		Monthly concentration, ln(mg/L)/yr	-.020	.0001
		FAC, ln(mg/L)/yr-----------------	-.020	.0001
09180000	Dolores River near Cisco, Utah---------	Monthly load, (T/d)/yr------------	2.69	.768
		Monthly load, ln(T/d)-------------	.003	.768
		Monthly concentration, (mg/L)/yr--	20.3	.018
		Monthly concentration, ln(mg/L)/yr	.017	.018
		FAC, ln(mg/L)/yr-----------------	.007	.045
09180500	Colorado River near Cisco, Utah---------	Monthly load, (T/d)/yr------------	-55.0	.002
		Monthly load, ln(T/d)/yr----------	-.006	.002
		Monthly concentration, (mg/L)/yr--	-6.41	.033
		Monthly concentration, ln(mg/L)/yr	-.008	.033
		FAC, ln(mg/L)/yr-----------------	-.008	.0001

Comparison of Trend-Analysis Results

Four methods of seasonal-regression analysis and seasonal-Kendall analysis were used for four different time periods to determine trends. Trend results varied in magnitudes and significance between time periods and method used. Results for the various time periods analyzed, constituents, and methods are presented in the Supplemental Data section at the end of the report.

Trend results indicate that selection of the appropriate time period for trend analysis is important. For example, during base-flow season, a significant downward trend in dissolved-solids load was found in the post-1965 time period for three of the four stations; however, no significant trends in dissolved-solids load were found in the base-flow season for the post 1969 time period for any of the stations (table 4). Other examples of the difference in trend results that can be obtained depending on the time period selected are shown in table 4. Therefore, it is important in future trend analyses that careful consideration and justification be given to the time period selected.

Seasonal-regression results (table 2) and the seasonal-Kendall results (table 3) for post-1965 data computed with Method 1 can generally be compared to assist in determining the applicability of seasonal-regression models. Seasonal-Kendall models are nonparametric, so they are applicable regardless of data-set distribution. If appropriate seasonal-regression results compare well to seasonal-Kendall results, then the corresponding seasonal-regression model is most likely applicable.

Seasonal-regression trend estimates for real-space monthly load data are generally greater in magnitude and less significant than corresponding seasonal-Kendall slope estimates. Both seasonal-regression and seasonal-Kendall estimates are consistent in direction of trends. The significance of seasonal-regression trends (at α=0.05) during peak-flow and return-flow periods generally agree with the significant overall seasonal-Kendall trends, except at station 09180500 Colorado River near Cisco, Utah, where seasonal regression fails to detect a significant trend in any season and seasonal Kendall detects a significant overall trend. Seasonal regression failed to detect any trends during the base-flow season using untransformed data.

The same observations are true for the seasonal-regression and seasonal-Kendall slope estimates for logarithmic-transformed monthly load data, except that seasonal-regression does detect a significant (α=0.05) trend during the return-flow season at station 09180500 Colorado River near Cisco, Utah. Actual significance levels seem to show better agreement in logarithmic models than in real-space models.

The effects of flow adjustment on trend results are variable in both seasonal-regression and seasonal-Kendall procedures. The following observations can be made, comparing the logarithmic seasonal-regression model to the logarithmic seasonal-regression model with flow adjustment of monthly loads:

Table 4.--*Trend results of mean monthly dissolved solids computed by Method 1, using the regression relation ln(DS)=f(time,ln(Q)).*

[(T/d)/yr=ton per day per year; P=significance probability; ln=natural logarithm; R^2=coefficient of determination; SE=standard error; N/A=not available]

Station number and name	Time period	Trends in monthly loads, in ln((T/d)/yr)							
		Season							
		Base		Peak		Return			
		Trend magnitude	P	Trend magnitude	P	Trend magnitude	P	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo------	pre-1965	-0.001	0.211	0.001	0.595	0.000	0.914	0.96	7
	post-1965	-.006	.016	-.001	.753	-.005	.014	.96	7
	post-1969	-.006	.150	.004	.461	-.011	.009	.96	7
09152500 Gunnison River near Grand Junction, Colo------------------	pre-1965	-.005	.0001	-.002	.152	-.006	.0001	.94	10
	post-1965	-.015	.0002	-.010	.051	-.021	.0001	.81	16
	post-1969	-.007	.244	-.014	.104	-.020	.001	.78	17
09180000 Dolores River near Cisco, Utah------	pre-1965	-.007	.325	.013	.344	N/A	N/A	.73	23
	post-1965	.004	.497	.014	.201	N/A	N/A	.77	29
	post-1969	-.001	.882	.021	.240	N/A	N/A	.76	30
09180500 Colorado River near Cisco, Utah------	pre-1965	-.002	.012	-.002	.083	-.003	.0001	.95	8
	post-1965	-.009	.0001	-.001	.875	-.008	.0006	.89	10
	post-1969	.000	.976	.004	.446	-.002	.600	.90	10

1. Flow adjustment increases the magnitude and significance of base-flow trends. Station 09180000 Dolores River near Cisco, Utah, is an exception; there the significance of the trend decreased.
2. Flow adjustment decreases the magnitude and significance of peak-flow trends.
3. Flow adjustment decreases the magnitude and increases the significance of return-flow trends.

Flow-adjustment effects were present, but not consistent, when the logarithmic seasonal-Kendall concentration and seasonal-Kendall FAC results were compared.

Logarithmic flow-adjusted seasonal-regression results for monthly loads are identical to concentration results for the same model; they can be directly compared with seasonal-Kendall FAC results. Trends from the seasonal-Kendall-FAC model were always more significant than seasonal-regression model trends found for any season at all stations. Seasonal-Kendall trends were significant (α=0.05) at all stations; seasonal-regression trends were not significant for either season at station 09180000 Dolores River near Cisco, Utah, or for peak flow at all four stations.

Advantages and disadvantages were found in both seasonal-regression and seasonal-Kendall models. Primary advantages of the seasonal-regression models were:

1. Slope estimates were statistically supported and could be tested, using standard hypothesis tests.
2. Trend estimates were given for each separate season. This feature allowed more critical assessment of seasonal trends and effects of flow adjustment.
3. Seasonal breakdown could be applied in many different ways: for example, monthly, bimonthly, or actual seasons.

Disadvantages of the seasonal-regression models were:

1. Assumptions of data distribution were difficult to satisfy and could not be adequately tested.
2. The models were not resistant to outliers.
3. The models could be affected by serial correlation in the data.
4. Results from the logarithmic models, which were necessary for this particular data set and seasonal breakdown, were difficult to interpret. However, the trends of the logarithmic models may be used as percentages. If b is the estimated trend, then the trend may be described as being $(e^b-1)\cdot 100$ percent per year.

Advantages of the seasonal-Kendall models were:

1. Transformations were not needed, because data-distribution assumptions were not necessary. The models were known to be applicable to all the data.
2. The models were resistant to outliers.
3. Computations were easy to make.

Disadvantages of the seasonal-Kendall models were:

1. The models could be affected by serial correlation in the data.
2. FAC results were difficult to interpret.

In general, the "best" model to be used for these data is a function of the intended uses of the results. Seasonal-Kendall procedures require fewer assumptions about the underlying distribution and give reliable "yes-no" results concerning existence of a trend. Seasonal-regression models are more difficult to apply and are sometimes of questionable validity, but the results they give are informative and well quantified.

Results obtained by using the logarithmic flow-adjusted seasonal-regression model data sets derived from Methods 1 and 2 (tables 8 and 9) in the Supplemental Data section) show that Method 2 results have a greater number of significant trends (65 significant trends at α=0.05 for all parameters at all stations) than the Method 1 results (39 significant trends). However, Method 1 data yield some significant trends, where Method 2 data do not. Trends of equal magnitude found in both data sets are not always of equal significance because the two data sets have different variances. The reasons for the other variable results are not entirely clear, but differences in model degrees of freedom and differences in the amount of serial correlation in the data are possible causes. When a data set has serial dependence, the probability of obtaining a positive test for trend when the process is not changing over time is higher than the preselected probability, which for this study was 0.05. It is probable that both data sets determined by data fill-in may be serially correlated; however, the amount of serial correlation built in by the monthly calculations cannot be readily determined without the existence of a complete data set. As mentioned previously, accounting for serial correlation is at best an art. However, the trend results determined are of value, as long as the user is aware that more trends then actually exist may be detected. Future trend studies using the preferred method of data fill-in and trend detection first should evaluate whether serial correlation exists, using a time-series analysis. This was not done here, because the main purpose of this study was to present various methods of determining trends in the Colorado River basin. It should be noted that serial correlation will equally affect the seasonal-regression and the seasonal-Kendall method of determining trend.

OPTIMIZATION OF DATA COLLECTION

Economic analysis of each stream-gaging station's worth is necessary to optimize the value of a water-resource monitoring network. The uncertainty or error in estimation of instantaneous water discharge or specific conductance at a station serves as an inverse surrogate of its economic worth. Uncertainty is expressed as the standard deviation of the error of estimate of true instantaneous water discharge or conductivity. This portion of the study presents a possible method to determine the uncertainty in both water discharge and water quality at individual gaging stations.

Uncertainty in water discharge or conductivity is often a function of the frequency of visits that are made to the gage to service the recording equipment and to make discharge and water-quality measurements. Frequent visits minimize the uncertainty at any particular stream gage; however, these visits require money and manpower.

A set of techniques called K-CERA (Kalman filtering for Cost-Effective Resource Allocation) was developed by Moss and Gilroy (1980) to study the cost effectiveness of stream-gaging networks. These techniques were used to develop uncertainty curves for instantaneous water discharge at the four gaging stations in the study area. The same techniques with some modifications were used for one of these stations, 09180500 Colorado River near Cisco, Utah, to develop an uncertainty curve for water-quality parameters.

The model used in the analysis assumes that the difference between the true instantaneous water discharge and predicted rating-curve discharge is a continuous first-order Markov process. The probability distribution of a set of these differences is assumed to be Gaussian (normal) with a zero mean. The variance of this distribution is referred to as the process variance. True instantaneous discharges can only be estimated through measurements, so the process variance is estimated using the mean-squared differences (residuals) between the rating curve and the discharge measurements less the errors in the discharge measurements. For more detail on the theory and application of the K-CERA model, see Moss and Gilroy (1980) and Gilroy and Moss (1981).

Water-Discharge Measurement Frequency

Computation of the error variance about the base-stage discharge relation was done in three steps:

1. A long-term rating was defined, generally based on measurements of 3 or more years, and deviations (residuals) of the measured discharges from the rating discharge were determined.
2. The time series of these residuals was analyzed to calculate the 1-day lag (lag-one) autocorrelation coefficient and the process variance required by the K-CERA model.
3. Finally, the error variance was defined within the model as a function of the lag-one autocorrelation coefficient, the process and measurement variances, and the frequency of discharge measurements.

Definition of long-term base ratings was complicated by the fact that periods of backwater from ice may last 1 to 3 months of each year. Rating curves based on ice measurements are not applicable to base ratings; measurements during ice periods were ignored for this study.

Logarithmic base-rating curves applicable to ice-free periods were determined for each station used in the evaluation. The rating function used was:

$$LQM=B1+B3*LOG(GHT-B2) \qquad (13)$$

where LQM=natural logarithm value of the measured discharge,
GHT=recorded gage height corresponding to the measured discharge,
B1, B2, B3=regression constants determined by a nonlinear procedure (Helwig and Council, 1979) which have the following physical interpretation:
B1=logarithm of discharge for a flow depth of 1 foot,
B2=gage height of zero flow, and
B3=slope of the rating curve.

Residuals about the base rating for an individual gage were used to define total variance. Measurement variance for the four gages was set equal to the square of the 5-percent standard error. Thus, the process variance required in the model is the total variance of the residuals about the base rating minus the constant-measurement variance. Time-series analysis of the rating residuals was used to compute sample estimates of the lag-one autocorrelation coefficient required to compute the variance during the time when the recorders were functioning.

Values of the lag-one autocorrelation coefficient, measurement and process variance, length of season, and data for the definition of missing-record probabilities are used jointly to define uncertainty functions for each gaging station. Uncertainty functions gave the relationship of error variance to the number of visits, assuming a measurement was made at each visit. The relation of standard error of estimate of instantaneous discharge to the number of measurements per year for the four gaging stations in this study is shown in figure 19.

Water-Quality Sampling Frequency

The error variance of conductivity as a function of the frequency of measurements was computed at station 09180500 Colorado River near Cisco, Utah, from a modified version of the water-discharge analyses. The modified K-CERA model used water-quality measurement errors and residuals about a water-quality stage rating to calculate process variance. A one-step procedure was used to relate instantaneous conductivity to stage. A similar model with modifications could be set up relating other water-quality constituents to stage. The rating function used was of the form:

$$LOG\ (parameter)=B1+B2\ LOG(GHT), \qquad (14)$$

where LOG (parameter)=the natural logarithm of either specific conductance, in µmhos/cm at 25°C,
B1, B2=regression constants, and
LOG (GHT)=the natural logarithm of the recorded gage height corresponding to the measured conductivity.

The uncertainty function based on this rating for station 09180500 Colorado River near Cisco is shown in figure 20.

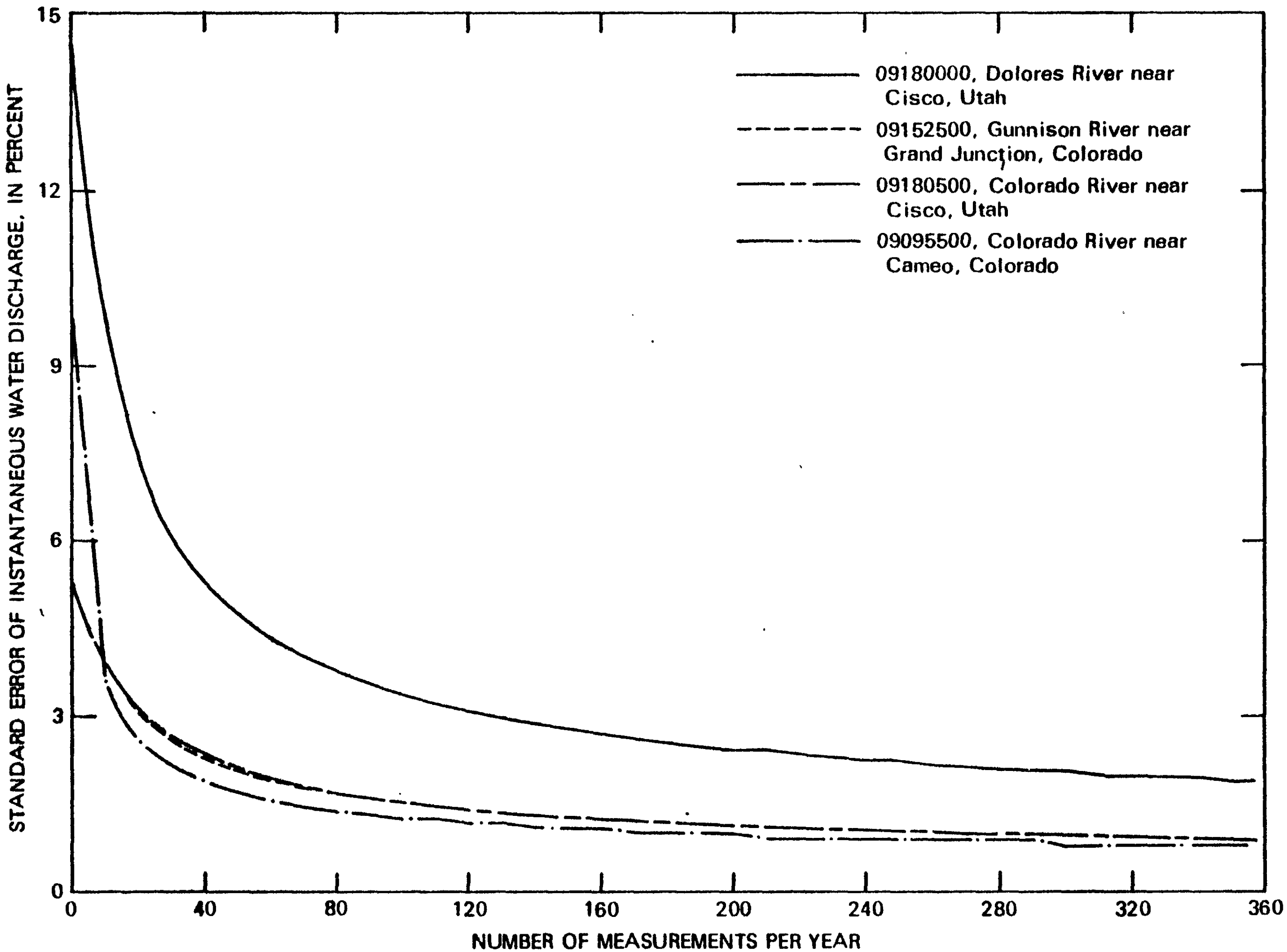

Figure 19.--Uncertainty curves of error expressed as a percentage of instantaneous discharge at the four study sites.

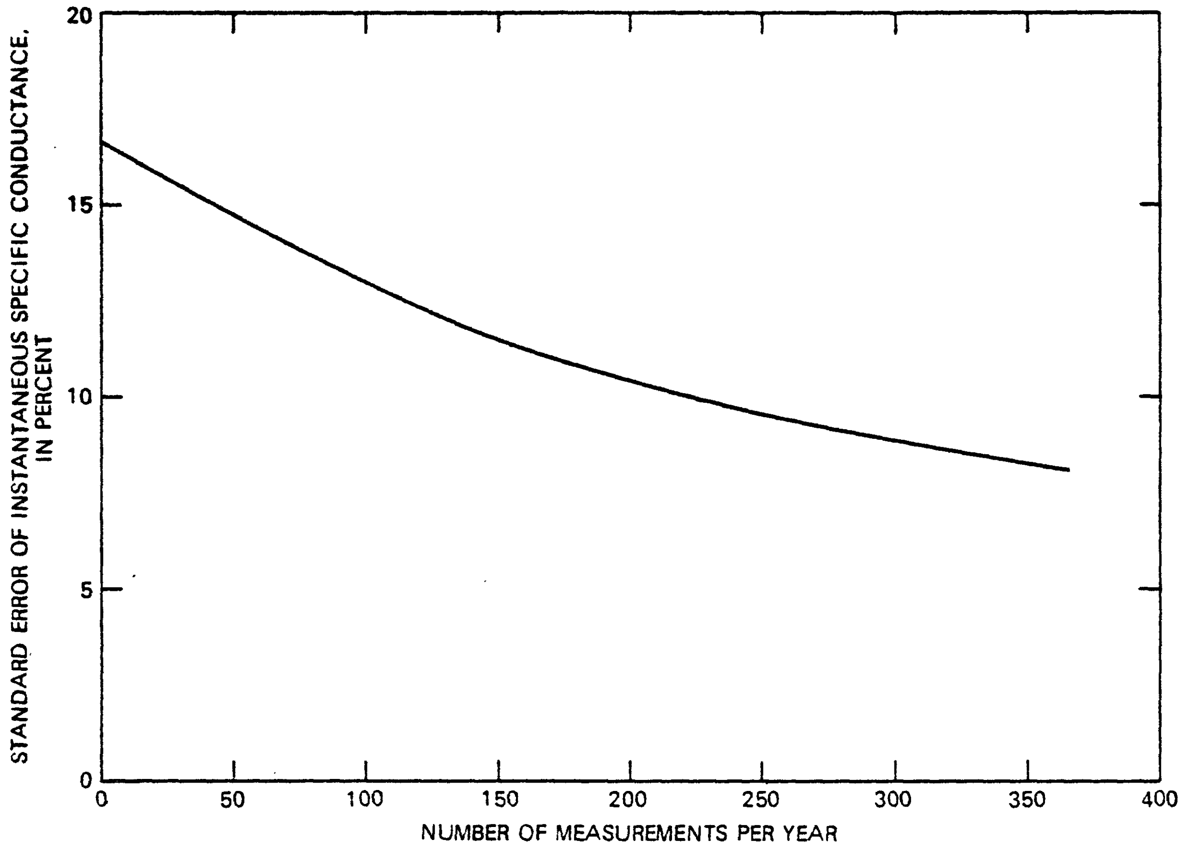

Figure 20.--Uncertainty curve of error expressed as a percentage of instantaneous specific conductance for station 09180500, Colorado River near Cisco, Utah.

Results

Apparent differences exist between the uncertainty relations developed from instantaneous water discharge and instantaneous conductivity. Higher standard error for zero measurements in figure 20 indicates there may be a higher total variation in the stage-conductivity rating curve than in the stage-discharge rating. This may be attributed to a more poorly defined and variable physical relationship between stage and conductivity, as opposed to the better defined stage-discharge relationship. The slower decay of the conductivity-uncertainty curve with increasing frequency of measurement also is seen in figure 20. Stage-conductivity residuals for the Colorado River near Cisco are not autocorrelated to the extent of the discharge residuals. This is a possible indication of less "memory" in the stage-conductivity system.

In general, it was found that the K-CERA method has potential for future application to salt-load data, but a more refined technique should be investigated. The lack of a true physical stage-water-quality relationship created difficulties in interpreting corresponding uncertainty curves. Gage-height data used to define stage-conductivity rating was unadjusted with respect to physical changes in channel control, so additional variation was included in the data.

SUMMARY

Monthly values were computed for water discharge, dissolved solids, calcium, magnesium, sodium, sulfate, chloride, and bicarbonate at four gaging stations in the Upper Colorado River Basin to analyze the data for trends. The stations used in this study were: (1) 09095500 Colorado River near Cameo, Colo.; (2) 09152500 Gunnison River near Grand Junction, Colo.; (3) 09180000 Dolores River near Cisco, Utah; and (4) 09180500 Colorado River near Cisco, Utah.

The long-term record for each station was divided, based on development in the upper basin. The 1965 and the 1969 water years were used as a dividing point. Pre-1965, post-1965, post-1969, and the entire period of record were analyzed for trends. The data were analyzed for seasonality by examining the variability in the monthly values; each station's record was divided accordingly.

Seasonal regressions were run on monthly and annual data using dummy variables to account for seasonality. Four different seasonal-regression models were examined attempting to satisfy the assumptions of regression analysis. Two seasonal regressions were run, using untransformed monthly values. The first regression used each of the parameters versus time; the second regression included discharge as an independent variable in the model. The other two regressions used logarithmic-transformed data, with and without discharge as an independent variable.

A seasonal-Kendall analysis also was used to determine temporal trends. This method was applied to monthly, annual, and flow-adjusted data. Each month was considered a separate season in this procedure, as opposed to the two or three seasons used in the regression models.

Trend results varied with monthly load-computational method, period of record, and trend-analysis model used. No conclusions were reached regarding which computational method was superior for use in trend analysis. Time-period selection for analysis was found to be important with regard to intended use of the results. Trend analysis on long periods of record potentially masks shorter duration trends that may be of interest.

Results were used to explore the suitability of various trend-analysis models. Seasonal-Kendall procedures were found to be applicable to almost any data set but only gave reliable "yes-no" results concerning existence of a trend. Seasonal-regression models were more difficult to apply and were sometimes of questionable validity, but the results were found to be more informative and quantified than the seasonal-Kendall results. The "best" model to use was found to be a function of the characteristics of the data set and the amount of trend information needed.

A recently developed method for determining optimal water-discharge data-collection frequency was described and applied to water-quality data. Uncertainty curves were developed at the four study sites, relating error in water-discharge records to number of measurements taken per year. Another uncertainty curve was developed relating error in a water-quality record to number of measurements taken per year. This method was found to have potential for application to water-quality data, but refinements are necessary.

SELECTED REFERENCES

Crawford, C. G., Slack, J. R., and Hirsch, R. M., 1983, Testing for trends in water-quality data using the statistical-analysis system: U.S. Geological Survey Open-File Report 83-550, 102 p.

Gilroy, E. J., and Moss, M. E., 1981, Cost-effective stream-gaging strategies for the Lower Colorado River Basin: U.S. Geological Survey Open-File Report 81-1019, 38 p.

Helwig, J. T., and Council, K. A., eds., 1979, SAS users guide, 1979 edition: Raleigh, North Carolina, SAS Institute, Incorporation, 494 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hirsch, R. M., Slack, J. R., and Smith, R. A., 1982, Techniques of trend analysis for monthly water quality data: Water Resources Research, v. 18, no. 1, p. 107-121.

Kendall, M. G., and Stuart, Alan, 1968, The advanced theory of statistics, v. 3 (2nd ed.): London, Charles Griffin and Co., Ltd., 557 p.

Kircher, J. E., and Karlinger, M. R., 1983, Effects of water development on surface water hydrology, Platte River basin in Colorado, Wyoming, and Nebraska upstream from Duncan, Nebraska: U.S. Geological Survey Professional Paper 1277-B, 49 p.

Kircher, J. E., and Von Guerard, Paul, 1982, Evaluation of sediment yield and sediment data-collection network in the Piceance basin, northwestern Colorado: U.S. Geological Survey Water-Resources Investigations 82-4046, 25 p.

Lane, W. L., 1975, Extraction of information on inorganic water quality, hydrology paper 73, Colorado State University, Fort Collins, Colorado.

Moss, M. E., and Gilroy, E. J., 1980, Cost-effective stream-gaging strategies for the Lower Colorado River Basin: U.S. Geological Survey Open-File Report 80-1048, 111 p.

Mueller, D. K., and Moody, C. D., 1983, Historical trends in concentration and load of major ions in the Colorado River system, presentation at the International Symposium on State-of-the-Art Control of Salinity, July 13-15, 1983, Salt Lake City, Utah, 13 p.

Statistical Analysis System Institute, Inc., 1982, SAS users guide to basics, 1982 edition: Cary, North Carolina, SAS Institute, Inc., 924 p.

Snedecor, G. W., and Cochran, W. G., 1967, Statistical methods, (6th ed.): Ames, Iowa, The Iowa State University Press, 539 p.

Smith, R. A., Hirsch, R. M., and Slack, J. R., 1982, A study of trends in total phosphorus measurements at NASQAN stations: U.S. Geological Survey Water-Supply Paper 2190, 34 p.

U.S. Bureau of Reclamation, 1983, Quality of Water, Colorado River basin: Progress Report No. 11, U.S. Department of the Interior, 148 p.

U.S. Geological Survey, 1979, WATSTORE, National Water Data Storage and Retrieval System: Reston, Virginia.

SUPPLEMENTAL DATA

Table 5.--*Trend results of monthly values computed by Method 1, using the regression relation, parameter=f(time), for the post-1965 time period*

[P=significance probability; R^2=coefficient of determination; SE=standard error; Q=water discharge, in cubic foot per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; (T/d)/yr=ton per day per year; (mg/L)/yr=milligram per liter per year; N/A=not available]

		Trends in monthly loads, in (T/d)/yr									
		Season									
		Base		Peak		Return		Overall			
Station number and name	Constituent	Trend magnitude	P	Trend magnitude	P	Trend magnitude	P	Trend magnitude	P	R^2	SE, in percent
09095500 Colorado River, near Cameo, Colo-------	Q	10.1	0.871	18.2	0.814	-19.7	0.739	-11.6	0.920	0.75	49
	CA	-2.8	.725	[1]-22.7	.007	-8.4	.249	[1]-28.3	.039	.76	29
	MG	-2.1	.302	-4.2	.053	-2.1	.302	-5.6	.111	.70	31
	NA	[1]-4.9	.039	-1.9	.537	[1]-4.4	.050	-1.4	.751	.37	10
	CL	[1]-7.7	.007	[1]-10.2	.004	[1]-6.7	.014	-9.1	.083	.26	9
	SO_4	-1.8	.765	[1]15.6	.040	-8.8	.128	8.6	.445	.66	19
	HCO_3	3.1	.854	7.2	.729	-9.3	.559	-5.2	.868	.75	36
	DS	-8.0	.792	-14.5	.714	-34.3	.236	-40.8	.480	.72	20
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	38.0	.265	-62.2	.187	-14.1	.669	-114	.089	.42	62
	CA	-5.5	.285	-9.1	.197	[1]-15.0	.003	-18.6	.066	.46	29
	MG	[1]-3.8	.022	-4.3	.061	[1]-7.4	.0001	[1]-7.8	.016	.39	27
	NA	-2.5	.213	-4.9	.079	[1]-10.0	.0001	[1]-12.4	.002	.37	25
	CL	[1]-1.1	.040	-.56	.45	-.81	.116	-.28	.791	.14	39
	SO_4	-11.9	.297	-25.0	.113	[1]-49.6	.0001	[1]-62.7	.006	.48	24
	HCO_3	7.4	.485	[1]-32.8	.026	-17.7	.087	[1]-57.9	.006	.36	46
	DS	-7.6	.785	[1]-90.5	.020	[1]-92.8	.0008	[1]-175.6	.002	.43	29
09180000 Dolores River, near Cisco, Utah-------	Q	-3.7	.845	[1]135	.0005	N/A	N/A	N/A	N/A	.56	119
	CA	-1.1	.737	[1]19.5	.013	N/A	N/A	N/A	N/A	.50	84
	MG	-.76	.307	[1]3.6	.046	N/A	N/A	N/A	N/A	.51	63
	NA	-.46	.821	[1]11.3	.006	N/A	N/A	N/A	N/A	.09	39
	CL	.74	.809	8.9	.145	N/A	N/A	N/A	N/A	.02	42
	SO_4	-3.5	.429	[1]23.1	.010	N/A	N/A	N/A	N/A	.36	68
	HCO_3	-.71	.907	[1]41.3	.0008	N/A	N/A	N/A	N/A	.57	104
	DS	-4.5	.754	92.2	.002	N/A	N/A	N/A	N/A	.47	51
09180500 Colorado River near Cisco, Utah-------	Q	32.9	.661	-123	.321	-17.4	.823	-173	.292	.65	56
	CA	-1.4	.871	[1]-31.9	.028	-6.0	.508	-36.5	.058	.62	31
	MG	-4.6	.066	[1]-9.1	.027	[1]-9.1	.0005	[1]-13.6	.013	.56	26
	NA	[1]-12.2	.033	.59	.950	[1]-22.4	.0002	-9.6	.443	.18	18
	CL	-.91	.884	2.8	.788	[1]-12.9	.049	-9.2	.504	.05	20
	SO_4	[1]-39.3	.015	-48.9	.066	[1]-59.8	.0004	[1]-69.3	.049	.62	19
	HCO_3	11.1	.731	-11.4	.815	.49	.987	-22.0	.734	.57	51
	DS	-47.4	.424	-98.0	.063	-110	.076	-160	.218	.55	24

[1]Trend significant at the 95-percent level.

Table 5.--*Trend results of monthly values computed by Method 1, using the regression relation, parameter=f(time), for the post-1965 time period*--Continued

Station number and name	Constituent	Trends in monthly concentrations, in (mg/L)/yr — Season — Base: Trend magnitude	Base: P	Peak: Trend magnitude	Peak: P	Return: Trend magnitude	Return: P	Overall: Trend magnitude	Overall: P	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-0.08	0.808	0.29	0.429	0.22	0.495	0.59	0.323	0.78	11
	MG	[1]-.35	.008	.05	.695	[1]-.20	.010	.21	.356	.68	16
	NA	[1]-2.03	.005	.43	.647	-.19	.782	2.27	.096	.78	20
	CL	[1]-2.92	.005	.21	.869	-.33	.739	2.81	.146	.76	22
	SO_4	[1]-1.55	.019	1.07	.192	-.64	.305	1.98	.106	.80	15
	HCO_3	-.47	.396	.20	.770	-.32	.548	.36	.730	.60	10
	DS	[1]-6.89	.022	-1.67	.668	-1.52	.591	7.03	.215	.79	14
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.50	.661	1.08	.493	-.16	.886	.42	.853	.437	34
	MG	-.16	.681	.20	.697	-.57	.127	-.21	.776	.39	32
	NA	[1]-2.92	.0001	.65	.483	[1]-2.36	.0004	1.22	.359	.40	38
	CL	[1]-.57	.0001	.12	.493	-.11	.347	[1].57	.021	.31	43
	SO_4	[1]-15.2	.0002	4.53	.406	[1]-11.5	.003	8.15	.293	.44	38
	HCO_3	[1]-2.53	.008	.07	.959	[1]-3.11	.0009	-.51	.781	.33	22
	DS	[1]-25.0	.0002	5.96	.513	[1]-19.9	.002	11.07	.394	.44	32
09180000 Dolores River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]3.75	.022	-1.16	.763	N/A	N/A	N/A	N/A	.27	47
	MG	[1]1.26	.029	-.23	.865	N/A	N/A	N/A	N/A	.37	42
	NA	[1]15.8	.010	7.22	.551	N/A	N/A	N/A	N/A	.29	66
	CL	[1]26.3	.007	10.7	.576	N/A	N/A	N/A	N/A	.28	70
	SO_4	5.66	.150	2.22	.775	N/A	N/A	N/A	N/A	.33	51
	HCO_3	[1]3.18	.0008	-.31	.865	N/A	N/A	N/A	N/A	.17	28
	DS	[1]55.1	.003	19.3	.597	N/A	N/A	N/A	N/A	.36	49
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-1.10	.028	.37	.651	-.25	.631	1.22	.264	.56	23
	MG	[1]-.89	.0001	.10	.760	[1]-.69	.0005	.29	.485	.58	24
	NA	[1]-2.93	.0001	1.60	.178	[1]-1.89	.012	2.64	.094	.58	26
	CL	[1]-1.72	.032	1.93	.145	-.74	.375	2.92	.097	.56	29
	SO_4	[1]-7.67	.0003	3.15	.359	[1]-5.00	.021	5.82	.202	.58	29
	HCO_3	-.89	.138	.31	.752	.69	.264	1.90	.149	.37	15
	DS	[1]-15.2	.0004	7.45	.287	-7.87	.075	14.8	.112	.59	22

[1]Trend significant at the 95-percent level.

Table 6.--*Trend results of monthly values computed by Method 1, using the regression relation, parameter=f(time, Q) for the post-1965 time period*

[p=significance probability; R^2=coefficient of determination; SE=standard error; Q=water discharge, in cubic foot per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; (T/d)/yr=ton per day per year; (mg/L)/yr=milligram per liter per year; N/A=not available]

Station number and name	Constituent	Trends in monthly loads, in (T/d)/yr — Season — Base: Trend magnitude	Base: p	Peak: Trend magnitude	Peak: p	Return: Trend magnitude	Return: p	Overall: Trend magnitude	Overall: p	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-1.84	0.614	[1]-9.27	0.021	-1.39	0.701	-8.82	0.178	0.95	13
	MG	-2.09	.177	-.74	.658	-2.17	.156	-.82	.765	.84	23
	NA	[1]-5.10	.011	-2.04	.445	-3.51	.067	-.45	.907	.57	8
	CL	[1]-8.04	.003	[1]-11.3	.001	[1]-5.89	.023	-9.14	.070	.35	9
	SO_4	-2.27	.518	[1]15.4	.001	-5.40	.109	12.3	.062	.89	11
	HCO_3	1.68	.822	7.58	.424	-3.23	.651	2.66	.849	.95	16
	DS	-11.8	.335	-17.0	.299	-19.6	.093	-24.9	.287	.96	8
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-2.98	.427	-8.08	.127	[1]-8.26	.032	-13.4	.080	.72	21
	MG	[1]-3.15	.012	[1]-3.87	.028	[1]-4.78	.0002	[1]-5.50	.030	.67	20
	NA	[1]-3.32	.038	-3.04	.167	[1]-9.02	.0001	[1]-8.73	.005	.63	19
	CL	[1]-1.39	.004	-.21	.742	-.62	.172	.56	.543	.36	34
	SO_4	-14.6	.129	-15.1	.254	[1]-44.2	.0001	[1]-44.8	.017	.65	20
	HCO_3	-3.26	.507	[1]-17.1	.012	[1]-12.7	.008	[1]-26.5	.006	.87	21
	DS	-27.0	.138	[1]-55.6	.028	[1]-78.2	.0001	[1]-106.8	.003	.77	18
09180000 Dolores River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.56	.726	-6.41	.123	N/A	N/A	N/A	N/A	.88	42
	MG	[1]-.65	.008	[1]-2.28	.021	N/A	N/A	N/A	N/A	.88	32
	NA	-.38	.848	[1]8.46	.048	N/A	N/A	N/A	N/A	.13	38
	CL	.75	.807	8.42	.199	N/A	N/A	N/A	N/A	.02	42
	SO_4	-2.85	.360	-.72	.914	N/A	N/A	N/A	N/A	.69	47
	HCO_3	.27	.912	3.94	.442	N/A	N/A	N/A	N/A	.93	41
	DS	-2.32	.787	10.9	.553	N/A	N/A	N/A	N/A	.81	30
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-4.53	.285	[1]-18.3	.014	-3.97	.365	-17.8	.062	.91	15
	MG	[1]-5.22	.001	[1]5.78	.037	[1]-8.32	.0001	[1]-8.87	.013	.82	16
	NA	[1]-12.6	.002	7.63	.278	[1]-20.0	.0001	.25	.978	.60	13
	CL	-.76	.876	7.95	.348	[1]-10.3	.043	-1.56	.886	.44	15
	SO_4	[1]-42.6	.001	-29.8	.152	[1]-55.2	.0001	-42.3	.115	.79	14
	HCO_3	2.31	.869	45.9	.061	6.80	.640	50.4	.109	.90	24
	DS	[1]-63.5	.029	7.55	.880	[1]-90.9	.003	-19.8	.759	.90	12

[1]Trend significant at the 95-percent level.

Table 6.--*Trend results of monthly values computed by Method 1, using the regression relation, parameter=f(time, Q) for the post-1965 time period*--Continued

Station number and name	Constituent	Trends in monthly concentrations, in (mg/L)/yr — Season — Base — Trend magnitude	Base — P	Peak — Trend magnitude	Peak — P	Return — Trend magnitude	Return — P	Overall — Trend magnitude	Overall — P	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-0.09	0.756	-0.15	0.635	-0.25	0.383	-0.30	0.549	0.86	9
	MG	[1]-.37	.001	-.01	.950	[1]-.38	.0008	-.02	.927	.78	14
	NA	[1]-1.96	.0001	.68	.295	-.83	.072	1.80	.051	.90	13
	CL	[1]-6.57	.002	2.58	.351	[1]-3.96	.045	5.19	.189	.90	10
	SO_4	[1]-2.84	.0001	.41	.632	-1.27	.053	1.98	.122	.90	14
	HCO_3	[1]-1.50	.003	1.19	.061	[1]-1.11	.021	1.58	.091	.89	11
	DS	-.39	.417	.49	.116	-.58	.207	.30	.737	.71	9
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.14	.850	.57	.572	[1]-2.53	.0008	-2.09	.154	.79	21
	MG	-3.6	.159	.20	.580	[1]-1.29	.0001	-.73	.153	.75	21
	NA	[1]-2.45	.0001	.09	.885	[1]-2.78	.0001	-.23	.801	.73	26
	CL	[1]-.51	.0001	.03	.833	-.17	.111	.37	.078	.50	37
	SO_4	[1]-12.6	.0001	.83	.808	[1]-14.2	.0001	-.75	.878	.79	23
	HCO_3	[1]-2.06	.011	-.65	.555	[1]-3.52	.0001	-2.11	.178	.54	18
	DS	[1]-20.8	.0001	-.32	.957	[1]-24.1	.0001	-3.64	.663	.77	21
09180000 Dolores River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]3.74	.019	.69	.858	N/A	N/A	N/A	N/A	.31	46
	MG	[1]1.26	.002	.75	.572	N/A	N/A	N/A	N/A	.44	40
	NA	[1]15.8	.008	11.3	.338	N/A	N/A	N/A	N/A	.34	64
	CL	[1]26.3	.005	16.9	.366	N/A	N/A	N/A	N/A	.33	7
	SO_4	5.66	.141	4.39	.568	N/A	N/A	N/A	N/A	.36	50
	HCO_3	[1]3.18	.0007	.07	.971	N/A	N/A	N/A	N/A	.19	27
	DS	[1]55.1	.002	32.9	.350	N/A	N/A	N/A	N/A	.42	47
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-1.04	.001	-.02	.976	-.50	.133	.53	.455	.83	14
	MG	[1]-.86	.0001	-.05	.824	[1]-.78	.0001	.03	.919	.79	17
	NA	[1]-2.71	.0001	1.58	.114	[1]-2.14	.0004	2.16	.094	.74	21
	CL	[1]-1.43	.037	2.23	.062	-.95	.181	2.71	.077	.69	24
	SO_4	[1]-7.44	.0001	.94	.675	[1]-6.00	.0001	2.38	.409	.84	18
	HCO_3	-.76	.171	.74	.446	.53	.357	2.02	.103	.47	14
	DS	[1]-14.3	.0001	5.41	.272	[1]-9.82	.001	9.84	.121	.82	14

[1]Trend significant at the 95-percent level.

Table 7.--*Trend results of monthly values computed by Method 1, using the regression relation, ln(parameter)=f(time), for the post-1965 time period*

[ln=natural logarithm; p=significance probability; R^2=coefficient of determination; SE=standard error; Q=water discharge, in cubic feet per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; (T/d)/yr=ton per day per year; (mg/L)/yr=milligram per liter per year; N/A=not available]

Station number and name	Constituent	Base: Trend magnitude	Base: p	Peak: Trend magnitude	Peak: p	Return: Trend magnitude	Return: p	Overall: Trend magnitude	Overall: p	R^2	SE, in percent
		Trends in monthly loads, in ln[(T/d)/yr] — Season									
09095500 Colorado River near Cameo, Colo-------	Q	0.005	0.578	-0.004	0.771	-0.007	0.474	-0.016	0.389	0.83	30
	CA	-.009	.416	[1]-.025	.022	[1]-.020	.038	[1]-.037	.042	.80	21
	MG	[1]-.024	.022	[1]-.022	.045	[1]-.034	.0006	-.032	.078	.77	21
	NA	[1]-.008	.014	-.003	.522	[1]-.007	.033	-.001	.837	.37	10
	CL	[1]-.009	.002	[1]-.011	.003	[1]-.007	.011	-.009	.096	.28	9
	SO_4	-.003	.554	.010	.155	-.011	.051	.002	.789	.64	17
	HCO_3	.003	.704	-.003	.774	-.009	.265	-.015	.334	.80	25
	DS	-.003	.572	-.004	.574	-.009	.096	-.009	.356	.74	16
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	[1].027	.033	-.023	.189	-.006	.601	[1]-.056	.024	.36	55
	CA	-.015	.096	-.018	.147	[1]-.029	.002	-.032	.075	.46	28
	MG	[1]-.026	.004	-.022	.060	[1]-.040	.0001	[1]-.037	.033	.38	28
	NA	-.010	.085	-.015	.063	[1]-.031	.0001	[1]-.036	.003	.37	25
	CL	[1]-.024	.005	-.009	.434	[1]-.021	.011	-.006	.706	.19	35
	SO_4	-.010	.090	-.013	.090	[1]-.025	.0001	[1]-.029	.011	.51	24
	HCO_3	.013	.217	-.026	.063	[1]-.025	.014	[1]-.063	.002	.30	44
	DS	-.004	.574	[1]-.020	.033	[1]-.024	.0002	[1]-.040	.002	.42	28
09180000 Dolores River, near Cisco, Utah-------	Q	-0.028	0.103	0.025	0.451	N/A	N/A	N/A	N/A	0.56	101
	CA	-.025	.204	.046	.334	N/A	N/A	N/A	N/A	.41	80
	MG	-.032	.039	.033	.357	N/A	N/A	N/A	N/A	.43	100
	NA	-.005	.514	[1].038	.024	N/A	N/A	N/A	N/A	.07	44
	CL	-.001	.875	.023	.191	N/A	N/A	N/A	N/A	.01	47
	SO_4	[1]-.023	.050	.024	.300	N/A	N/A	N/A	N/A	.31	64
	HCO_3	-.012	.483	.020	.548	N/A	N/A	N/A	N/A	.50	102
	DS	-.008	.380	.026	.165	N/A	N/A	N/A	N/A	.36	49
09180500 Colorado River near Cisco, Utah--------	Q	.009	.284	-.025	.080	-.003	.717	[1]-.037	.049	.64	39
	CA	-.002	.687	[1]-.022	.016	-.004	.436	[1]-.024	.045	.65	24
	MG	[1]-.014	.005	[1]-.020	.014	[1]-.019	.0003	[1]-.025	.021	.58	22
	NA	[1]-.009	.023	-.002	.814	[1]-.014	.0007	-.007	.446	.16	18
	CL	-.001	.903	.001	.925	-.007	.160	-.005	.589	.05	21
	SO_4	[1]-.014	.0004	[1]-.013	.044	[1]-.014	.0009	-.013	.140	.65	18
	HCO_3	.004	.583	-.025	.054	.000	.973	-.030	.091	.55	37
	DS	-.006	.178	-.013	.082	[1]-.010	.041	-.017	.095	.55	21

[1]Trend significant at the 95-percent confidence level.

Table 7.--*Trend results of monthly values computed by Method 1, using the regression relation, ln(parameter)=f(time), for the post-1965 time period*--Continued

Station No. and name	Con-stit-uent	Base: Trend magni-tude	Base: P	Peak: Trend magni-tude	Peak: P	Return: Trend magni-tude	Return: P	Overall: Trend magni-tude	Overall: P	R^2	SE, in percent
		Trends in monthly concentrations, in ln[(mg/L)/yr] — Season									
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-0.001	0.875	0.005	0.423	0.002	0.684	0.008	0.425	.80	12
	MG	-.017	.063	.008	.363	-.012	.160	.014	.374	.72	18
	NA	-.014	.102	.003	.774	.000	.997	.017	.287	.84	25
	CL	-.015	.112	.008	.504	-.001	.942	.006	.708	.83	28
	SO_4	-.009	.131	.014	.059	-.004	.452	.019	.091	.85	17
	HCO_3	-.002	.554	.001	.902	-.002	.575	.001	.909	.61	12
	DS	-.009	.117	.002	.789	-.002	.714	.009	.407	.83	16
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.006	.588	.004	.772	-.001	.932	-.002	.908	.47	33
	MG	-.005	.626	-.001	.967	-.012	.246	-.007	.717	.42	34
	NA	[1]-.037	.0001	.008	.574	[1]-.024	-.009	.021	.268	.44	40
	CL	[1]-.051	.0001	.014	.293	-.015	.115	[1].050	.008	.42	40
	SO_4	[1]-.037	.0003	.001	.490	-.019	.055	.028	.161	.45	43
	HCO_3	[1]-.014	.009	-.003	.657	[1]-.018	.0009	-.007	.514	.33	27
	DS	[1]-.031	.0002	.003	.773	[1]-.018	.023	.016	.316	.45	34
09180000 Dolores River near Cisco, Utah------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	0.021	0.081	-0.031	0.270	N/A	N/A	N/A	N/A	0.44	43
	MG	.014	.302	-.044	.189	N/A	N/A	N/A	N/A	.51	52
	NA	.022	.164	.013	.687	N/A	N/A	N/A	N/A	.56	93
	CL	.026	.134	-.002	.952	N/A	N/A	N/A	N/A	.55	106
	SO_4	.005	.656	-.001	.953	N/A	N/A	N/A	N/A	.55	54
	HCO_3	[1].016	.009	-.005	.666	N/A	N/A	N/A	N/A	.15	31
	DS	.019	.078	.000	.986	N/A	N/A	N/A	N/A	.55	59
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-.011	.027	.003	.717	-0.001	0.824	0.013	0.238	.60	23
	MG	[1]-.023	.0001	.005	.623	[1]-.016	.009	.012	.337	.64	26
	NA	[1]-.018	.005	[1].023	.032	-.011	.094	[1].030	.035	.72	29
	CL	-.010	.181	[1].025	.034	-.003	.641	[1].031	.047	.72	33
	SO_4	[1]-.023	.0006	.011	.302	-.011	.127	.024	.102	.65	31
	HCO_3	-.005	.197	-.001	.875	.003	.359	.007	.366	.38	16
	DS	[1]-.015	.003	.011	.177	-.007	.211	.020	.074	.67	23

[1]Trend significant at the 95-percent level.

Table 8.--*Trend results of monthly values computed by Method 1, using the regression relation, ln(parameter)=f(time,ln(Q)), for the post-1965 time period*

[ln=natural logarithm; p=significance level; R^2=coefficient of determination; SE=standard error; Q=water discharge, in cubic feet per second; CA=calcium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; (T/d)/yr=ton per day per year; (mg/L)/yr=milligram per liter per year; N/A=not available]

Station number and name	Constituent	Trends in monthly loads, in ln[(T/d)/yr]: Season: Base: Trend magnitude	Base: p	Peak: Trend magnitude	Peak: p	Return: Trend magnitude	Return: p	Overall trend: Trend magnitude	Overall trend: p	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-0.003	0.541	-0.005	0.270	-0.004	0.358	-0.007	0.406	0.97	9
	MG	[1]-.021	.003	-.004	.625	[1]-.021	.002	-.004	.756	.91	14
	NA	[1]-.009	.0004	-.002	.643	[1]-.005	.032	.003	.614	.61	8
	CL	[1]-.010	.0004	[1]-.011	.002	[1]-.007	.015	-.007	.170	.37	8
	SO_4	[1]-.007	.043	[1].012	.003	[1]-.007	.019	.011	.061	.89	9
	HCO_3	-.001	.802	.000	.965	-.003	.269	-.003	.643	.97	10
	DS	[1]-.006	.016	-.001	.753	[1]-.005	.014	-.001	.866	.96	7
09152500 Gunnison River near Grand Junction, Colo	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.004	.487	-.009	.244	[1]-.017	.004	-.022	.054	.80	17
	MG	[1]-.017	.004	-.014	.063	[1]-.026	.0001	[1]-.023	.038	.76	17
	NA	[1]-.019	.0001	-.009	.129	[1]-.028	.0001	[1]-.018	.035	.69	18
	CL	[1]-.038	.0001	-.001	.876	[1]-.018	.004	.018	.142	.55	26
	SO_4	[1]-.017	.0002	-.008	.195	[1]-.023	.0001	-.014	.121	.71	18
	HCO_3	-.007	.107	-.010	.105	[1]-.020	.0001	[1]-.022	.012	.87	18
	DS	[1]-.015	.0002	-.010	.051	[1]-.021	.0001	[1]-.017	.030	.81	16
09180000 Dolores River near Cisco, Utah	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.008	.427	-.008	.716	N/A	N/A	N/A	N/A	.87	35
	MG	-.007	.358	-.008	.670	N/A	N/A	N/A	N/A	.85	28
	NA	.001	.930	[1].035	.025	N/A	N/A	N/A	N/A	.20	41
	CL	.003	.703	.024	.173	N/A	N/A	N/A	N/A	.08	45
	SO_4	-.007	.300	.010	.452	N/A	N/A	N/A	N/A	.80	36
	HCO_3	[1].014	.018	-.002	.803	N/A	N/A	N/A	N/A	.94	30
	DS	.004	.497	.014	.201	N/A	N/A	N/A	N/A	.77	29
09180500 Colorado River near Cisco, Utah	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-.007	.023	-.006	.197	-.003	.300	-.003	.675	.90	13
	MG	[1]-.017	.0001	-.009	.108	[1]-.017	.0001	-.009	.210	.83	14
	NA	[1]-.011	.0002	.005	.298	[1]-.013	.0001	.003	.647	.62	12
	CL	-.001	.696	.004	.426	-.004	.186	.001	.872	.48	15
	SO_4	[1]-.017	.0001	-.006	.280	[1]-.013	.0001	-.002	.796	.79	14
	HCO_3	-.003	.458	-.002	.670	.003	.438	.003	.705	.92	15
	DS	[1]-.009	.0001	-.001	.875	[1]-.008	.0006	.000	.944	.89	10

[1]Trend significant at the 95-percent confidence level.

Table 8.--*Trend results of monthly values computed by Method 1, using the regression relation, ln(parameter)=f(time,ln(Q)), for the post-1965 time period*--Continued

Station number and name	Constituent	Base: Trend magnitude	Base: P	Peak: Trend magnitude	Peak: P	Return: Trend magnitude	Return: P	Overall trend: Trend magnitude	Overall trend: P	R^2	SE, in percent
		Trends in monthly concentrations, in ln[(mg/L)/yr] — Season									
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-0.003	0.541	-0.005	0.270	-0.004	0.358	-0.007	0.406	0.90	9
	MG	[1]-.021	.003	-.004	.625	[1]-.021	.002	-.004	.756	.84	14
	NA	[1]-.009	.0004	-.002	.643	[1]-.005	.032	.003	.614	.98	8
	CL	[1]-.010	.0004	[1]-.011	.002	[1]-.007	.015	-.007	.170	.98	8
	SO_4	[1]-.007	.043	[1].012	.003	[1]-.003	.019	.011	.061	.69	9
	HCO_3	-.001	.802	.000	.965	-.003	.269	-.003	.643	.47	10
	DS	[1]-.006	.016	-.001	.753	[1]-.005	.014	-.001	.866	.97	7
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.004	.487	-.009	.244	[1]-.017	.004	-.022	.054	.85	17
	MG	[1]-.017	.004	-.014	.063	[1]-.026	.0001	[1]-.023	.038	.84	17
	NA	[1]-.019	.0001	-.009	.129	[1]-.028	.0001	[1]-.018	.035	.88	18
	CL	[1]-.038	.0001	-.001	.876	[1]-.018	.004	.018	.142	.75	26
	SO_4	[1]-.017	.0002	-.008	.195	[1]-.023	.0001	-.014	.121	.90	18
	HCO_3	-.007	.107	-.010	.105	[1]-.020	.0001	[1]-.022	.012	.58	18
	DS	[1]-.015	.0002	-.010	.051	[1]-.021	.0001	[1]-.017	.030	.81	16
09180000 Dolores River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	0.008	.427	-.008	.716	N/A	N/A	N/A	N/A	N/A	35
	MG	-.007	.358	-.008	.670	N/A	N/A	N/A	N/A	N/A	28
	NA	.001	.930	[1].035	.025	N/A	N/A	N/A	N/A	N/A	41
	CL	.003	.703	.024	.173	N/A	N/A	N/A	N/A	N/A	45
	SO_4	-.007	.300	.010	.452	N/A	N/A	N/A	N/A	N/A	36
	HCO_3	[1].014	.018	-.002	.803	N/A	N/A	N/A	N/A	N/A	30
	DS	.004	.497	.014	.201	N/A	N/A	N/A	N/A	N/A	29
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-.007	.023	-.006	.197	-.003	.300	-.003	.675	.87	13
	MG	[1]-.017	.0001	-.009	.108	[1]-.017	.0001	-.009	.210	.89	14
	NA	[1]-.011	.0002	.005	.298	[1]-.013	.0001	.003	.647	.95	12
	CL	-.001	.696	.004	.426	-.004	.186	.001	.872	.94	15
	SO_4	[1]-.017	.0001	-.006	.280	[1]-.013	.0001	-.002	.796	.93	14
	HCO_3	-.003	.458	-.002	.670	.003	.438	.003	.705	.48	15
	DS	[1]-.009	.0001	-.001	.875	[1]-.008	.0006	.000	.944	.93	10

[1]Trend significant at the 95-percent level.

Table 9.--*Trend results of monthly values computed by Method 2, using the regression relation, ln(parameter)=f(time,ln(Q)), for the post-1965 time period*

[ln=natural logarithm; p=significance level; R^2=coefficient of determination; SE=standard error; Q=water discharge, in cubic foot per second; CA=calcium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; (T/d)/yr=ton per day per year; (mg/L)/yr=milligram per liter per year; N/A=not available]

Station number and name	Constituent	Trends in monthly loads, in [ln(T/d)/yr]: Season: Base: Trend magnitude	Base: P	Peak: Trend magnitude	Peak: P	Return: Trend magnitude	Return: P	Overall trend: Trend magnitude	Overall trend: P	R^2	SE, in percent
09095500 Colorado River near Cameo, Colo	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	0.001	0.352	-0.003	0.073	[1]-0.003	0.024	[1]-0.007	0.005	0.99	5
	MG	[1]-.007	.0001	-.004	.066	[1]-.008	.0001	-.005	.131	.97	7
	NA	[1]-.002	.131	.002	.360	[1]-.004	.003	-.001	.914	.64	6
	CL	.000	.999	[1]-.011	.0001	[1]-.005	.0001	[1]-.017	.0001	.34	6
	SO_4	[1]-.004	.020	.004	.080	[1]-.006	.0002	.001	.592	.92	8
	HCO_3	[1].002	.032	[1]-.005	.004	-.001	.326	[1]-.008	.0003	.99	5
	DS	[1]-.003	.007	-.002	.240	[1]-.006	.0001	[1]-.005	.049	.96	5
09152500 Gunnison River near Grand Junction, Colo	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.007	.062	-.009	.081	[1]-.014	.0001	[1]-.017	.021	.82	16
	MG	[1]-.019	.0001	[1]-.013	.006	[1]-.027	.0001	[1]-.021	.002	.80	15
	NA	[1]-.018	.0001	-.010	.060	[1]-.023	.0001	[1]-.015	.037	.73	16
	CL	[1]-.027	.0001	[1]-.015	.0003	[1]-.024	.0001	[1]-.013	.029	.84	13
	SO_4	[1]-.015	.0005	-.009	.129	[1]-.025	.0001	[1]-.018	.032	.66	19
	HCO_3	[1]-.011	.0001	[1]-.010	.0002	[1]-.014	.0001	[1]-.012	.0009	.97	8
	DS	[1]-.018	.0001	[1]-.012	.016	[1]-.025	.0001	[1]-.020	.006	.79	16
09180000 Dolores River near Cisco, Utah	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.004	.122	[1]-.035	.0001	N/A	N/A	N/A	N/A	.97	15
	MG	[1]-.006	.006	-.007	.119	N/A	N/A	N/A	N/A	.95	14
	NA	[1].012	.009	.016	.088	N/A	N/A	N/A	N/A	.26	28
	CL	[1].016	.001	.011	.265	N/A	N/A	N/A	N/A	.10	32
	SO_4	[1]-.013	.0001	-.004	.397	N/A	N/A	N/A	N/A	.95	13
	HCO_3	[1].020	.0001	[1]-.013	.001	N/A	N/A	N/A	N/A	.99	12
	DS	[1].007	.023	.005	.421	N/A	N/A	N/A	N/A	.83	20
09180500 Colorado River near Cisco, Utah	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-.003	.018	[1]-.008	.0001	[1]-.003	.034	[1]-.008	.006	.97	6
	MG	[1]-.017	.0001	[1]-.005	.034	[1]-.015	.0001	-.003	.327	.94	7
	NA	[1]-.008	.0001	.001	.633	[1]-.009	.0001	.000	.932	.77	9
	CL	-.006	.792	.004	.246	-.001	.672	.004	.458	.50	10
	SO_4	[1]-.013	.0001	[1]-.006	.026	[1]-.012	.0001	-.005	.152	.87	8
	HCO_3	[1]-.003	.002	.000	.866	[1].004	.0002	.001	.662	.99	5
	DS	[1]-.009	.0001	-.001	.639	[1]-.010	.0001	-.002	.496	.94	7

[1]Trend significant at the 95-percent confidence level.

Table 9.--*Trend results of monthly values computed by Method 2, using the regression relation, ln(parameter)=f(time,ln(Q)), for the post-1965 time period*--Continued

Station number and name	Constituent	Base: Trend magnitude	Base: P	Peak: Trend magnitude	Peak: P	Return: Trend magnitude	Return: P	Overall trend: Trend magnitude	Overall trend: P	R^2	SE, in percent
		Trends in monthly concentrations, in ln[(mg/L)/yr] — Season									
09095500 Colorado River near Cameo, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	0.001	0.352	-0.003	0.073	[1]-0.003	0.024	[1]-0.007	0.005	0.96	5
	MG	[1]-.007	.0001	-.004	.066	[1]-.008	.0001	-.005	.131	.94	7
	NA	-.002	.131	.002	.360	[1]-.004	.003	-.001	.914	.99	6
	CL	.000	.999	[1]-.011	•.0001	[1]-.005	.0001	[1]-.017	.0001	.99	6
	SO_4	[1]-.004	.020	.004	.080	[1]-.006	.0002	.001	.692	.97	8
	HCO_3	[1].002	.032	[1]-.005	.004	-.001	.326	[1]-.008	.0003	.99	5
	DS	[1]-.003	.007	-.002	.240	[1]-.006	.0001	[1]-.005	.049	.98	5
09152500 Gunnison River near Grand Junction, Colo-------------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.007	.062	-.009	.081	[1]-.014	.0001	[1]-.017	.021	.86	16
	MG	[1]-.019	.0001	[1]-.013	.006	[1]-.027	.0001	[1]-.021	.002	.90	15
	NA	[1]-.018	.0001	-.010	.060	[1]-.023	.0001	[1]-.015	.037	.90	16
	CL	[1]-.027	.0001	-.015	.0003	[1]-.024	.0001	[1]-.013	.029	.92	13
	SO_4	[1]-.015	.001	-.009	.129	[1]-.025	.0001	[1]-.018	.032	.88	19
	HCO_3	[1]-.011	.0001	[1]-.010	.0002	[1]-.014	.0001	[1]-.012	.0009	.99	8
	DS	[1]-.018	.0001	[1]-.012	.016	[1]-.025	.0001	[1]-.020	.060	.88	16
09180000 Dolores River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	.004	.122	[1]-.035	.0001	N/A	N/A	N/A	N/A	.85	15
	MG	[1]-.006	.006	-.007	.119	N/A	N/A	N/A	N/A	.95	14
	NA	[1].012	.009	.016	.088	N/A	N/A	N/A	N/A	.93	28
	CL	[1].016	.001	.011	.265	N/A	N/A	N/A	N/A	.93	32
	SO_4	[1]-.013	.0001	-.004	.397	N/A	N/A	N/A	N/A	.96	13
	HCO_3	[1].020	.0001	[1]-.013	.001	N/A	N/A	N/A	N/A	.93	12
	DS	[1].007	.023	.005	.421	N/A	N/A	N/A	N/A	.94	20
09180500 Colorado River near Cisco, Utah-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	[1]-.003	.018	[1]-.008	.0001	[1]-.003	.034	[1]-.008	.006	.96	6
	MG	[1]-.017	.0001	[1]-.005	.034	[1]-.015	.0001	-.003	.327	.97	7
	NA	[1]-.008	.0001	.001	.633	[1]-.009	.0001	.000	.932	.97	9
	CL	-.006	.792	.004	.246	-.001	.672	.004	.458	.97	10
	SO_4	[1]-.013	.0001	[1]-.006	.026	[1]-.012	.0001	-.005	.152	.97	8
	HCO_3	[1].003	.002	.000	.866	[1].004	.0002	.001	.662	.99	5
	DS	[1]-.009	.0001	-.001	.639	[1]-.010	.0001	-.002	.496	.97	7

[1]Trend significant at the 95-percent confidence level.

Table 10.--*Trend results of monthly and annual values computed by Method 1, using the seasonal-Kendall procedure for the pre- and post-1965 time period*

[Q=water discharge, in cubic feet per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; T/d=ton per day; mg/L=milligram per liter; N/A=not available; FAC=flow-adjusted concentration]

		Pre-1965							
Station number and name	Constituent	Monthly load (T/d)		Monthly concentration (mg/L)		Monthly FAC ln(mg/L)		Annual load (T/d)	
		Trend magnitude	Significance probability	Trend magnitude	Significance probability	Trend magnitude	Significance probability	Trend magnitude	Significance probability
09095500 Colorado River near Cameo, Colo----------------	Q	-0.14	0.336	-4.86	0.336	N/A	N/A	[1]-92.4	0.038
	CA	-.35	.624	.17	.088	0.001	0.270	[1]-8.40	.029
	MG	[1]-1.04	.0001	[1]-.13	.0001	[1]-.009	.0001	[1]-3.04	.006
	NA	-.41	.551	.39	.055	.000	.928	-1.10	.488
	CL	.70	.218	.46	.131	.001	.071	.44	.843
	SO_4	-1.81	.076	.07	.727	-.001	.102	[1]-8.92	.038
	HCO_3	[1]-4.41	.026	-.19	.267	-.001	.056	-23.42	.060
	DS	-8.19	.118	.93	.303	-.001	.378	[1]-43.0	.038
09152500 Gunnison River near Grand Junction, Colo-------	Q	-.07	.197	-2.40	.197	N/A	N/A	-28.0	.363
	CA	[1]-2.08	.005	.06	.626	-.001	.091	-8.82	.224
	MG	[1]-1.96	.0001	[1]-.34	.0001	[1]-.01	.0001	[1]-4.66	.043
	NA	[1]-4.54	.0001	[1]-.95	.0001	[1]-.01	.0001	[1]-7.44	.023
	CL	[1]-.71	.0001	[1]-.21	.0001	[1]-.01	.0001	[1]-1.25	.038
	SO_4	[1]-12.0	.0001	[1]-2.88	.0001	[1]-.007	.0001	[1]-20.6	.038
	HCO_3	-1.07	.374	.08	.441	.000	.874	-11.6	.434
	DS	[1]-21.6	.0001	[1]-4.39	.0001	[1]-.005	.0001	-44.6	.266
09180000 Dolores River near Cisco, Utah----------------	Q	+.03	.719	1.23	.719	N/A	N/A	24.2	.348
	CA	.50	.438	.32	.654	.01	.066	-1.79	.711
	MG	.35	.308	.27	.654	.008	.131	-.57	.536
	NA	-.18	.857	-3.27	.095	-.002	.700	-1.84	.466
	CL	-.91	.700	-4.70	.105	-.003	.625	-1.64	.602
	SO_4	[1]5.81	.004	1.50	.396	[1].02	.0001	6.70	.348
	HCO_3	-1.95	.085	[1]-3.48	.0001	[1]-.04	.0001	6.54	.348
	DS	7.23	.316	-8.97	.247	.005	.292	7.62	.251
09180500 Colorado River near Cisco, Utah----------------	Q	-.10	.466	-3.39	.466	N/A	N/A	-64.6	.199
	CA	.72	.555	.07	.354	.001	.230	-5.75	.359
	MG	[1]-3.57	.0001	[1]-.28	.0001	[1]-.007	.0001	[1]-5.87	.002
	NA	[1]-7.03	.0001	-.15	.415	[1]-.004	.0001	[1]-7.37	.030
	CL	[1]6.14	.0001	[1]1.03	.0001	[1].005	.0001	5.37	.053
	SO_4	[1]-26.7	.0001	[1]-2.15	.0001	[1]-.006	.0001	[1]-29.4	.006
	HCO_3	[1]-8.13	.001	[1]-.60	.0001	[1]-.003	.0001	-22.8	.183
	DS	[1]-31.0	.001	-1.61	.079	[1]-.003	.0001	-48.8	.088

[1]Trend significant at the 95-percent confidence level.

Table 10.--*Trend results of monthly and annual values computed by Method 1, using the seasonal-Kendall procedure for the pre- and post-1965 time period*--Continued

Station number and name	Constituent	Post-1965: Monthly load (T/d) Trend magnitude	Monthly load (T/d) Significance probability	Monthly concentration (mg/L) Trend magnitude	Monthly concentration (mg/L) Significance probability	Monthly FAC ln(mg/L) Trend magnitude	Monthly FAC ln(mg/L) Significance probability	Annual load (T/d) Trend magnitude	Annual load (T/d) Significance probability
09095500 Colorado River near Cameo, Colo----------------	Q	0.24	1.000	0.24	1.000	N/A	N/A	43.2	0.533
	CA	[1]-6.74	.017	.11	.590	[1]-0.005	0.027	3.01	.602
	MG	[1]-2.81	.0001	-.09	.324	[1]-.02	.0001	-1.71	.602
	NA	[1]-3.55	.006	-.35	.331	[1]-.005	.0001	-.49	1.000
	CL	[1]-7.04	.0001	-.97	.051	[1]-.008	.0001	-5.58	.119
	SO_4	.09	.987	-.37	.366	-.002	.402	7.25	.640
	HCO_3	1.54	.831	-.25	.316	-.002	.440	7.05	.533
	DS	-6.00	.547	-1.60	.323	[1]-.004	.0001	-5.53	1.000
09152500 Gunnison River near Grand Junction, Colo-------	Q	7.70	.461	7.69	.461	N/A	N/A	.12	1.000
	CA	[1]-8.90	.0001	-.19	.580	[1]-.01	.0001	-8.17	.211
	MG	[1]-5.06	.0001	[1]-.42	.017	[1]-.02	.0001	-5.40	.074
	NA	[1]-5.63	.0001	[1]-1.58	.0001	[1]-.02	.0001	[1]-7.04	.033
	CL	[1]-.86	.0001	[1]-.30	.0001	[1]-.02	.0001	-.75	.161
	SO_4	[1]-25.0	.0001	[1]-8.16	.0001	[1]-.02	.0001	[1]-33.4	.044
	HCO_3	-5.62	.241	[1]-2.01	.0001	[1]-.01	.0001	-7.80	.360
	DS	[1]-41.6	.005	[1]-14.5	.0001	[1]-.02	.0001	-64.1	.100
09180000 Dolores River near Cisco, Utah----------------	Q	-2.82	.222	-2.82	.222	N/A	N/A	-11.7	1.000
	CA	-1.00	.369	1.71	.109	.006	.392	6.87	.074
	MG	[1]-.71	.046	.90	.076	-.003	.614	1.96	.107
	NA	2.14	.088	[1]3.76	.039	.009	.059	3.53	.087
	CL	3.31	.082	[1]6.08	.037	.008	.068	5.72	.062
	SO_4	-2.14	.317	.45	.680	-.004	.393	1.37	.876
	HCO_3	.004	1.000	[1]2.08	.003	[1]-.011	.015	-6.30	1.000
	DS	2.68	.768	[1]20.3	.018	[1].007	.045	10.2	.756
09180500 Colorado River near Cisco, Utah----------------	Q	10.7	.459	10.72	.459	N/A	N/A	-34.8	.692
	CA	-3.78	.184	-.44	.072	[1]-.005	.009	-3.97	.373
	MG	[1]-6.09	.0001	[1]-.49	.0001	[1]-.015	.0001	[1]-9.42	.038
	NA	[1]-11.6	.0001	[1]-1.03	.013	[1]-.009	.0001	[1]-19.6	.023
	CL	.47	.916	-.22	.549	-.000	.934	-4.48	.488
	SO_4	[1]-47.0	.0001	-4.33	.0001	[1]-.014	.0001	[1]-63.2	.023
	HCO_3	11.2	.217	.16	.672	.001	.805	-.70	1.000
	DS	[1]-55.0	.002	[1]-6.41	.033	[1]-.008	.0001	-87.5	.553

[1]Trend significant at the 95-percent level.

Table 11.--*Trend results of monthly and annual values computed by Method 2, using the seasonal-Kendall procedure for the post-1965 time period*

[Q=water discharge, in cubic feet per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4 =sulfate; HCO_3=carbonate; DS=dissolved solids; T/d=ton per day; mg/L=milligram per liter; N/A=not available; FAC=flow-adjusted concentration]

Station number and name	Constituent	Post-1965 Monthly load (T/d) Trend magnitude	Monthly load (T/d) Significance probability	Monthly concentration (mg/L) Trend magnitude	Monthly concentration (mg/L) Significance probability	Monthly FAC ln(mg/L) Trend magnitude	Monthly FAC ln(mg/L) Significance probability	Annual load (T/d) Trend magnitude	Annual load (T/d) Significance probability
09095500 Colorado River near Cameo, Colo----------------	Q	0.000	1.000	-13.28	0.094	N/A	N/A	-11.01	0.880
	CA	-1.313	.217	.096	.201	-0.001	0.129	-3.368	.545
	MG	[1]-1.072	.0001	[1]-.079	.009	[1]-.007	.0001	-.764	.225
	NA	[1]-1.408	.045	.242	.269	-.002	.118	-1.439	.363
	CL	[1]-3.582	.0001	.357	.412	[1]-.004	.0001	[1]-4.145	.005
	SO_4	-4.081	.026	-.018	.956	[1]-.002	.013	-2.485	.762
	HCO_3	[1]-1.163	.320	[1].125	.048	.000	.974	-5.609	.495
	DS	[1]-19.88	.001	-.005	1.000	[1]-.004	.0001	-22.37	.289
09152500 Gunnison River near Grand Junction, Colo-------	Q	.000	1.000	5.539	.654	N/A	N/A	-15.72	.880
	CA	-2.334	.201	[1]-1.187	.008	[1]-.009	.0001	-5.397	.325
	MG	[1]-2.965	.0001	[1]-.769	.0001	[1]-.020	.0001	[1]-3.516	.041
	NA	[1]-4.365	.0001	[1]-1.237	.0001	[1]-.017	.0001	[1]-5.029	.041
	CL	[1]-1.056	.0001	[1]-.253	.0001	[1]-.022	.0001	[1]-1.087	.028
	SO_4	[1]-25.66	.0001	[1]-6.762	.001	[1]-.017	.0001	[1]-27.76	.034
	HCO_3	[1]-3.571	.048	[1]-1.123	.0001	[1]-.010	.0001	-7.199	.198
	DS	[1]-51.31	.0001	[1]-13.37	.0001	[1]-.019	.0001	[1]-56.88	.041
09180000 Dolores River near Cisco, Utah----------------	Q	.00	1.000	-1.538	.412	N/A	N/A	12.33	.940
	CA	-.130	.751	[1].640	.017	[1]0.003	.045	-2.044	.649
	MG	-.239	.099	-.033	.835	[1].006	.0001	-.274	.545
	NA	[1]3.370	.0001	[1]4.563	.006	[1].014	.0001	[1]3.187	.028
	CL	[1]5.741	.0001	[1]7.196	.006	[1].017	.0001	[1]6.454	.004
	SO_4	[1]-3.437	.002	-1.301	.217	[1]-.009	.0001	-2.087	.449
	HCO_3	.345	.289	[1]1.129	.0001	[1].012	.0001	.298	.820
	DS	6.269	.165	[1]16.41	.024	[1].008	.001	2.787	.940
09180500 Colorado River near Cisco, Utah-----------------	Q	.000	1.000	4.252	.853	N/A	N/A	5.551	.940
	CA	-4.791	.146	[1]-.432	.035	[1]-.004	.0001	-5.695	.705
	MG	[1]-5.763	.0001	[1]-.473	.0001	[1]-.014	.0001	[1]-4.510	.034
	NA	[1]-8.424	.0001	[1]-.485	.024	[1]-.005	.0001	-10.53	.173
	CL	2.695	.158	.074	.922	-.001	.438	4.710	.449
	SO_4	[1]-41.28	.0001	[1]-3.175	.001	[1]-.012	.0001	-47.89	.058
	HCO_3	2.009	.491	[1].202	.050	[1].003	.0001	2.772	.762
	DS	[1]-64.96	.0001	[1]-4.392	.041	[1]-.009	.0001	-52.37	.289

[1]Trend significant at the 95-percent confidence level.

Table 12.--*Trend results of monthly values computed by Method 1, with the regression relation, parameter=f(time), for the pre- and post-1965 time periods*

[Q=water discharge, in cubic feet per second; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; T/d=tons per day; mg/L=milligrams per liter; N/A=not available; dashes=trend not significant at the 95-percent level]

Station number and name	Constituent	Pre-1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo	Q	------	-227	-----	-22.1	N/A	N/A	N/A	N/A
	CA	------	-13	-----	------	------	+0.455	-------	------
	MG	------	-4.9	-----	-5.3	-0.209	------	-0.251	------
	NA	------	-7	-----	------	------	------	-------	------
	CL	------	------	-----	------	------	------	-------	------
	SO_4	------	------	-----	------	------	------	-------	------
	HCO_3	------	-6.5	-----	-61	-.76	------	-------	------
	DS	------	-101	-----	-92	------	------	-------	------
09152500 Gunnison River near Grand Junction, Colo	Q	------	-83	-----	------	N/A	N/A	N/A	N/A
	CA	------	------	-----	------	------	------	-1.42	------
	MG	------	-2.5	-----	------	-.45	------	-1.01	-0.76
	NA	-2.9	-7.0	-3.0	-7.2	-1.22	------	-3.04	-2.26
	CL	------	------	-----	------	-.26	------	-5.3	-.35
	SO_4	------	------	-----	------	-4.3	------	-11.3	-8.7
	HCO_3	------	-20	-----	------	------	------	-------	------
	DS	------	-45	-----	------	-7.0	------	-16	-12
09180000 Dolores River near Cisco, Utah	Q	------	+68	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+16	N/A	N/A	------	------	N/A	N/A
	MG	------	+2	N/A	N/A	------	------	N/A	N/A
	NA	------	------	N/A	N/A	------	------	N/A	N/A
	CL	------	------	N/A	N/A	------	------	N/A	N/A
	SO_4	------	------	N/A	N/A	------	------	N/A	N/A
	HCO_3	------	+22	N/A	N/A	-4.1	------	N/A	N/A
	DS	------	+50	N/A	N/A	------	------	N/A	N/A
09180500 Colorado River near Cisco, Utah	Q	------	-215	-----	-249	N/A	N/A	N/A	N/A
	CA	------	------	-----	------	------	------	+.42	+1.0
	MG	------	-8.4	-4.6	-11.2	-.55	------	-.28	------
	NA	------	-13.3	-10.8	-28.6	------	------	-.96	------
	CL	+20.5	------	+4.6	-14.8	+2.0	------	-------	------
	SO_4	-17	-48	-37	-69	-4.5	------	-2.4	------
	HCO_3	------	-59	-----	-70	-1.2	------	-.30	+1.2
	DS	-144	------	-61	-212	-4.6	------	-------	------

Table 12.--*Trend results of monthly values computed by Method 1, with the regression relation, parameter=f(time), for the pre- and post-1965 time periods*--Continued

Station number and name	Constituent	Post-1965: Monthly load (T/d), Season: Base	Peak	Return	Overall	Post-1965: Monthly concentration (mg/L), Season: Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo	Q	-----	------	-----	------	N/A	N/A	------	------
	CA	-----	-23	-----	-28	------	-----	------	------
	MG	-----	------	-----	------	-0.35	-----	------	------
	NA	-5	------	-----	------	-2.0	-----	------	------
	CL	-8	-10	-7	------	-2.9	-----	------	------
	SO_4	-----	------	-----	------	-1.6	-----	------	------
	HCO_3	-----	------	-----	------	------	-----	------	------
	DS	-----	------	-----	------	-7.0	-----	------	------
09152500 Gunnison River near Grand Junction, Colo	Q	-----	------	-----	------	N/A	N/A	N/A	N/A
	CA	-----	------	-15	------	------	-----	------	------
	MG	-3.8	------	-7.4	-7.8	------	-----	------	------
	NA	-----	------	-10	-12	-2.9	-----	-2.4	------
	CL	-1.1	------	-----	------	-.57	-----	------	+0.57
	SO_4	-----	------	-50	-63	-15	-----	-12	------
	HCO_3	-----	-33	-----	-58	-2.5	-----	-3.1	------
	DS	-----	-90	-93	-176	-2.5	-----	-20	------
09180000 Dolores River near Cisco, Utah	Q	-----	+135	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-----	+19	N/A	N/A	+1.26	-----	N/A	N/A
	MG	-----	+3.6	N/A	N/A	+1.3	-----	N/A	N/A
	NA	-----	+11.3	N/A	N/A	+16	-----	N/A	N/A
	CL	-----	------	N/A	N/A	+26	-----	N/A	N/A
	SO_4	-----	+23	N/A	N/A	------	-----	N/A	N/A
	HCO_3	-----	+41	N/A	N/A	+3	-----	N/A	N/A
	DS	-----	+92	N/A	N/A	+55	-----	N/A	N/A
09180500 Colorado River near Cisco, Utah	Q	-----	------	-----	------	N/A	N/A	N/A	N/A
	CA	-----	-31	-----	------	-1.1	-----	------	------
	MG	-----	-9.1	-9.1	-13.6	-.89	-----	-.69	------
	NA	-12	------	-22	------	-2.9	-----	-1.9	------
	CL	-----	------	-----	------	-1.7	-----	------	------
	SO_4	-39	------	-60	------	-7.7	-----	-5.0	------
	HCO_3	-----	------	-----	------	------	-----	------	------
	DS	-----	------	-----	------	-15	-----	------	------

Table 13.--*Trend results of monthly values computed by Method 1, with the regression relation, parameter=f(time, Q), for the pre- and post-1965 time period*

[Q=water discharge, in cubic feet per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; CO_3=carbonate; DS=dissolved solids; T/d=ton per day; mg/L=milligram per liter; N/A=not available; dashes=trend not significant at the 95-percent level]

Station number and name	Constituent	Pre-1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+7	------	+7.2	------	-----	------	-----
	MG	------	-1.5	-1.2	-2.1	-0.21	-----	-0.22	-----
	NA	------	-----	+2.2	------	------	-----	------	-----
	CL	------	-----	------	------	------	-----	------	-----
	SO_4	------	-----	------	------	-.57	-----	------	-----
	HCO_3	------	-----	------	------	-.75	-----	------	-----
	DS	------	-----	------	------	-2.3	-----	------	-----
09152500 Gunnison River near Grand Junction,Colo--------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+5.5	------	+4.5	------	-----	-.66	-----
	MG	-1.1	-1.4	-1.8	-2.2	-.45	-----	-.72	-0.53
	NA	-2.9	-4.7	-5.0	-6.9	-1.2	-0.60	-2.1	-1.5
	CL	-.60	-----	-.80	------	-.27	-----	-.36	-.17
	SO_4	-8.1	-----	-14.7	------	-4.4	-----	-5.7	-----
	HCO_3	------	+5.2	------	------	------	-----	------	-----
	DS	-14	-----	-25	------	-7.0	-----	-9.8	-----
09180000 Dolores River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	-----	N/A	N/A	------	-----	N/A	N/A
	MG	------	-----	N/A	N/A	------	-----	N/A	N/A
	NA	------	-----	N/A	N/A	------	-----	N/A	N/A
	CL	------	-----	N/A	N/A	------	-----	N/A	N/A
	SO_4	------	-----	N/A	N/A	------	-----	N/A	N/A
	HCO_3	------	-----	N/A	N/A	-4.1	-----	N/A	N/A
	DS	------	-----	N/A	N/A	------	-----	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+10	------	+11	-.36	-----	+.26	+.78
	MG	-2.1	-5.9	-3.7	-7.5	-.55	-----	-.39	-----
	NA	+4.3	-8.3	-8.8	-21.5	------	-----	-1.3	-1.4
	CL	+20	-----	+5.8	-11	12.1	-----	-----	-1.7
	SO_4	-17	-27	-29	-38	-4.5	-----	-3.3	-----
	HCO_3	------	-----	------	------	-1.2	-----	-.37	1.91
	DS	------	-----	-37	-57	-4.6	-----	-4.6	-----

Table 13.--*Trend results of monthly values computed by Method 1, with the regression relation, parameter=f(time, Q), for the pre- and post-1965 time period*--Continued

Station number and name	Constituent	Post-1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	-9.3	------	------	------	-----	------	-----
	MG	------	-----	------	------	-0.37	-----	-.38	-----
	NA	-5.1	-----	------	------	-2	-----	------	-----
	CL	-8.0	-11	-5.9	------	-2.8	-----	------	-----
	SO_4	------	+15	------	------	-1.5	-----	-1.1	-----
	HCO_3	------	-----	------	------	------	-----	------	-----
	DS	------	-----	------	------	-6.6	-----	-4	-----
09152500 Gunnison River near Grand Junction, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	-----	-8.3	------	------	-2.5	------	-----
	MG	-3.2	-3.9	-4.8	-5.5	------	-----	-1.3	-----
	NA	-3.3	-----	-9.0	-8.7	-2.5	-----	-2.8	-----
	CL	-1.4	-----	------	------	-.51	-----	------	-----
	SO_4	------	-----	-44	-45	-12.6	-----	-14	-----
	HCO_3	------	-17	-13	-27	-2.1	-----	-3.5	-----
	DS	------	-56	-78	-107	-21	-----	-24	-----
09180000 Dolores River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	-----	N/A	N/A	+3.7	-----	N/A	N/A
	MG	------	-2.4	N/A	N/A	+1.3	-----	N/A	N/A
	NA	------	-----	N/A	N/A	+16	-----	N/A	N/A
	CL	------	-----	N/A	N/A	+26	-----	N/A	N/A
	SO_4	------	-----	N/A	N/A	------	-----	N/A	N/A
	HCO_3	------	-----	N/A	N/A	+3	-----	N/A	N/A
	DS	------	-----	N/A	N/A	+55	-----	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	-18	------	------	-1.04	-----	------	-----
	MG	-5.2	-5.8	-8.3	-8.9	-.86	-----	-.78	-----
	NA	-12.6	-----	-20	------	-2.7	-----	-2.1	-----
	CL	------	-----	-10	------	-1.4	-----	------	-----
	SO_4	-43	-----	-55	------	-7.4	-----	-6	-----
	HCO_3	------	-----	------	------	------	-----	------	-----
	DS	-64	-----	-91	------	-14	-----	-9.8	-----

Table 14.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time)*

[Q,=water discharge, in cubic feet per second; CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; T/d=ton per day; mg/L=milligram per liter; N/A=not available; dashes=trend not significant at the 95-percent level]

Station number and name	Constituent	Pre-1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo------------------	Q	------	-0.025	------	-0.023	------	-0.025	------	-0.023
	CA	------	-.014	------	------	------	+.011	------	+.012
	MG	------	-.024	------	-.025	-0.010	------	-0.012	------
	NA	------	-.009	+0.004	------	------	+.015	------	+.015
	CL	------	------	------	------	------	+.024	------	+.023
	SO_4	------	-.011	------	------	------	+.014	------	+.013
	HCO_3	------	-.022	------	-.017	-.004	------	------	------
	DS	------	-.015	------	-.012	------	+.010	------	+.011
09152500 Gunnison River near Grand Junction, Colo-------	Q	------	------	------	------	------	------	------	------
	CA	------	------	------	------	------	------	-.006	------
	MG	------	------	------	------	-.007	------	-.013	------
	NA	-0.009	-.015	-.006	-.012	-.009	------	-.017	------
	CL	-.011	-.011	-.008	------	-.013	------	-.020	------
	SO_4	-.005	------	------	------	-.007	------	-.018	------
	HCO_3	------	------	------	------	------	------	------	------
	DS	------	------	------	------	-.006	------	-.010	------
09180000 Dolores River near Cisco, Utah----------------	Q	------	------	N/A	N/A	------	------	N/A	N/A
	CA	------	+.072	N/A	N/A	------	------	N/A	N/A
	MG	------	------	N/A	N/A	------	------	N/A	N/A
	NA	------	------	N/A	N/A	------	------	N/A	N/A
	CL	------	------	N/A	N/A	------	------	N/A	N/A
	SO_4	------	------	N/A	N/A	------	------	N/A	N/A
	HOC_3	------	------	N/A	N/A	-.070	------	N/A	N/A
	DS	------	------	N/A	N/A	------	------	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	------	-.011	------	-.018	------	-.011	------	-.018
	CA	------	------	------	------	------	+.005	+.003	+.011
	MG	-.005	-.011	-.008	-.014	-.011	------	-.005	------
	NA	+.003	-.008	-.007	-.017	------	------	------	------
	CL	+.016	------	------	-.011	+.011	+.012	+.006	------
	SO_4	-.005	-.008	-.006	-.010	-.009	------	------	------
	HCO_3	------	------	------	------	-.006	------	------	+.007
	DS	------	-.008	-.004	-.013	-.004	------	------	------

Table 14.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time)*--Continued

Station number and name	Constituent	Post-1965: Monthly load (T/d), Season: Base	Peak	Return	Overall	Monthly concentration (mg/L), Season: Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo	Q	------	------	------	------	------	------	------	N/A
	CA	------	-0.025	-0.020	-0.037	------	------	------	N/A
	MG	-0.024	-.022	-.034	------	------	------	------	N/A
	NA	-.008	------	-.007	------	------	------	------	N/A
	CL	-.009	-0.011	-.007	------	------	------	------	N/A
	SO_4	------	------	------	------	------	------	------	N/A
	HCO_3	------	------	------	------	------	------	------	N/A
	DS	------	------	------	------	------	------	------	N/A
09152500 Gunnison River near Grand Junction, Colo	Q	+.027	------	------	-.056	+0.027	------	------	-0.056
	CA	------	------	-.029	------	------	------	------	------
	MG	-.026	------	-.040	-.037	------	------	------	------
	NA	------	------	-.031	-.036	-.037	------	-0.024	------
	CL	-.024	------	-.021	------	-.051	------	------	+.050
	SO_4	------	------	-.025	-.029	-.037	------	------	------
	HCO_3	------	------	-.025	-.063	-.014	------	-.018	------
	DS	------	-.020	-.024	-.040	-.031	------	-.018	------
09180000 Dolores River near Cisco, Utah	Q	------	------	N/A	N/A	------	------	N/A	N/A
	CA	------	------	N/A	N/A	------	------	N/A	N/A
	MG	-0.032	------	N/A	N/A	------	------	N/A	N/A
	NA	------	-0.038	N/A	N/A	------	------	N/A	N/A
	CL	------	------	N/A	N/A	------	------	N/A	N/A
	SO_4	------	------	N/A	N/A	------	------	N/A	N/A
	HCO_3	------	------	N/A	N/A	+.016	------	N/A	N/A
	DS	------	------	N/A	N/A	------	------	N/A	N/A
09180500 Colorado River near Cisco, Utah	Q	------	------	------	------	------	------	------	------
	CA	------	-.022	------	-.024	-.011	------	------	------
	MG	-.014	-.020	-0.019	-.025	-.023	------	-.016	------
	NA	-.009	------	-.014	------	-.018	+.023	------	+.030
	CL	------	------	------	------	------	+.025	------	+.031
	SO_4	-.014	-.013	-.014	------	-.023	------	------	------
	HCO_3	------	------	------	------	------	------	------	------
	DS	------	------	-.010	------	-.015	------	------	------

Table 14.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time)*--Continued

Station number and name	Constituent	Post-1969							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	------	-0.040	-0.032	N/A	------	-0.040	-0.032	N/A
	CA	------	------	-.027	N/A	------	+.030	------	N/A
	MG	-0.030	------	-.040	N/A	------	+.023	------	N/A
	NA	-.015	-.020	-.016	N/A	------	------	------	N/A
	CL	-.015	-.023	-.014	N/A	------	------	------	N/A
	SO_4	-.022	------	-.033	N/A	------	+.38	------	N/A
	HCO_3	------	------	-.033	N/A	------	+.022	------	N/A
	DS	-.019	------	-.025	N/A	------	+.027	------	N/A
09152500 Gunnison River near Grand Junction, Colo-------	Q	------	------	-.040	N/A	------	------	-.040	N/A
	CA	------	------	-.030	N/A	------	------	------	N/A
	MG	-.030	------	-.040	N/A	------	------	------	N/A
	NA	-.020	------	-.040	N/A	------	------	------	N/A
	CL	-.060	------	-.040	N/A	-.030	------	------	N/A
	SO_4	------	------	-.040	N/A	------	------	------	N/A
	HCO_3	------	------	-.050	N/A	------	------	------	N/A
	DS	-.020	------	-.040	N/A	------	------	------	N/A
09180000 Dolores River néar Cisco, Utah----------------	Q	------	------	N/A	N/A	------	------	N/A	N/A
	CA	------	------	N/A	N/A	------	------	N/A	N/A
	MG	------	------	N/A	N/A	------	------	N/A	N/A
	NA	------	+.050	N/A	N/A	------	------	N/A	N/A
	CL	------	------	N/A	N/A	------	------	N/A	N/A
	SO_4	------	------	N/A	N/A	------	------	N/A	N/A
	HCO_3	------	------	N/A	N/A	------	------	N/A	N/A
	DS	------	------	N/A	N/A	------	------	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	------	-.050	------	N/A	------	-.050	------	N/A
	CA	------	-.030	------	N/A	------	------	------	N/A
	MG	------	-.030	-.020	N/A	------	------	------	N/A
	NA	------	------	------	N/A	------	+.040	------	N/A
	CL	------	------	-.010	N/A	------	+.050	------	N/A
	SO_4	------	------	------	N/A	------	+.030	------	N/A
	HCO_3	------	-.050	------	N/A	------	------	------	N/A
	DS	------	------	------	N/A	-----	+.030	------	N/A

Table 14.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time)*--Continued

Station number and name	Constituent	Entire period of record: Monthly load (T/d), Season: Base	Peak	Return	Overall	Annual load (T/d): Pre-1965	Post 1965	Post-1969	Entire period of record
09095500 Colorado River, near Cameo, Colo	Q	+0.007	-0.011	+0.006	N/A	-0.025	------	------	------
	CA	------	-.010	------	N/A	-.015	------	------	------
	MG	------	------	------	N/A	-.027	------	------	------
	NA	------	-.004	+.002	N/A	------	------	------	------
	CL	+.001	-.003	+.002	N/A	------	-0.006	-0.012	------
	SO_4	------	------	------	N/A	------	------	------	------
	HCO_3	------	-.011	------	N/A	-.018	------	------	------
	DS	------	-.008	------	N/A	-.010	------	------	------
09152500 Gunnison River near Grand Junction, Colo	Q	+.020	-.019	+.014	N/A	------	------	------	------
	CA	+.004	-.010	------	N/A	-.019	------	------	------
	MG	------	-.005	------	N/A	-.056	-.030	------	------
	NA	-.007	-.010	-.008	N/A	-.060	-.022	------	-0.011
	CL	-.005	-.014	-.006	N/A	-.024	------	-.014	-.013
	SO_4	-.004	-.004	-.003	N/A	-.011	-.019	------	-.008
	HCO_3	+.010	-.019	+.008	N/A	------	------	------	------
	DS	------	-.010	------	N/A	------	-.018	------	------
09180000 Dolores River near Cisco, Utah	Q	------	+.030	N/A	N/A	------	------	------	------
	CA	------	+.030	N/A	N/A	------	+.014	------	------
	MG	------	+.030	N/A	N/A	------	+.012	------	------
	NA	+.010	+.020	N/A	N/A	------	+.012	+.020	+.020
	CL	+.010	------	N/A	N/A	------	+.014	------	+.020
	SO_4	------	+.030	N/A	N/A	------	------	------	+.010
	HCO_3	+.040	------	N/A	N/A	------	------	------	------
	DS	+.010	+.030	N/A	N/A	------	------	------	+.020
09180500 Colorado River near Cisco, Utah	Q	+.010	-.010	------	N/A	------	------	------	------
	CA	------	-.010	------	N/A	------	------	------	------
	MG	-.016	-.010	-.010	N/A	------	-.021	------	------
	NA	-.002	-.010	-.010	N/A	-.004	-.012	------	-.004
	CL	+.006	------	+.010	N/A	+.007	------	------	+.004
	SO_4	-.007	-.010	-.010	N/A	-.007	-.017	------	-.008
	HCO_3	+.003	-.010	------	N/A	------	------	------	------
	DS	------	-.010	-.010	N/A	------	------	------	-.004

Table 15.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time,ln(Q))*

[Q,=water discharge, in cubic feet per second, CA=calcium; MG=magnesium; NA=sodium; CL=chloride; SO_4=sulfate; HCO_3=carbonate; DS=dissolved solids; T/d=ton per day; mg/L=milligram per liter; N/A=not available; dashes=trend not significant at the 95-percent level]

Station number and name	Constituent	Pre-1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	------	------	------	+0.006	------	------
	MG	-0.008	-0.010	------	------	-0.008	------	-0.010	------
	NA	------	------	+0.003	------	------	------	+.003	------
	CL	------	------	------	------	------	------	------	------
	SO_4	------	------	------	------	------	------	------	------
	HCO_3	-.003	------	------	------	-.003	------	------	------
	DS	------	------	------	------	------	------	------	------
09152500 Gunnison River near Grand Junction, Colo--------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	------	------	------	------	------	------
	MG	-.007	-.007	-.009	-0.009	-.007	-.007	-.009	-0.009
	NA	-.009	-.011	-.012	-.014	-.009	-.011	-.012	-.014
	CL	-.013	-.008	-.014	-.009	-.013	-.008	-.014	-.009
	SO_4	-.006	------	-.006	------	-.006	------	-.005	------
	HCO_3	------	------	------	------	------	------	------	------
	DS	-.005	------	-.006	------	-.005	------	-.006	------
09180000 Dolores River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	MG	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	NA	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	CL	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	SO_4	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	HOC_3	-.077	------	N/A	N/A	N/A	N/A	N/A	N/A
	DS	------	------	N/A	N/A	N/A	N/A	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+.003	+.002	+.006	------	+.003	+.002	+.006
	MG	-.008	-.008	-.006	-.006	-.008	-.008	-.006	-.006
	NA	------	-.005	-.006	-.012	------	-.005	-.006	-.012
	CL	+.014	------	+.004	-.007	+.014	------	+.004	-.007
	SO_4	-.007	-.005	-.005	------	-.007	-.005	-.005	------
	HCO_3	-.005	------	-.002	+.005	-.005	------	-.002	+.005
	DS	-.002	------	-.003	-.003	-.002	------	-.003	-.003

Table 15.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time,ln(Q))*--Continued

Station number and name	Constituent	Post 1965							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	------	------	------	------	------	------
	MG	-0.021	------	-0.021	------	-0.021	------	-0.021	------
	NA	-.009	------	-.005	------	-.003	------	-.005	------
	CL	-.010	-0.011	-.007	------	------	-0.011	-.007	------
	SO_4	-.007	+.012	-.007	------	------	+.012	-.007	------
	HCO_3	------	------	------	------	------	------	------	------
	DS	-.006	------	-.005	------	------	------	-.005	------
09152500 Gunnison River near Grand Junction, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	-.017	------	------	------	-.017	------
	MG	-.017	------	-.026	-0.023	-.017	------	-.026	-0.023
	NA	-.019	------	-.028	-.018	-.019	------	-.028	-.018
	CL	-.038	------	-.018	------	-.038	------	-.018	------
	SO_4	-.017	------	-.023	------	-.017	------	-.023	------
	HCO_3	------	------	-.020	-.023	------	------	-.020	-.022
	DS	-.015	------	-.021	-.017	-.015	------	-.021	-.017
09180000 Dolores River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	MG	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	NA	------	+0.036	N/A	N/A	N/A	N/A	N/A	N/A
	CL	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	SO_4	------	------	N/A	N/A	N/A	N/A	N/A	N/A
	HCO_3	+.014	------	N/A	N/A	N/A	N/A	N/A	N/A
	DS	------	------	N/A	N/A	N/A	N/A	N/A	N/A
09180500 Colorado River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	-.007	------	------	------	-.007	------	------	------
	MG	-.017	------	-.017	------	-.017	------	-0.017	------
	NA	-.011	------	-.013	------	-.011	------	-.013	------
	CL	------	------	------	------	------	------	------	------
	SO_4	-.017	------	-.013	------	-.017	------	-.013	------
	HCO_3	------	------	------	------	------	------	------	------
	DS	-.009	------	-.008	------	-.009	------	-.008	------

Table 15.--*Trend results of monthly values computed by Method 1, with the regression relation, ln(parameter)=f(time,ln(Q))*--Continued

Station number and name	Constituent	Post 1969							
		Monthly load (T/d)				Monthly concentration (mg/L)			
		Season				Season			
		Base	Peak	Return	Overall	Base	Peak	Return	Overall
09095500 Colorado River near Cameo, Colo----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	+0.013	------	------	------	------	------	-0.004
	MG	-0.019	------	-0.027	------	-0.002	+0.005	-0.001	+.006
	NA	------	------	-.010	------	------	-.005	------	-.007
	CL	------	-.021	-.013	-0.026	------	-.019	------	-.025
	SO_4	------	+.016	-.015	------	------	------	-.005	------
	HCO_3	------	------	------	------	+.003	------	+.002	-.002
	DS	------	------	-.011	------	------	------	-.004	-.006
09152500 Gunnison River near Grand Junction, Colo-------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	-.020	-.030	-.010	-.010	-.010	-.010
	MG	-.014	------	-.020	-.030	-.020	-.010	-.020	-.010
	NA	------	------	-.030	-.030	-.020	-.020	-.020	-.020
	CL	-.050	------	-.020	------	-.030	-.040	-.030	-.030
	SO_4	------	------	-.020	-.030	-.020	-.010	-.020	-.010
	HCO_3	------	------	-.020	-.030	-.020	-.020	-.020	-.020
	DS	------	------	-.020	-.030	-.020	-.010	-.020	-.010
09180000 Dolores River near Cisco, Utah----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	N/A	N/A	+.003	-.007	N/A	N/A
	MG	------	------	N/A	N/A	------	-.010	N/A	N/A
	NA	------	------	N/A	N/A	+.020	+.030	N/A	N/A
	CL	------	------	N/A	N/A	+.020	+.030	N/A	N/A
	SO_4	------	------	N/A	N/A	-.006	------	N/A	N/A
	HCO_3	------	------	N/A	N/A	+.010	-.009	N/A	N/A
	DS	------	------	N/A	N/A	+.010	+.010	N/A	N/A
09180500 Colorado River near Cisco, Utah-----------------	Q	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CA	------	------	------	------	------	-.005	-.003	-.006
	MG	------	------	-0.01	------	-.013	------	-.013	------
	NA	------	------	------	------	------	------	------	------
	CL	------	------	------	------	------	------	------	------
	SO_4	------	------	------	------	-.006	------	-.008	------
	HCO_3	------	------	------	------	------	+.007	------	+.007
	DS	------	------	------	------	-.002	+.004	-.004	------