Summary Statistics and Trend Analysis of Water-Quality Data at Sites in the Gila River Basin, New Mexico and Arizona

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CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.40	millimeter
foot (ft)	0.305	meter
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	0.001233	hectometer
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
pound (lb)	0.907	megagram

In this report, temperature is reported in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$^{\circ}C = (^{\circ}F - 32)/1.8$$

ABBREVIATED UNITS FOR WATER CHEMISTRY

Chemical concentration and water temperature are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter (µS/cm) at 25°C.

Dissolved—In this report, the term "dissolved" refers to constituents in a representative water sample that pass through a 0.45-micrometer membrane filter or a 0.7-micrometer glass fiber filter for organic analysis. Determinations of dissolved constituents are made on subsamples of the filtrate.

Whole water, recoverable—The term "total" used in this report means "whole water, recoverable," which refers to constituents in solution after a representative water-suspended-sediment sample is digested (usually using a dilute acid solution). Complete dissolution of particulate matter often is not achieved by the digestion treatment, and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. For inorganic determinations, digestions are performed in the original sample container to ensure digestion of material absorbed on the container walls. To achieve comparability of analytical data, equivalent digestion procedures would be required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

VERTICAL DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called "Sea Level Datum of 1929."

Summary Statistics and Trend Analysis of Water-Quality Data at Sites in the Gila River Basin, New Mexico and Arizona

By Stanley Baldys, III, Lisa K. Ham, *and* Kenneth D. Fossum

Abstract

Summary statistics and temporal trends for 19 water-chemistry constituents and for turbidity were computed for 13 study sites in the Gila River basin, Arizona and New Mexico, from data collected beginning as early as October 1972 through September 1987. A nonparametric statistical technique, the seasonal Kendall tau test for flow-adjusted data, was used to analyze temporal changes in water-chemistry data. For the 19 selected constituents and turbidity, decreasing trends outnumbered increasing trends by more than two to one.

Decreasing trends were found for 49 data sets at the 13 study sites. Sites having the largest number of decreasing trends were Gila River at Calva and Gila River above diversions, at Gillespie Dam (eight each). Data for Gila River at Calva indicated decreasing values of hardness, dissolved chloride, dissolved sodium, dissolved sulfate, dissolved solids, total phosphorus, dissolved lead, and total manganese. Data for Gila River above diversions, at Gillespie Dam indicated decreasing concentrations for hardness, dissolved chloride, dissolved sodium, dissolved sulfate, dissolved solids, dissolved barium, dissolved lead, and total manganese. The largest number of decreasing trends measured for a constituent was six for dissolved lead. The next largest number of decreasing trends for a constituent was for total manganese and dissolved solids (five each). Dissolved chloride, dissolved sodium, and hardness had decreasing trends at four of the study sites.

Increasing trends for the 19 water-chemistry constituents and for turbidity were found for 24 data sets at the 13 study sites. Pinal Creek at Inspiration Dam had the largest number (six) of increasing trends—dissolved chloride, dissolved sodium, dissolved sulfate, dissolved solids, total manganese, and dissolved chromium. Gila River near mouth, near Yuma had three increasing trends—dissolved sulfate, total lead, and total ammonia plus organic nitrogen. The largest number of increasing trends measured for a single constituent or property was for pH (four), dissolved sulfate (three), dissolved chromium (three), and dissolved manganese (three). Increasing values of constituents or turbidity generally were found in three areas in the basin—at Pinal Creek above Inspiration Dam, at sites above reservoirs, and at sites on the main stem of the Gila River from Gillespie Dam to the mouth.

INTRODUCTION

Water-resources managers are interested in effectively evaluating and understanding short- and long-term trends of water quality in streams in the Gila River basin. The Gila River basin is a valuable source of water for agricultural, industrial, and municipal uses throughout central Arizona and western New Mexico. In Arizona, the increased population from 499,261 in 1940 to 3,605,700 in 1988 (Valley National Bank, 1988) has resulted in increased demands on surface-water and ground-water resources.

The U.S. Geological Survey (USGS), in cooperation with the Arizona Department of Environmental Quality (ADEQ), assessed temporal changes in water-chemistry data collected at 13 sites in the Gila River basin. A nonparametric statistical technique, the seasonal Kendall tau test for flow-adjusted data, was selected as the method used for trend analysis. Water-chemistry data collected at several sites in the Gila River basin, mostly by the ADEQ and the USGS, were available for trend analysis.

Purpose and Scope

This report describes temporal and areal variability of 19 water-chemistry constituents and turbidity in samples collected at 13 streamflow-gaging stations in the Gila River basin beginning as early as February 1926 at one station through September 1987. The chemical constituents and turbidity used in computations of summary statistics and analyses of temporal trends were selected by joint agreement of the USGS and the ADEQ on the basis of previous studies in which increases occurred at one or more sites and streamflow data suggested input from point- or nonpoint-pollution sources. An attempt was made to select those for which the State of Arizona had developed or was developing quality standards for surface waters. The 19 constituents selected were pH, hardness, dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, total ammonia plus organic nitrogen, total phosphorus, dissolved arsenic, dissolved barium, total boron, dissolved chromium, suspended copper, total copper, dissolved lead, total lead, total manganese, dissolved zinc, and total organic carbon. The study sites were selected on the basis of availability of historical data and the *importance* of the stream segment to the Gila River basin. Six of the 13 gaging stations are on the main stem of the Gila River. The remaining seven stations are on major tributaries to the Gila River—one on the San Francisco River, one on the San Pedro River, two on the Agua Fria River, two on the Salt River, and one on Pinal Creek, which is tributary to the Salt River.

Previous Studies

Only a few appraisals have been done on the quality of surface water in the Gila River basin. Hem (1950) studied water-chemistry characteristics of the Gila River basin above Coolidge Dam. Feth and Hem (1963) did a reconnaissance study of the water chemistry of headwater springs in the Gila River basin. Robertson (1975) reported on hexavalent-chromium concentrations in the ground water in the northeastern part of the Phoenix area. Kister and Hardt (1966) investigated salinity of ground water in west Pinal County. Baldys (1990) did a trend analysis on the Verde River. Smith and others (1982a) defined water chemistry of surface water in canals carrying water diverted at Granite Reef Dam. Wilson (1988) reported on water chemistry of base flow in the Agua Fria River in the northern part of the Agua Fria River basin. Brown and Pool (1989) studied the ground-water chemistry in the San Carlos Indian Reservation. Arizona Department of Health Services (1976, 1986) and Arizona Department of Environmental Quality (1986, 1988, 1990, and 1992) reported on the water chemistry of surface waters for the entire State.

The seasonal Kendall tau test applied to flow-adjusted data was used as the method of trend analysis in this report. The test was described by Kendall (1975), Hirsch (1981), Smith and others (1982a), and Alley (1988). This method of trend analysis has been used in several hydrologic investigations (Smith and others 1982a; Buell and Grams, 1985; Goetz and others, 1987; Smith and others, 1987).

Basin Description

The Gila River basin lies within the boundaries of three major water provinces of Arizona and New Mexico—the Plateau uplands province, Central highlands province, and the Basin and Range lowland province (fig. 1). The drainage area for the basin is about 57,950 mi^2 at streamflow-gaging station, Gila River near mouth, near Yuma (09520700). The two largest cities in Arizona—Phoenix, with a population of 954,485 and Tucson, with a population of 412,590—are in

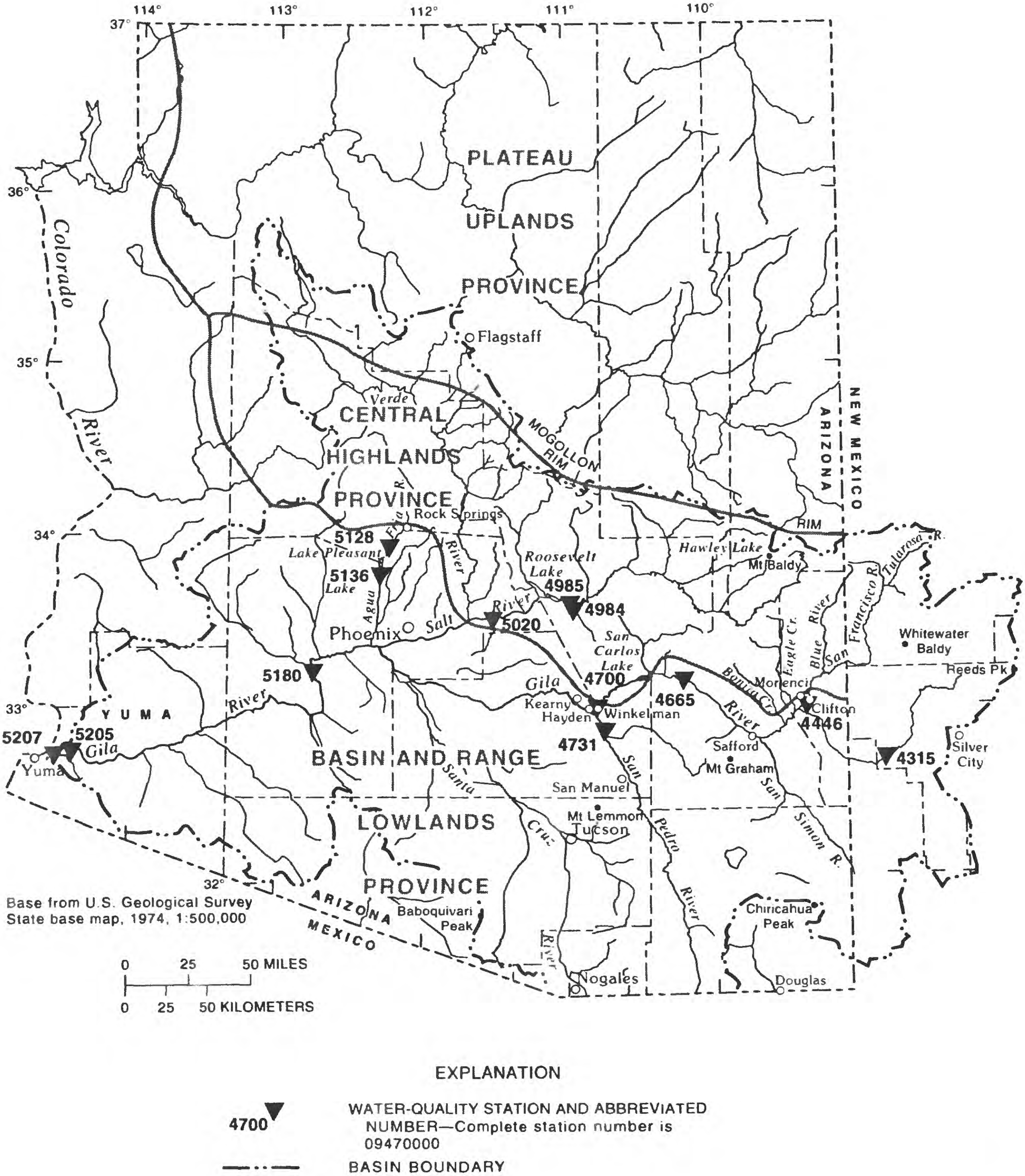


Figure 1. Study area, water provinces, and water-quality stations, Salt and Gila River basins.

the Gila River basin (Valley National Bank, 1988). Land use has changed in these metropolitan areas; land that was formerly used for agriculture has been converted to urban use. The computer industry is predominant in the basin (Valley National Bank, 1988), although some heavy industries such as copper mines and associated smelters are in Clifton-Morenci, Globe-Miami, Hayden-Kearny, and San Manuel. A copper smelter at Douglas discontinued operation in 1986.

The Central highlands water province includes the central part of Arizona and the far western part of New Mexico. The province consists principally of rugged volcanic mountains. Some peaks are at an altitude of about 11,000 ft above sea level and include Mount Baldy near McNary, 11,403 ft; Whitewater Baldy, 10,892 ft; and Reeds Peak, 10,001 ft. Whitewater Baldy and Reeds Peak are north of Silver City, New Mexico. The Mogollon Rim is an escarpment that consists mostly of Paleozoic sedimentary rocks such as sandstone, siltstone, claystone, and limestone (Arizona Bureau of Mines, 1969). Along the base of the Mogollon Rim, many springs issue from the Coconino Sandstone and underlying Supai Formation of Pennsylvanian and Permian age and Redwall Limestone of Mississippian age (Arizona Bureau of Mines, 1969).

The Central highlands receives the greatest amount of precipitation in Arizona, partly because of the orographic effect of the Mogollon Rim. The Mogollon Rim forms much of the north boundary of the water province. Average annual precipitation at Hawley Lake in the White Mountains, part of the Mogollon Rim, is 37.4 in. (Sellers and others, 1985). Average annual precipitation at Winkelman near the southwest boundary of the water province is 14.0 in. (Sellers and others, 1985).

The Gila River heads in the eastern part of the Central highlands in western New Mexico where the boundary of the province is the Continental Divide. The Tularosa River in New Mexico and the Blue River in Arizona join to become the San Francisco River, which flows southward to join the main stem of the Gila River near the city of Clifton. Bonita Creek and Eagle Creek—major tributaries to the Gila River—join the Gila River south of Clifton. The Gila River then flows through Safford Valley to Coolidge Dam where the San Carlos Reservoir is formed. The usable capacity of the reservoir is 935,000 acre-ft. Water is released according to needs of downstream users and seldom reaches the Phoenix metropolitan area. The two largest tributaries to the Gila River west of Clifton are the Salt River and the Verde River. The average flow is 896 ft^3/s at the Salt River near Roosevelt streamflow-gaging station (09498500), which is upstream from four reservoirs on the Salt River (Garrett and Gellenbeck, 1991). The reservoirs—Roosevelt Lake, Apache Lake, Canyon Lake, and Saguaro Lake—have a combined usable capacity of 1,710,000 acre-ft. The average flow is 559 ft^3/s at Verde River below Tangle Creek, which is upstream from two major reservoirs (Garrett and Gellenbeck, 1991). The reservoirs below Verde River below Tangle Creek—Horseshoe Reservoir and Bartlett Reservoir—have a combined usable capacity of 309,600 acre-ft.

The Basin and Range lowlands water province is in the southern and southwestern part of Arizona. The province is made up of broad alluvial-floored basins bounded by high mountain ranges and receives little precipitation (Arizona Bureau of Mines, 1969). The highest peak in the Basin and Range province is Mount Graham, 10,720 ft, near Safford. Other peaks in the province include Mount Lemmon near Tucson, 9,157 ft; Chiricahua Peak near Douglas, 9,796 ft; and Baboquivari Peak west of Tucson, 7,734 ft. The altitude of the Gila River ranges from 1,950 ft above sea level at the Central highlands boundary to 120 ft at the streamflow-gaging station, Gila River near mouth, near Yuma. Average annual precipitation is 7.0 in. at the Phoenix airport and 3.4 in. in Yuma (Sellers and others, 1985)

The mountains of the Basin and Range lowlands are composed chiefly of granite, gneiss, schist, and quartzite; some mountains are capped by volcanic rocks that range from Precambrian to Tertiary in age (Arizona Bureau of Mines, 1969). The valleys are filled with unconsolidated deposits that may be as much as 3,000 ft thick (Arizona Bureau of Mines, 1969).

Major tributaries to the Gila River in the Basin and Range lowlands to the east and south of Phoenix include the San Simon, San Pedro, and Santa Cruz Rivers. Mean annual flows in the three tributaries are each less than 40 ft^3/s; flows in the San Simon and Santa Cruz Rivers seldom reach the Gila River. The Agua Fria River is a major tributary to the Gila River west of Phoenix. Flow in the Agua Fria River is regulated by Waddell Dam, which forms Lake Pleasant. The usable capacity of Lake Pleasant is 157,600 acre-ft. Flow in the Gila River west of Phoenix is regulated by the earthen dam at Painted Rock Reservoir, which has a usable capacity of 2,492,000 acre-ft.

The Gila River basin encompasses a region characterized by diverse temperatures and vegetation. In the lower deserts, temperatures often exceed 115°F during the summer months; in the mountainous areas, subzero temperatures are common during winter months. Vegetation types, in general, follow patterns of rainfall and altitude in the basin. Cactus and other types of desert shrubs are found in the low-altitude and low-rainfall areas of the basin. Chaparral and pinyon pine are found between 3,500 and 7,000 ft (McDougall, 1973). Mixed-conifer vegetation is found in areas that receive large amounts of precipitation, generally higher than 7,000 ft (McDougall, 1973).

Data-Collection History

Water-chemistry data were collected in the Gila River basin beginning in February 1926, but sampling for the constituents outlined in this report did not begin at most of the study sites until the mid-1970's or early 1980's (fig. 1, table 1). Much of the early sampling was done only for water-temperature and specific-conductance determinations and did not include determinations of major ions, nutrients, and metal concentrations. The collection of the water-chemistry data used to compute summary statistics and trends began October 1972 through September 1987. Samples were collected using methods developed by the USGS and summarized by Sylvester and others (M.A. Sylvester, hydrologist, USGS, written commun., 1990). The method of sample collection generally involved depth-integrating samples by withdrawing water at several verticals in the stream; the location of the verticals was determined by dividing the stream into equal-discharge increments or equal-width increments. Samples were processed using standard methods of the USGS and sent to laboratories in Atlanta, Georgia, or Denver, Colorado, for chemical analyses.

Stage and discharge data were collected at all 13 study sites. The period of surface-water data collection at a site generally exceeded the period of water-chemistry data collection because surface-water data collection began as early as 1910. Mean-annual flow computed for each site ranged from 12.3 ft^3/s at Pinal Creek at Inspiration Dam, near Globe (09498400) to 979 ft^3/s at Salt River below Stewart Mountain Dam (09502000).

METHODS

The methods of data analysis used in this study have been used in previous studies and are well documented. Summary statistics were calculated for the 19 water-chemistry constituents and for turbidity at each site using software programs developed by Helsel and Cohn (1988). Data used in this analysis are stored in the USGS National Water Information System. Temporal trends in the water-chemistry data were analyzed using the seasonal Kendall tau test, standard statistical software packages, and a low-adjustment procedure by Smith and others (1982a).

Summary Statistics

Summary statistics calculated for the 19 water-chemistry constituents and for turbidity included values of the mean, median, minimum, maximum, standard deviation, and standard error of the mean. Visual summaries of the distribution of the data are shown in boxplots that are constructed by ranking data from smallest to largest. A box is drawn from the 25th percentile to the 75th percentile; box length equals the interquartile range. A center line between the 25th and 75th percentiles is drawn across the box at the median (50th percentile). "Whiskers" are then drawn from the quartiles to two adjacent values. The upper adjacent value is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. The lower adjacent value is defined similarly. Values more extreme than the adjacent values and within a range of 1.5 to 3.0 times the interquartile range are called outlier values and are plotted with the letter "x." Data values greater than or less than three times the

Table 1. Study sites for trend analysis, Salt and Gila River basins

Station number	Station name	Drainage area, in square miles	Mean annual streamflow, in cubic feet per second	Date of collection	
				From	To
09431500	Gila River near Redrock, New Mexico	2,829	209	9–73	9–87
09444600	San Francisco River near Clifton	2,766	213	1–76 10–80 10–86	9–79 3–84 9–87
09466500	Gila River at Calva	11,470	328	10–74	9–87
09470000	Gila River at Winkelman	13,268	[1]294	1–76	9–84
09473100	San Pedro River below Aravaipa Creek, near Mammoth	4,360	([2])	10–80	9–86
09498400	Pinal Creek at Inspiration Dam, near Globe	195	12.3	11–79	9–87
09498500	Salt River near Roosevelt	4,306	903	1–76	9–87
09502000	Salt River below Stewart Mountain Dam	6,232	979	10–72	9–87
09512800	Agua Fria River near Rock Springs	1,130	88.3	1–82	9–87
09513600	Agua Fria River below Waddell Dam	1,433	[3]96.5	3–82	9–87
09518000	Gila River above diversions, at Gillespie Dam	49,650	404	6–74	9–87
09520500	Gila River near Dome	57,850	([4])	4–73 1–79 10–83	8–73 1–79 9–87
09520700	Gila River near mouth, near Yuma	57,950	([4])	10–72	9–84

[1]Adjusted for storage in San Carlos Reservoir, Arizona.
[2]Surface-water data collection less than 5 years.
[3]Average discharge at station, 09513000, Agua Fria River at Waddell Dam, Arizona.
[4]Not calculated because of many diversions, storage reservoirs, and other uses upstream from station.

interquartile range are called extreme values and are plotted with a circle.

Standard statistical procedures were used to calculate the statistics for data sets that did not contain "less than" values, which are also referred to as censored data. Censored data are values reported from analytical techniques as less than the minimum reporting level (MRL). Some data sets contain multiple MRL's. This study used the logarithmic-probability regression method developed by Helsel and Cohn (1988) to compute summary statistics for data sets of constituents that contained "less than" values.

Seasonal Kendall Tau Test on Flow-Adjusted Data

The seasonal Kendall tau test is a distribution-free test that is not affected by the problems that affect ordinary least-squares (OLS) regression analysis (water-chemistry constituent against time), with the exception of serial correlation. The major advantage of distribution-free tests is that the underlying probability distribution of the random variable is immaterial (Smith and others, 1982a). This test accounts for the effects of discharge on the concentration of a particular water-chemistry constituent. The seasonal Kendall tau test is preferred over other methods of trend analysis, such as regression analysis, because it can be applied to data sets containing outlier values (nonnormal distributed data sets), gaps or missing data, data reported as below reporting limits, and data correlated in time (seasonality). The seasonal Kendall tau test used in this study was derived by Hirsch (1981) from the method presented by Kendall (1975).

The seasonal Kendall tau test on flow-adjusted data is done in two steps. In the first step, water-chemistry data are flow adjusted using OLS regression analysis to remove some of the variability of the water-chemistry data. Most water-chemistry data in a mathematically untransformed state when regressed against time do not have residuals from the regression that satisfy the assumptions of normality and homogeneity of variances needed for regression analysis. These assumptions are not met because the seasonal variability of the data is likely to be distributed nonuniformly. A method to remove some of the variability is to use an exogenous variable; in the case of water-chemistry constituent concentrations, the exogenous variable generally is instantaneous discharge. In the OLS regression analysis, the water-chemistry variable in question is regressed against instantaneous discharge. An example of this method is the regressing of concentrations of dissolved sodium against instantaneous discharge for data from the San Francisco River near Clifton (09444600; data transferred to base-10 logarithmic units; fig. 2). The equation used for the regression is

$$f(c_i) = B_0 + B_1 f(Q_i) + e', \quad (1)$$

where

c_i = instantaneous concentration of the water-chemistry constituent,

Q_i = instantaneous water discharge,

$B_{0,1}$ = regression parameters, and

e' = sample residual (error) in regression.

The instantaneous-discharge value, Q_i, can be transformed mathematically by a number of methods in order to produce a better model. This

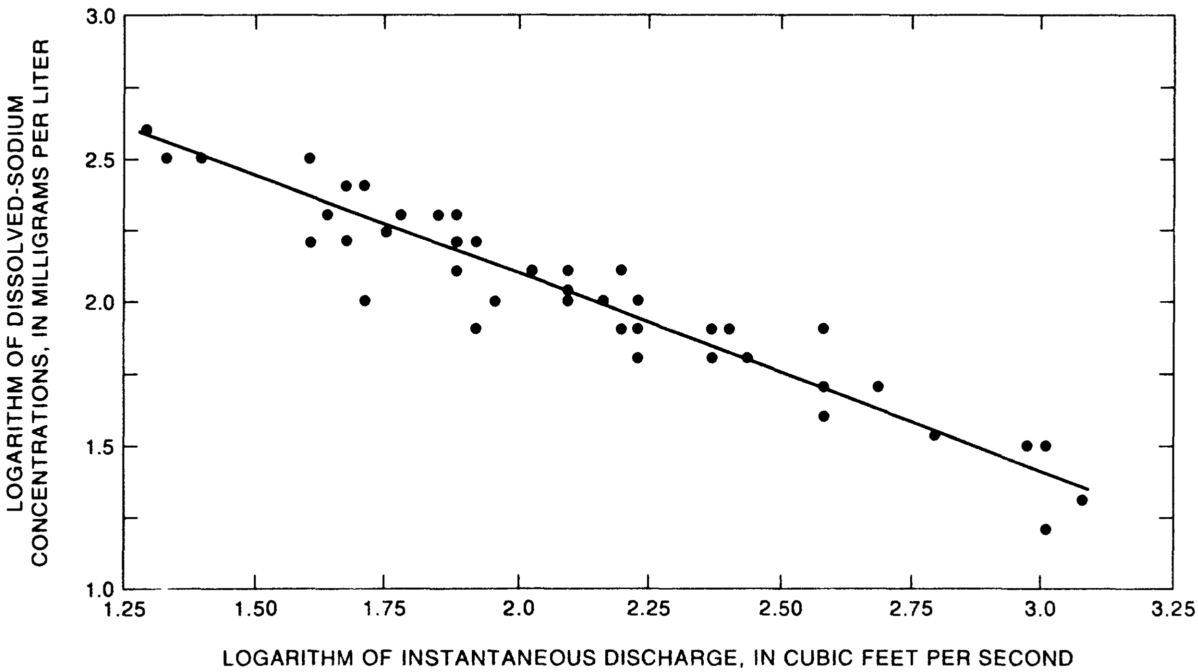


Figure 2. Logarithms of concentrations of dissolved sodium and instantaneous discharges resulting from regression equation for San Francisco River near Clifton.

study used the following transformation functions of $f(Q_i)$.

Transformation	Type
$f(Q_i)=Q_i$	Linear (LIN)
$f(Q_i)=\log10(Q_i)$	Logarithmic (LOG)
$f(Q_i)=1/Q_i$	Inverse (INV)
$f(Q_i)=1/(1+BQ_i)$	Hyperbolic (HYP)

(B of the hyperbolic transformation is equal to $10[(-2.5)(\log10(Q_i))+X]$ where X varies from $10^{0.5}$ to $10^{3.5}$ by increments of $10^{0.5}$.)

The hyperbolic transformation was used by Buell and Grams (1985) in their investigation of temporal trends in selected water-chemistry constituents and turbidity for streams in Georgia. The constituent concentrations (c_i) were used in either their raw format $f(c_i)$ - c_i or as a logarithmic base-10 transformed value $f(c_i)$-$\log10(c_i)$. Using these transformations, several regression equations were computed. The equation with the best residual plot showing a normal distribution and with a coefficient of determination (r^2) greater than 0.100 was selected to define the relation between discharge and the concentration of the constituent in question. The r^2 value for the regression line in figure 2 is 0.946, which shows high correlation between concentration and discharge; however, the residuals from this equation show little correlation with instantaneous discharge (fig. 3). This relation was used to provide a conditional expected value of concentration for every discharge value.

Equation 1 was checked for normality of residuals. If residuals were normally distributed and the r^2 value for equation 1 was greater than 0.100, the residuals were renamed flow-adjusted concentrations and the seasonal Kendall tau test was applied. In cases where the regression relations were poor ($r^2<0.100$), the estimated conditional expected concentration was defined as the mean concentration of the data set of the water-chemistry variable. The flow-adjusted concentration for these cases in which the mean concentration was substituted was defined as the actual concentration minus the mean concentration of the data set. Values for r^2 are reported in percent for the remainder of this report. An r^2 value of 0.100 is considered equivalent to 10 percent.

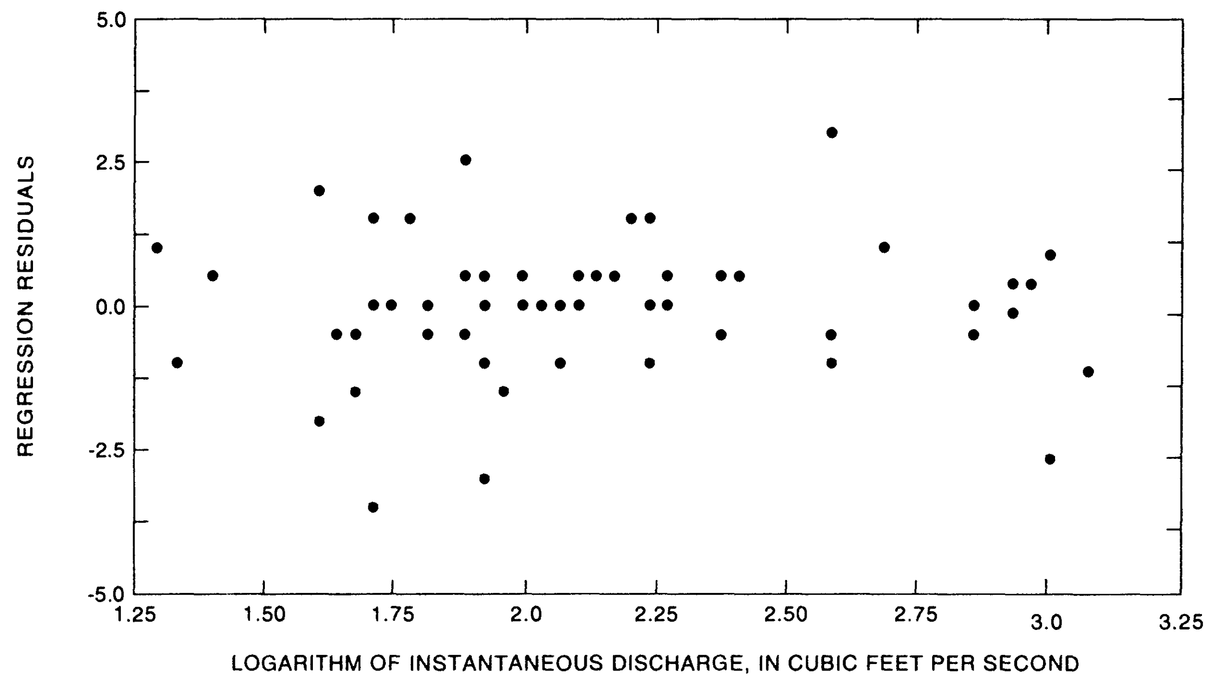


Figure 3. Sample residuals from the regression of the logarithms of dissolved-sodium concentrations and instantaneous discharges for samples collected at San Francisco River near Clifton.

In the second step of the method, which is the application of the seasonal Kendall tau test, all possible pairs of data values within a season are compared. In the seasonal Kendall tau test, the year is divided into 12 segments (monthly). If more than one sample value is collected during the same month of the same year, the first value collected was used in the analysis. Only data pairs that occur during the same month of the year are compared in the analysis, which reduces the problem of seasonality that generally occurs in water-chemistry data. If the later value (in time) is greater, a plus is scored; if the later value is smaller, a minus is scored; and if the values are equal (tied), a zero is scored. The null hypothesis of no significant trend is accepted if the number of pluses is about the same as the number of minuses. Many more pluses than minuses indicate an increasing trend, and conversely, a dominance of minuses indicate a decreasing trend (Smith and others, 1982b).

The seasonal Kendall tau slope estimator, which is an extension of the seasonal Kendall tau test, estimates the magnitude of the trend of the water-chemistry constituent. The estimate is defined by Smith and others (1982b) as the median of the differences (expressed as slopes) of the ordered pairs of data values that are compared in the seasonal Kendall tau test. The difference of each pair of data points is divided by the number of years separating them and recorded in place of a minus or plus. The values of the differences divided by the number of years are ranked, and the median value is accepted as the change per year of the water-chemistry constituent.

The seasonal Kendall tau test was applied to flow-adjusted concentration (FAC) data for the 19 selected constituents and for turbidity at the 13 data-collection sites. The p value was calculated for the seasonal Kendall tau test on the FAC data. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. This report considers a p value of 0.1000 or less to be statistically significant and a rejection of the null hypothesis; hence, a trend in the water-chemistry constituent exists. A p value of greater than 0.1000 would indicate that the null hypothesis was true and that no trend exists in the water-chemistry constituent.

The magnitude of the trend in question is reported as a constant rate of change per year for computations that did not use a logarithmic transformation of data. When a logarithmic transformation of data is used, the change measured in the raw (retransformed) data is not constant per year but is exponential with time because the change in log units is linear over time (E.J. Gilroy, mathematician, USGS, written commun., 1989). Hence, values for the trend measured by the seasonal Kendall tau test on FAC data where logarithmic transformation of the water-chemistry data were made represent only the amount of change for 1 year. The change is not consistent over the period of data collection of the constituent. The magnitude of the trend of the constituent is not calculated where more than 50 percent "less than" values occur in the data set.

SUMMARY STATISTICS AND TREND ANALYSES

From approximately 110 constituents sampled at each site, 19 constituents and turbidity were selected for trend analysis. The constituents and turbidity were selected by joint agreement of the USGS and ADEQ, and attempts were made to include those for which State of Arizona quality standards existed or were being developed. The constituents included pH, hardness, dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, total ammonia plus organic nitrogen, total phosphorus, dissolved arsenic, dissolved barium, total boron, dissolved chromium, suspended copper, total copper, dissolved lead, total lead, total manganese, dissolved zinc, and total organic carbon. The data for these constituents and turbidity were sufficient for statistical and trend analysis.

The chemical constituents and turbidity were compared with Federal quality criteria for water, Federal primary and secondary drinking-water regulations and health advisories, and State of Arizona quality standards for surface water (U.S. Environmental Protection Agency, 1986, 1991, 1993; State of Arizona, 1992). Maximum contaminant levels (MCL's) are the U.S. Environmental Protection Agency (USEPA) maximum permissible levels of contaminants in unfiltered water that is delivered to any user of a public water system. Secondary maximum contaminant levels (SMCL's) are USEPA nonenforceable guidelines that indicate upper aesthetic limits for certain constituents in unfiltered water. Higher concentrations of the constituents may or may not pose health risks. A drinking-water equivalent level (DWEL) is a lifetime exposure concentration protective of adverse, noncancer health effects, that assumes all of the exposure to a contaminant is from a drinking-water source. The State of Arizona has developed water-quality standards for each stream segment on the basis of the unique use of the water in that segment. Six main uses are identified—full body contact, incidental human contact, aquatic and wildlife, agricultural irrigation, agricultural livestock watering, and domestic water sources. The State has identified, on a site-specific basis, waters classified as unique for which standards generally are more stringent and as effluent dominated for which standards are not as stringent.

Summary statistics and trend analysis for each of the water-chemistry constituents and turbidity analyzed are described in this section, and the associated tables are presented at the end of this report. The summary-statistics table for each constituent or property by study site shows the number of samples analyzed; the mean, median, minimum, and maximum values; and the standard deviation and standard error of the mean of each data set. The trend-analysis table shows the type of transformations used in the flow-adjustment procedure, the median value of the data set, the calculated amount of increasing or decreasing concentrations per year, and the statistical significance (p value) of the seasonal Kendall tau test on flow-adjusted data.

pH

The pH of a water sample is used to define the amount of hydrogen-ion activity in the sample and is a measure of acid-base equilibrium achieved by various dissolved compounds, salts, and gases. Because pH is a major influence on the degree of toxicity and solubility of many compounds, pH is a useful index of the status of equilibrium reactions in which the water precipitates (Hem, 1985). The SMCL for pH of drinking water is 6.5 to 8.5 (U.S. Environmental Protection Agency, 1993). The State quality standards for surface water are shown in the table below (State of Arizona, 1992).

Values of pH were similar at the 13 study sites (fig. 4). Median values ranged from 7.9 at Gila River near Dome (09520500) and Gila River near mouth, near Yuma to 8.4 at Agua Fria River near Rock Springs (09512800; table 2, at the end of this report). The highest value of 9.8 was reported at Gila River at Calva (09466500) where irrigation-return flow occurs. The lowest value of 5.7, which was well below the Arizona minimum standard of 6.5, was recorded at Pinal Creek at Inspiration Dam. The Pinal Creek basin is affected by a contaminant plume from mine drainage (Eychaner and others, 1989).

Increasing values of pH were reported for 4 of the 13 sites (table 3, at the end of this report). Three of these sites were on the Gila River—at Calva (09466500; 0.029 units/yr); at Winkelman (09470000; 0.040 units/yr); and above diversions, at Gillespie Dam (09518000; 0.058 units/yr). The fourth increasing value of pH was reported for samples collected at Salt River below Stewart Mountain Dam (09502000; 0.044 units/yr). An increasing value of pH represents an increase in the hydroxyl component and a decrease in the quantity

Allowable limits, pH	Domestic water source	Full body contact	Partial body contact	Aquatic and wildlife	Agricultural use	
					Irrigation	Livestock
Maximum	9.0	9.0	9.0	9.0	9.0	9.0
Minimum	5.0	6.5	6.5	6.5	4.5	6.5
Maximum change due to human activities	([1])	.5	.5	.5	([1])	([1])

[1]No standard.

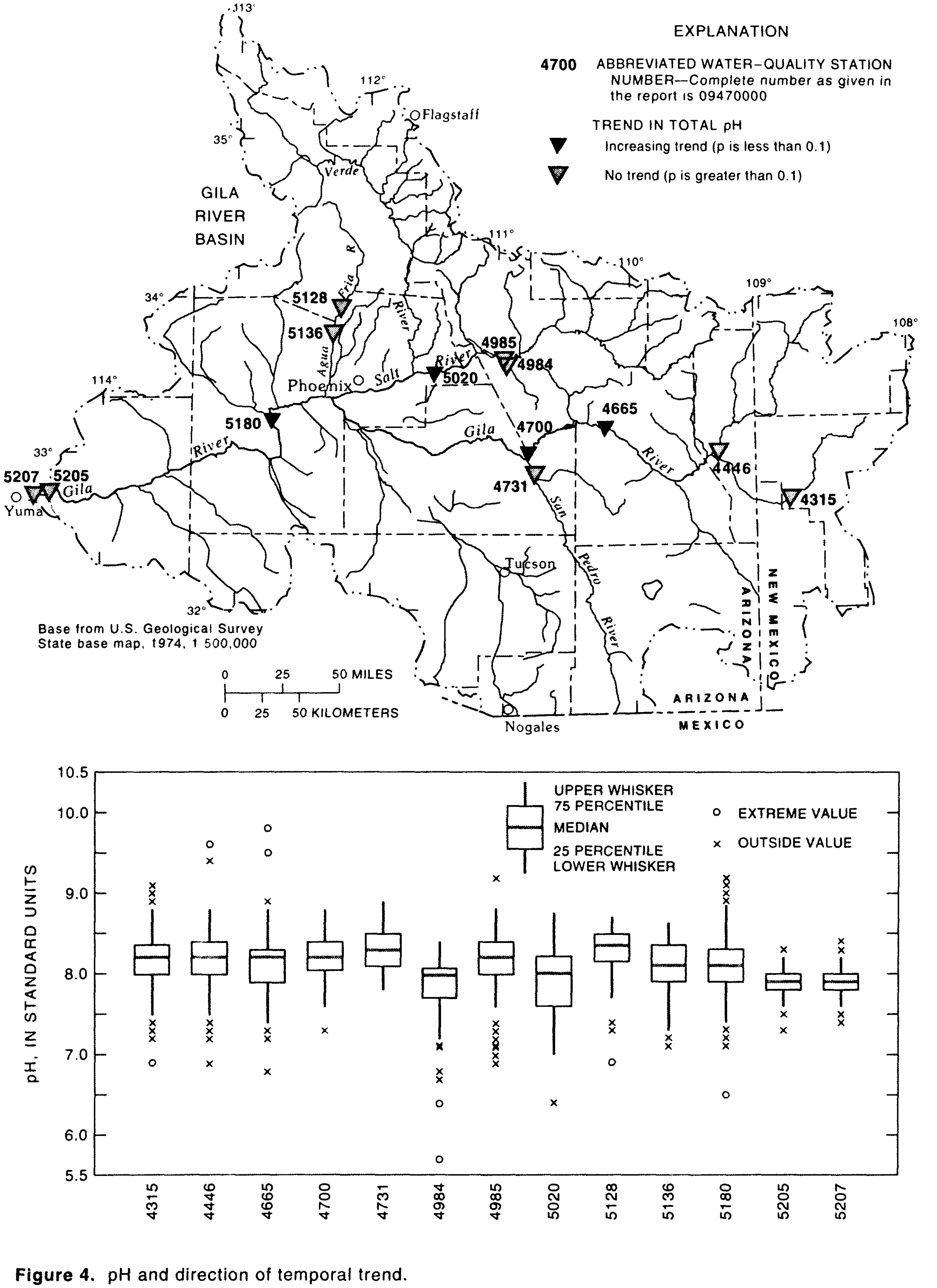


Figure 4. pH and direction of temporal trend.

of hydrogen ions; that is, water is becoming more alkaline and less acidic. The increasing values did not exceed the 0.5 pH unit change that is the State standard. Decreasing values of pH were not found. The flow-adjusted procedure was not effective for pH and was used at only 3 of the 13 sites; at these 3 sites, r^2 values were less than 13 percent.

Turbidity

Turbidity is suspended matter, which could be natural or human induced. Sources of suspended matter include clay, silt, finely divided organic and inorganic matter, insoluble organic compounds, and microscopic aquatic organisms. All of these contribute to the turbidity of the water, which can be detrimental to aquatic life and interfere with recreational use and aesthetic enjoyment of the water. The Federal criterion for freshwater fish and other aquatic life reads:

> "Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life"

(U.S. Environmental Protection Agency, 1986). The Federal MCL for safe drinking water is 0.5–1.0 nephelometric turbidity units (NTU; U.S. Environmental Protection Agency, 1993). The State has a quality standard for turbidity of 50 NTU for rivers, streams, and other flowing waters and 25 NTU for lakes, reservoirs, tanks, and ponds (State of Arizona, 1992).

Turbidity values varied throughout the study area and were affected mostly by reservoirs (table 4, at the end of this report). Median values ranged from 1.0 NTU at Agua Fria River near Rock Springs to 40 NTU at Gila River at Calva. The lowest maximum value of 31 NTU was measured at Agua Fria River below Waddell Dam (09513600), and the highest maximum value of 21,000 NTU was measured at Gila River at Calva. Overall, low turbidity values were found at sites downstream from a dam, indicating that sediments are caught and held upstream from the dam. Four sites—Gila River near Redrock, New Mexico (09431500); Gila River at Calva; San Pedro River below Aravaipa Creek, near Mammoth (09473100); and Agua Fria River near Rock Springs—had a minimum value of <0.01 NTU. These sites also had the highest maximum values, which indicate that these streams have a large fluctuation of suspended material, as evident by large interquartile ranges. The State quality standard of 50 NTU was not exceeded by median values at any of the study sites.

An increasing turbidity trend (0.09 NTU/yr) was found in only 1 of the 13 data sets, Agua Fria River near Rock Springs (fig. 5). A decreasing turbidity trend of -0.12 NTU/yr was calculated for Salt River below Stewart Mountain Dam. The flow-adjusted procedure worked well with flow-adjustment equations used at 12 of the 13 sites (table 5, at the end of this report). The r^2 values ranged from 14.6 to 70.8. The Salt River near Roosevelt site was the only site where the flow-adjustment procedure was not used (no correlation between discharge and turbidity).

Hardness

Hardness commonly is defined by the presence of calcium and magnesium and is reported as calcium carbonate in this report. Hardness is computed by multiplying the sum of milliequivalents per liter of calcium and magnesium by 50 (Hem, 1985). The degree of hardness has been classified into four categories according to the amount of calcium carbonate ($CaCO_3$) in the water sample (U.S. Environmental Protection Agency, 1986).

Concentration of calcium carbonate, in milligrams per liter	Classification
0–75	Soft
75–150	Moderately hard
150–300	Hard
300 and higher	Very hard

The softer the water is, the less calcium and magnesium present. Limestone is a natural source of hardness. Federal and State drinking-water regulations for hardness have not been established. The State has not established quality standards for hardness in surface waters.

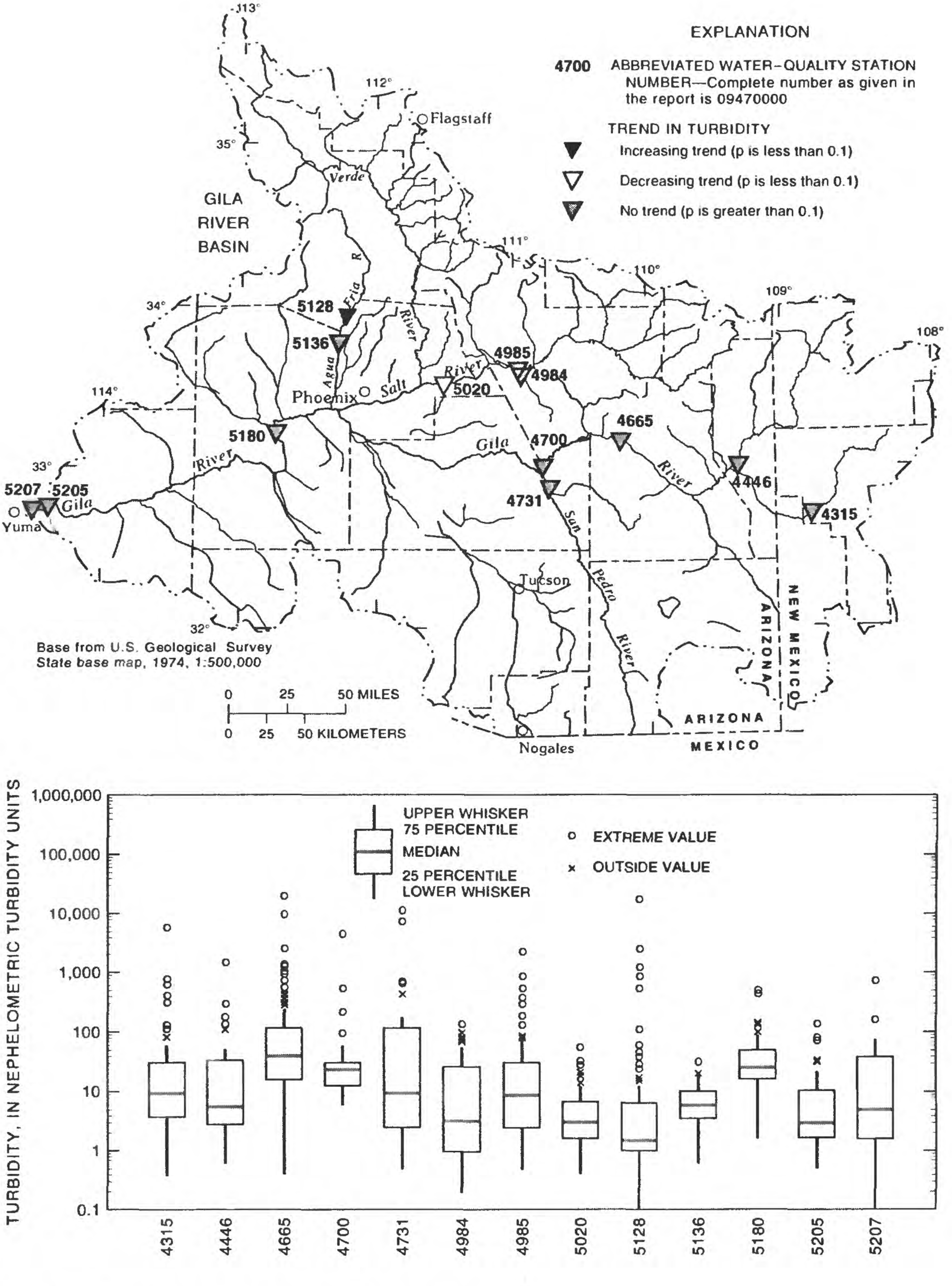


Figure 5. Turbidity and direction of temporal trend.

On the basis of median concentrations, water at six sites was very hard, and water at another six sites was hard. Median hardness concentrations ranged from 120 mg/L at Gila River near Redrock to 1,900 mg/L at Pinal Creek at Inspiration Dam (table 6, at the end of this report). The Pinal Creek site appears to be influenced by mine drainage; the median value was 60 percent greater than the median value of the other 12 sites. In contrast, the area surrounding the Gila River near Redrock site is relatively undisturbed. Minimum hardness concentrations ranged from 46 mg/L at Gila River near Redrock to 830 mg/L at Pinal Creek at Inspiration Dam. At Pinal Creek, a tributary to the Salt River, the minimum value for hardness was 830 mg/L, the median value was 1,900 mg/L, and the maximum value was 2,400 mg/L. The Salt River near Roosevelt site is 0.3 mi downstream from the Pinal Creek tributary; the minimum value for hardness was 70 mg/L, the median value was 250 mg/L, and the maximum value was 440 mg/L. Boxplots of the data show a significantly different distribution of data for hardness for the Pinal Creek site than at other sites (fig. 6).

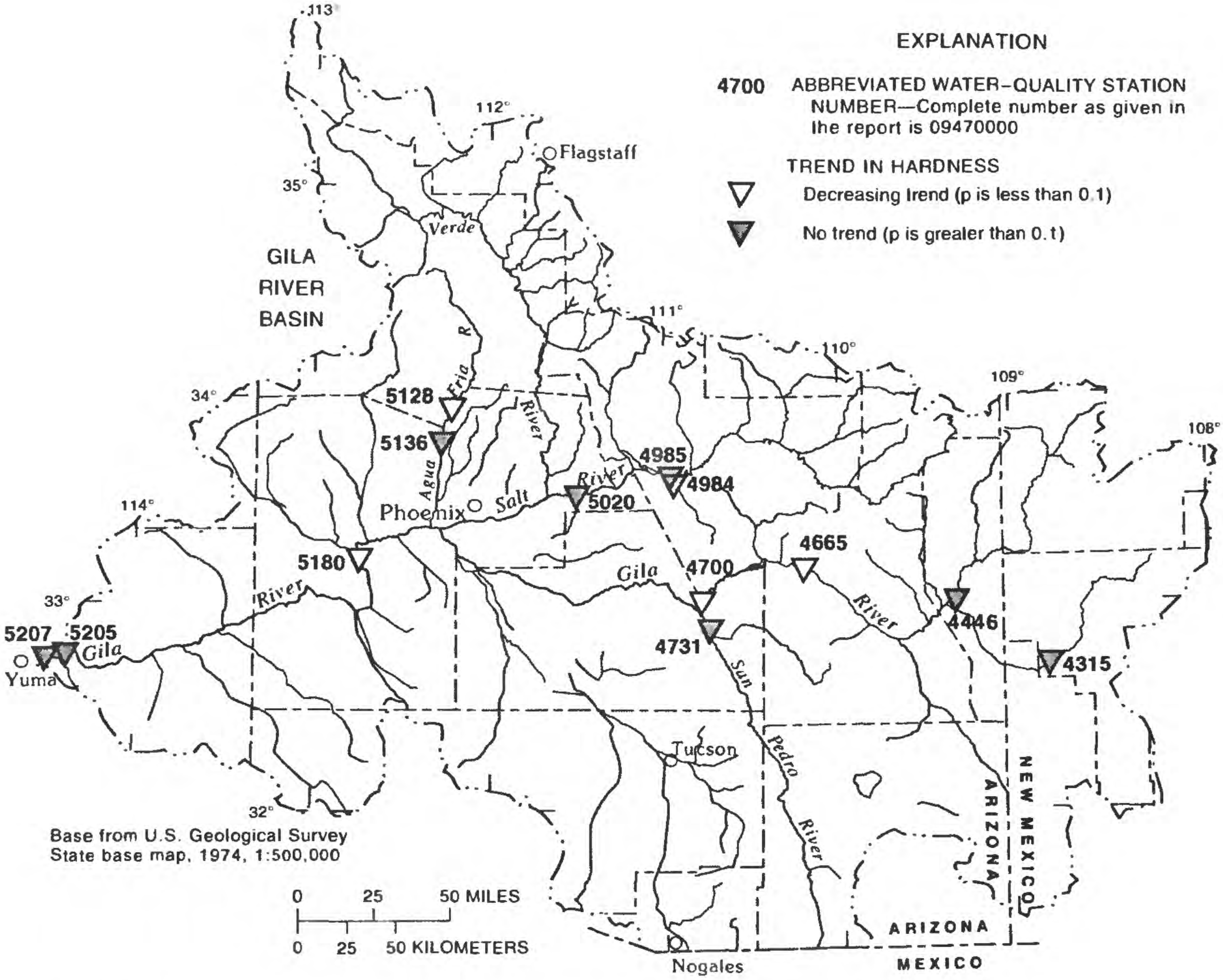
Decreasing trends in hardness concentrations were calculated for 4 of the 13 sites (table 7, at the end of this report). Three of the four sites are on the Gila River—at Calva (-0.07 (mg/L)/yr), at Winkelman (-0.18 (mg/L)/yr), and above diversions, at Gillespie Dam (-0.07 (mg/L)/yr). The fourth site is Agua Fria River near Rock Springs (-0.13 (mg/L)/yr). Increasing trends in hardness concentrations were not found for any sites including Pinal Creek at Inspiration Dam, which had the greatest median concentration (1,900 mg/L). The flow-adjusted equations were used for all sites except the Salt River below Stewart Mountain Dam. Aside from the Agua Fria River below Waddell Dam site ($r^2 = 21.4$), the r^2 values ranged from 48.7 to 84.3.

Dissolved Solids

Dissolved solids are inorganic salts and (or) small amounts of organic matter. The most common components of dissolved solids include the inorganic anions—carbonates, chlorides, sulfates, and nitrates—and the cations—sodium, potassium, calcium, and magnesium. Dissolved solids enter the environment through rock weathering and agricultural and industrial activity. Large concentrations of dissolved solids are undesirable in water because of the possible laxative effect, unpalatable mineral taste, and corrosive effect, hence the necessity for additional treatment for waters used as potable supplies. The SMCL for concentrations of dissolved solids in drinking water is 500 mg/L (U.S. Environmental Protection Agency, 1993). The State of Arizona does not enforce quality standards for dissolved solids in surface water within the study area but requires the monitoring of concentrations of dissolved solids.

Concentrations of dissolved solids varied widely throughout the study area (table 8, at the end of this report). Median concentrations for the main stem of the Gila River ranged from 229 mg/L at the farthest upstream station, Gila River near Redrock, to 2,570 mg/L at Gila River above diversions, at Gillespie Dam. Median concentrations of dissolved solids for tributaries to the Gila River ranged from 298 mg/L at Agua Fria River below Waddell Dam to 3,000 mg/L at Pinal Creek at Inspiration Dam. Nine of the study sites had median dissolved-solids concentrations greater than 500 mg/L. Dissolved-solids concentrations at sites below reservoirs on the Gila River typically are smaller than those immediately above reservoirs. The minimum dissolved-solids concentration of 68.0 mg/L was recorded at Gila River near Redrock and the maximum value of 5,870 mg/L at Gila River near Dome.

Dissolved-solids concentrations were found to be increasing at one site and decreasing at five sites, and no trend was apparent at the other seven sites (fig. 7). The trend of increasing dissolved-solids concentrations (0.49 (mg/L)/yr) at the Pinal Creek site had highly significant levels ($p<0.0001$) and had the largest median concentration (3,000 mg/L; table 9, at the end of this report). The confluence of Pinal Creek and the Salt River is 0.3 mi upstream from Salt River near Roosevelt; however, dissolved-solids concentrations do not appear to be increasing at Salt River near Roosevelt. Flow in Pinal Creek accounts for 2 to 3 percent of the flow measured at the Roosevelt site. Two of the five sites where trends of dissolved-solids concentrations were decreasing are upstream from the reservoirs: Gila River at Calva (-0.05 (mg/L)/yr) and Agua Fria



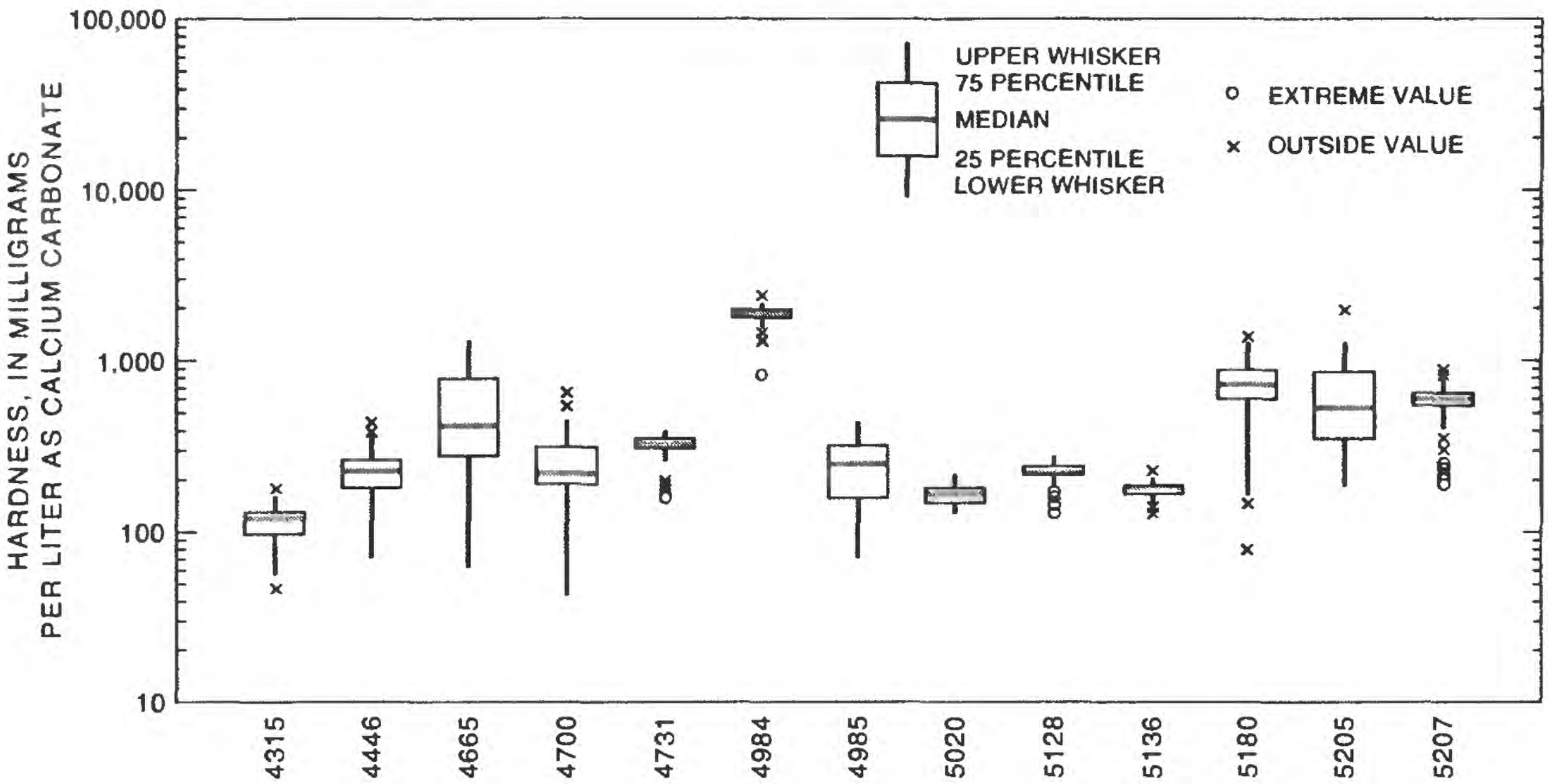


Figure 6. Hardness and direction of temporal trend.

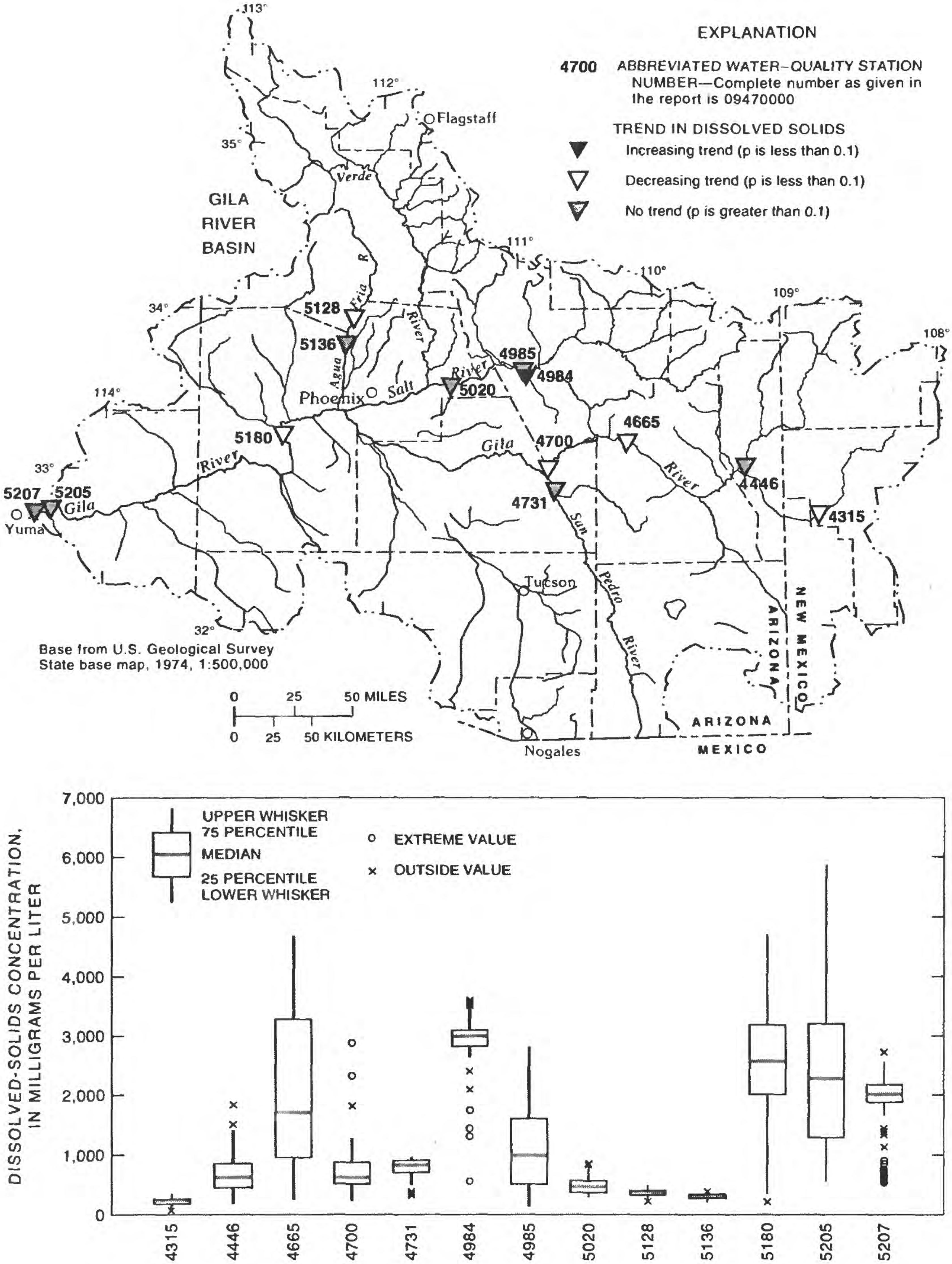


Figure 7. Dissolved solids and direction of temporal trend.

River near Rock Springs (-0.30 (mg/L)/yr). The other three sites with trends of decreasing dissolved-solids concentrations are at Gila River near Redrock (-0.45 (mg/L)/yr); Gila River at Winkelman (-0.20 (mg/L)/yr); and Gila River above diversions, at Gillespie Dam (-0.08 (mg/L)/yr). Concentrations of dissolved solids correlated with flow-adjusted discharge at 12 of the 13 study sites; Salt River below Stewart Mountain Dam was the only exception. The r^2 values ranged from 23.4 to 91.2.

Dissolved Sodium

Dissolved sodium is found in large concentrations throughout the study area. Major sources of dissolved sodium in the Salt River basin are natural springs occurring in the Central highlands (Feth and Hem, 1963). Increased concentrations of dissolved sodium can occur as a result of extensive ground-water pumping (Kister and Hardt, 1966). Irrigation-return flows, which contain large concentrations of dissolved sodium, can contribute significantly to the chemistry of surface waters receiving the return flow. The DWEL for sodium is 20 mg/L (unfiltered; U.S. Environmental Protection Agency, 1993). Quality standards have not been established by the State for dissolved sodium in surface waters.

Concentrations of dissolved sodium varied considerably from site to site. The largest interquartile ranges were calculated for Gila River at Calva and the sites downstream from Gillespie Dam and may indicate effects of irrigation-return flow. Minimum concentrations of dissolved sodium ranged from 2.50 mg/L at 4 of the 13 sites to 110 mg/L at Gila River near mouth, near Yuma (table 10, at the end of this report). Median concentrations of dissolved sodium ranged from 31.0 mg/L at Gila River near Redrock to 610 mg/L at Gila River above diversions, at Gillespie Dam. The maximum concentration of dissolved sodium, 1,200 mg/L, was recorded at Gila River at Calva.

Increasing trends in concentrations of dissolved sodium were reported for 2 of the 13 study sites, San Pedro River below Aravaipa Creek (0.17 (mg/L)/yr) and Pinal Creek at Inspiration Dam (0.18 (mg/L)/yr; fig. 8). Decreasing trends in concentrations of dissolved sodium were reported at four sites; three are on the main stem of the Gila River—near Redrock (-0.05 (mg/L)/yr), at Calva (-0.04 (mg/L)/yr), and at Gillespie Dam (-0.05 (mg/L)/yr). Decreasing trends in concentrations of dissolved sodium reported at these three main-stem sites could reflect changes in management practices that would reduce the amounts of irrigation-return flows to the Gila River. The fourth site is Agua Fria River near Rock Springs (-0.28 (mg/L)/yr). Streamflow correlated fairly well with concentrations of dissolved sodium. Concentrations of dissolved sodium were flow adjusted at 12 of the 13 sites with r^2 values as high as 94.6 at San Francisco River near Clifton (table 11, at the end of this report).

Dissolved Sulfate

Dissolved sulfate is a sulfur compound that enters the environment through atmospheric deposition, mine runoff, industrial waste, and rock weathering. Concentrations exceeding a background level could indicate contamination by human activities that could cause water to be unsuitable for public supply. The SMCL for sulfate in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 1993). The State has no quality standard for dissolved sulfate in surface water; however, the State requires agencies to monitor and report sulfate concentrations in drinking-water systems.

Concentrations of dissolved sulfate varied considerably from site to site. A minimum concentration of <1.0 mg/L was recorded at Gila River near Redrock (table 12, at the end of this report). The largest minimum concentration of dissolved sulfate was 760 mg/L at Pinal Creek at Inspiration Dam. The median concentration of dissolved sulfate at the Pinal Creek site (1,800 mg/L) was more than three times larger than the closest median concentration of 555 mg/L at Gila River above diversions, at Gillespie Dam. Boxplots of distributions of concentrations of dissolved sulfate at the study sites show increased levels at the Pinal Creek site (fig. 9). Additional sites on the main stem of the Gila that had median concentrations of 400 mg/L or more are Gila River above diversions, at Gillespie Dam; Gila River near Dome; and Gila River near mouth, near Yuma. The

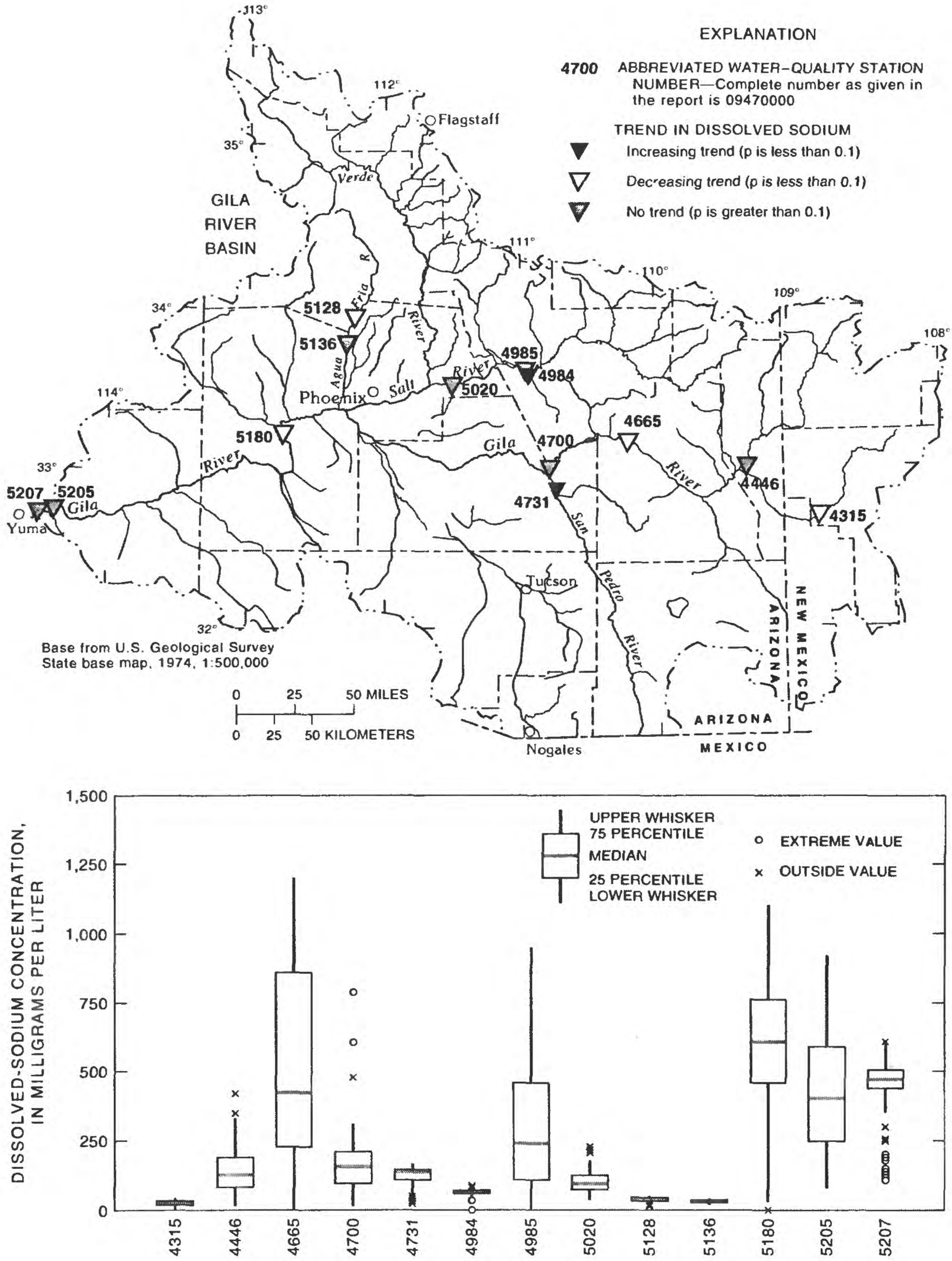
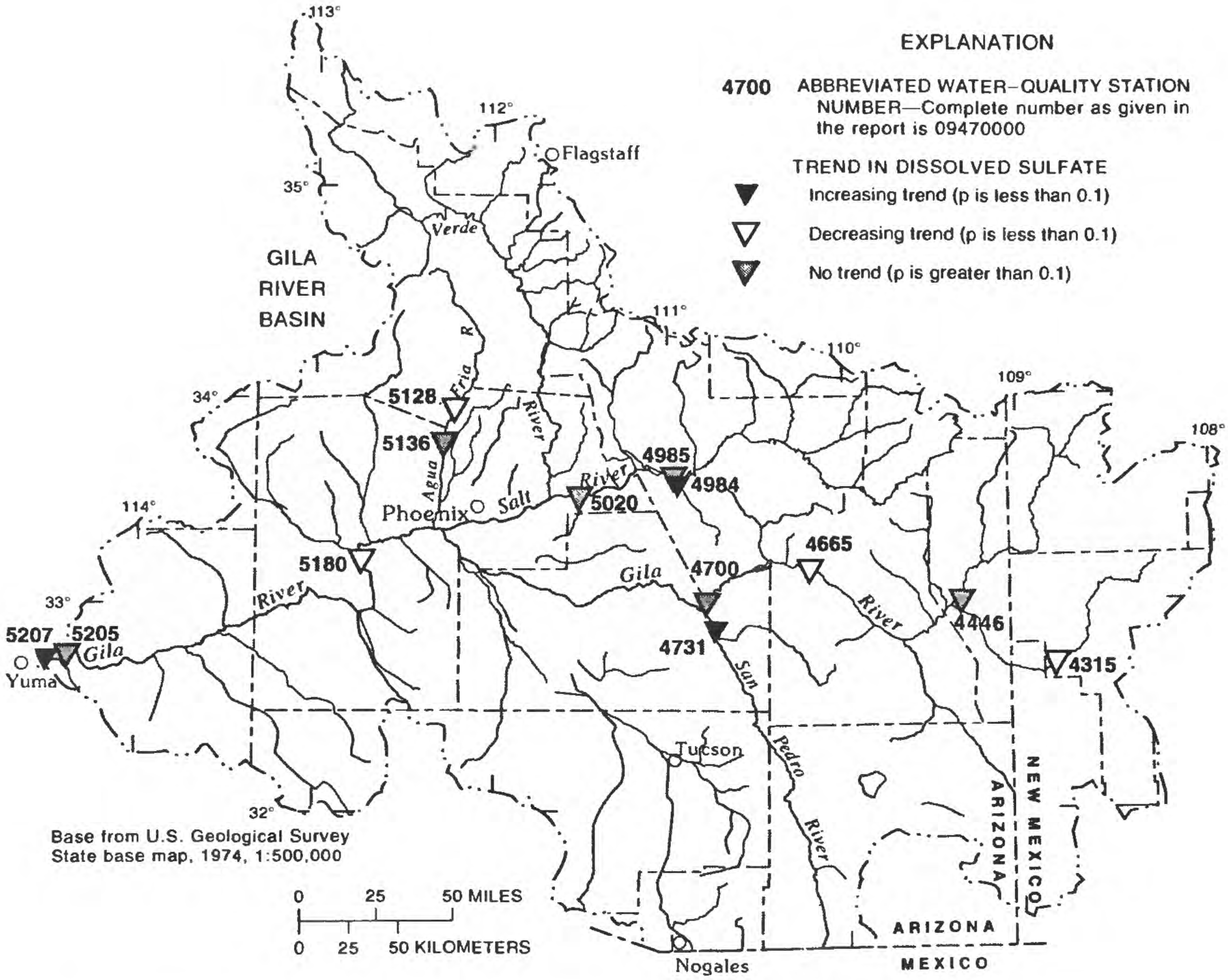


Figure 8. Dissolved sodium and direction of temporal trend.



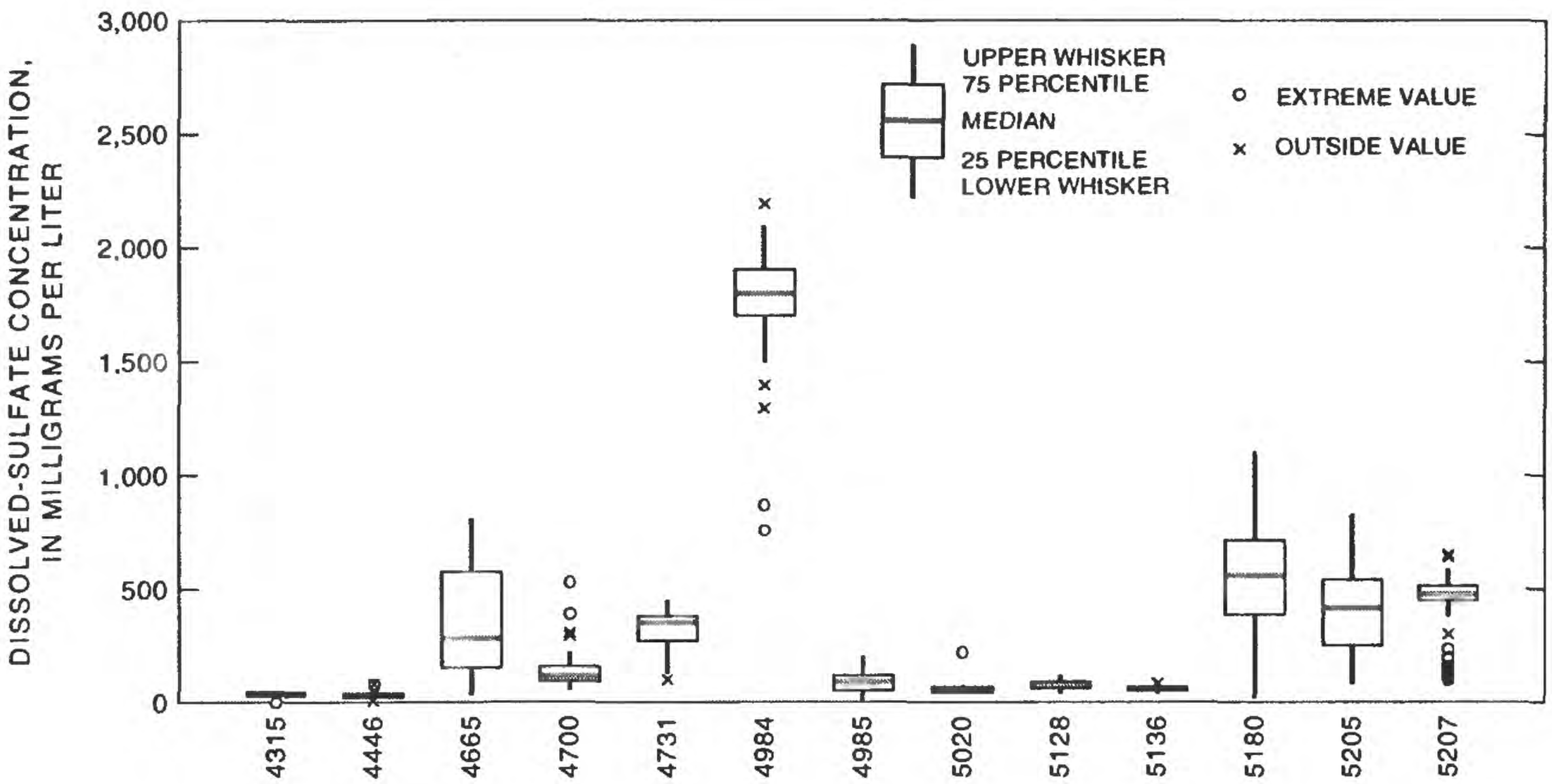


Figure 9. Dissolved sulfate and direction of temporal trend.

median concentration of dissolved sulfate at San Pedro River below Aravaipa Creek (350 mg/L) was larger than that at other Gila River tributary sites.

Increasing trends in concentrations of dissolved sulfate were identified at three sites—San Pedro River below Aravaipa Creek (1.34 (mg/L)/yr); Pinal Creek at Inspiration Dam (0.55 (mg/L)/yr); and Gila River near mouth, near Yuma (0.12 (mg/L)/yr; table 13, at the end of this report). Decreasing trends in concentrations of dissolved sulfate were observed at four sites—Gila River at Calva (0.05 (mg/L)/yr), Gila River near Redrock (-0.09 (mg/L)/yr), Agua Fria River near Rock Springs (-0.44 (mg/L)/yr), and Gila River above diversions (-0.08 (mg/L)/yr). The median concentration of dissolved sulfate above the SMCL for drinking water was found at 6 of the 13 sites. Concentrations of dissolved sulfate correlate fairly well with streamflow, and flow-adjustment equations were determined for 12 of the 13 study sites. The r^2 varied from 10.0 at San Francisco River near Clifton to 80.8 at Gila River near Dome.

Dissolved Chloride

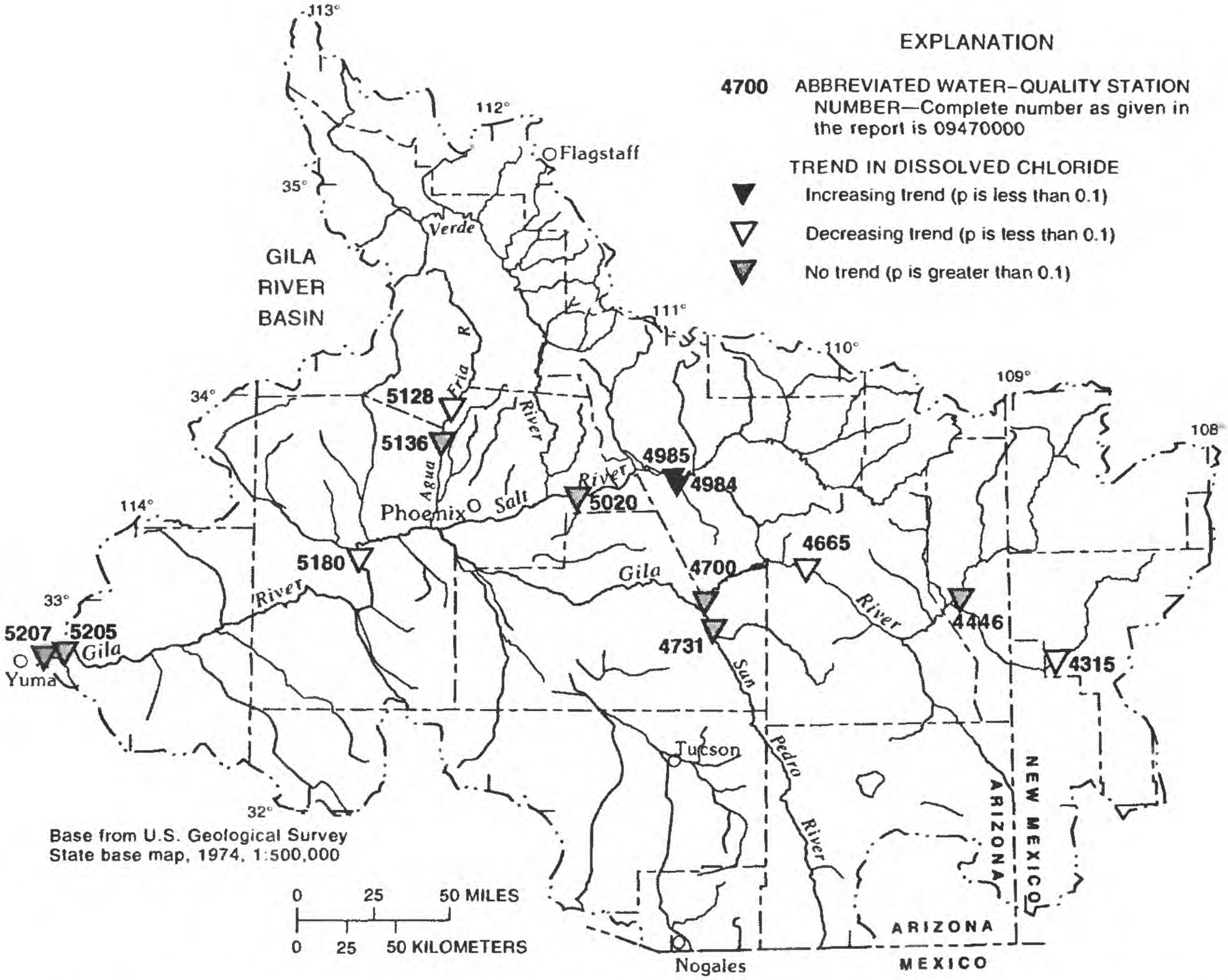
Dissolved chloride is present in all natural waters but generally in small concentrations. The presence of hot springs, however, may add significant quantities of chloride (Feth and Hem, 1963). The Gila River system receives several hundred tons of sodium chloride per day that strongly influences the chemistry of the river water, especially from spring flows into the Salt River. The SMCL for chloride in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 1993). State quality standards for chloride in surface water have not been established.

Considerable variability occurred in distributions of dissolved chloride from site to site (fig. 10). Minimum concentrations of dissolved chloride varied from 2.0 mg/L at Gila River near Redrock to 150 mg/L at Gila River near mouth, near Yuma (table 14, at the end of this report). Median concentrations of dissolved chloride exceeded the Federal standard at 5 of the 13 sites. Two of the five sites, Gila River at Calva (590 mg/L) and Salt River near Roosevelt (390 mg/L), are at the head of reservoirs. The reservoirs act as a buffer by reducing the mean concentration through tributary inflows; these tributaries have smaller concentrations of dissolved chloride. A 67-percent reduction of mean concentrations of dissolved chloride occurred from Gila River at Calva to Gila River at Winkelman. The Gila River at Winkelman site is downstream from San Carlos Dam; the Gila River at Calva site is upstream from the San Carlos Reservoir. The maximum concentration of dissolved chloride (2,200 mg/L) was recorded at Gila River at Calva.

Increasing trends in concentrations of dissolved chloride were calculated at 2 of the 13 sites, Pinal Creek at Inspiration Dam (1.76 (mg/L)/yr) and Salt River near Roosevelt (0.03 (mg/L)/yr; table 15, at the end of this report). The only site where the median concentration was larger than the Federal standard and concentrations were increasing was Salt River near Roosevelt (390 mg/L). The presence of significant increasing concentrations of 1.76 (mg/L)/yr at Pinal Creek at Inspiration Dam, a few miles upstream from Salt River near Roosevelt, indicates that water from Pinal Creek may be a major contributor to the increasing concentrations of dissolved chloride at Salt River near Roosevelt. Decreasing trends were calculated at four sites. Three sites were on the main stem of the Gila River—near Redrock (-0.07 (mg/L)/yr); at Calva (-0.07 (mg/L)/yr); and above diversions, at Gillespie Dam (-0.05 (mg/L)/yr). The fourth site was Agua Fria River near Rock Springs (-0.36 (mg/L)/yr). Flow-adjustment procedures were used for 12 of the 13 sites. The r^2 values ranged from 14.1 to 88.2.

Total Ammonia plus Organic Nitrogen

Total ammonia plus organic nitrogen (as nitrogen), a vital source of nutrition for plant and animal life, is converted by soil bacteria into nitrite and nitrate. Large concentrations of ammonia plus organic nitrogen cause algal blooms in water bodies, which in turn, cause taste and odor problems in potable water supplies. Large concentrations of ammonia plus organic nitrogen in a stream can indicate the presence of contamination from agricultural and urban runoff. No Federal drinking-water regulations exist for total ammonia plus organic nitrogen. The State has quality standards for total nitrogen in many surface-water



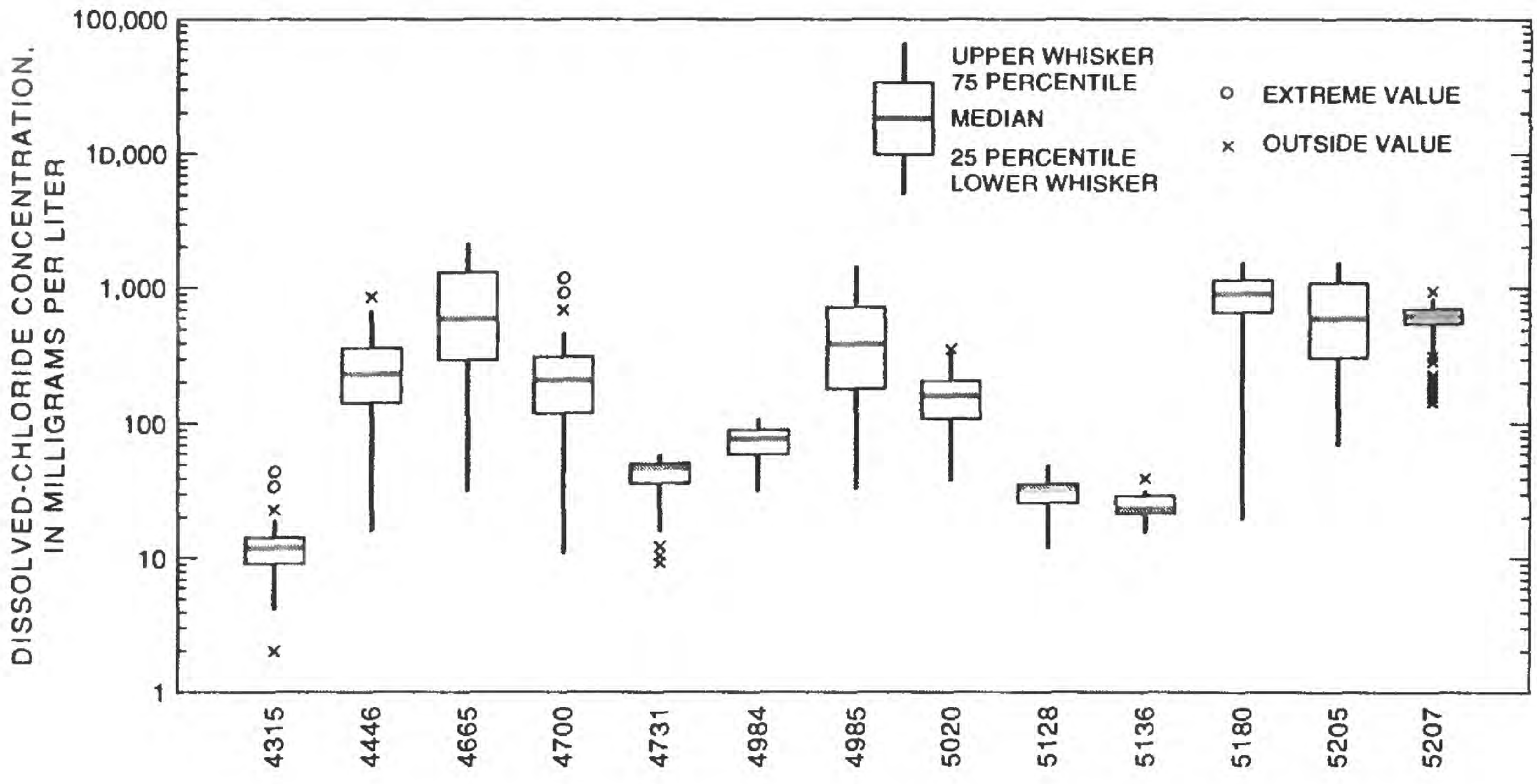


Figure 10. Dissolved chloride and direction of temporal trend.

segments within the study area but does not specify regulations for total ammonia plus organic nitrogen (State of Arizona, 1992).

Summary statistics and boxplots indicate that data for concentrations of ammonia plus organic nitrogen in the Gila River basin contain many extreme values (fig. 11). Minimum concentrations of total ammonia plus organic nitrogen ranged from <0.01 mg/L at Pinal Creek at Inspiration Dam to 0.60 mg/L at Gila River above diversions, at Gillespie Dam (table 16, at the end of this report). Maximum concentrations varied greatly from 1.40 mg/L at Agua Fria River below Waddell Dam to 74.0 mg/L at Gila River at Calva. Median values, however, ranged from 0.40 mg/L at several sites that are not influenced by sewage effluent to 3.70 mg/L at Gila River above diversions, at Gillespie Dam, which is dominated by sewage effluent.

Increasing trends in concentrations of total ammonia plus organic nitrogen were reported for the San Francisco River near Clifton (0.02 (mg/L)/yr) and Gila River near mouth, near Yuma (0.10 (mg/L)/yr; table 17, at the end of this report). San Francisco River near Clifton, however, did have the smallest median concentration (0.40 mg/L). The other site with an increasing trend, Gila River near mouth, near Yuma, is a site where flow is dominated by irrigation-return flow. The only decreasing trend was at Agua Fria River below Waddell Dam (-0.05 (mg/L)/yr). The remaining 10 sites showed no trend in the concentration of total ammonia plus organic nitrogen. Flow-adjusted analyses were used on 5 of the 13 sites. The value of r^2 ranged from 10.6 at Gila River near Redrock to 49.3 at San Pedro River below Aravaipa Creek.

Total Phosphorus

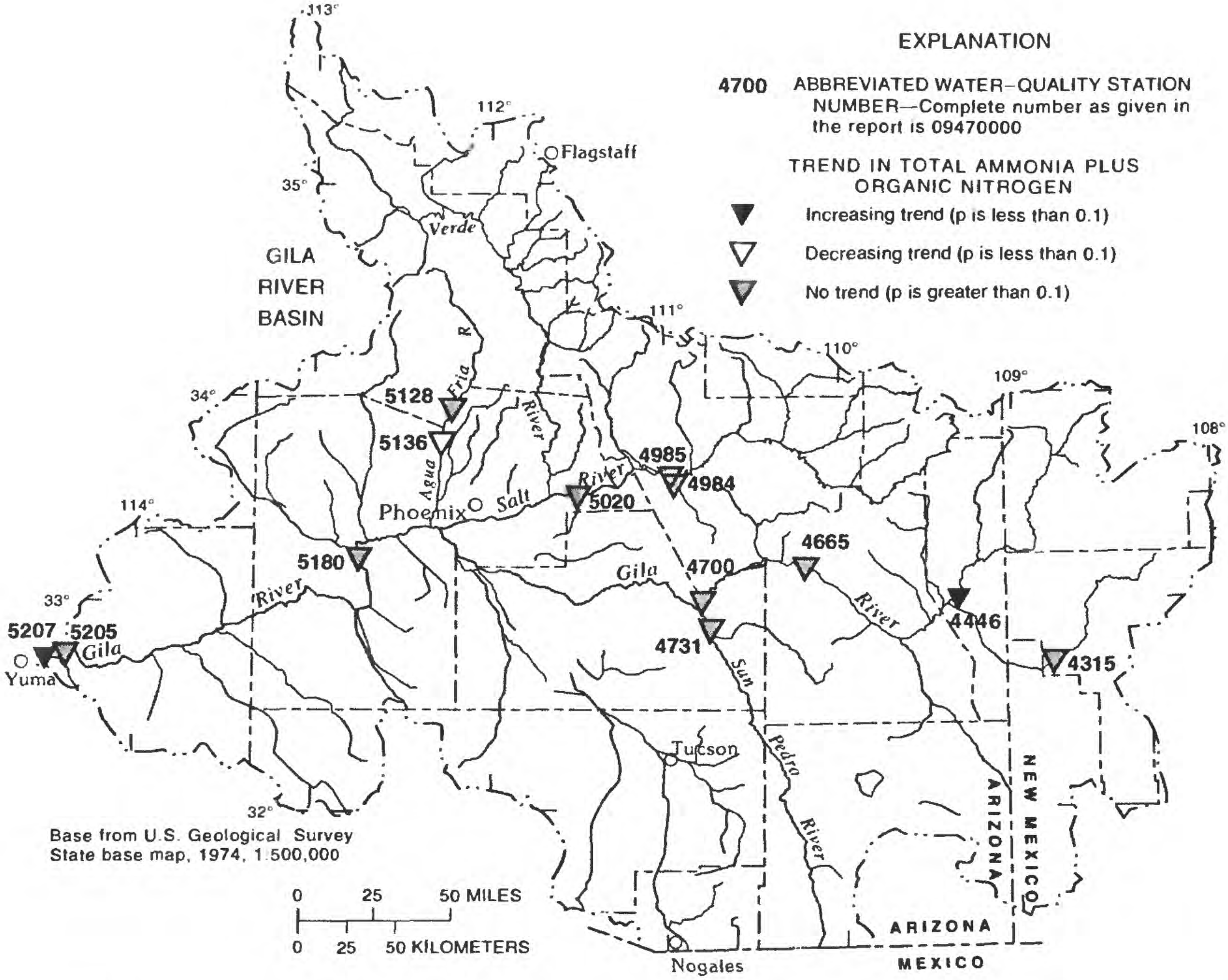
Phosphorus is a major nutrient required for plants; however, large concentrations of phosphorus promote eutrophication in streams and reservoirs. Inorganic phosphorus compounds generally have a low solubility; however, in its elemental form, phosphorus is toxic and bioaccumulates in the environment. Phosphorus is commonly found in igneous rock. Possible human sources of total phosphorus in the environment are municipal wastewater discharge, return flows that carry agricultural and domestic fertilizers, and leaking septic-tank systems. Federal drinking-water standards are not defined for total phosphorus. The State has quality standards for total phosphorus in many different surface-water segments, and each has a different value (see the table below; State of Arizona, 1992).

Summary statistics were computed for concentrations of total phosphorus from data sets ranging from 37 samples at San Pedro below Aravaipa Creek to 149 samples at Salt River near Roosevelt (table 18, at the end of this report). Minimum concentrations of 0.01 mg/L or less were found at 10 of the 13 sites. Maximum concentrations in samples collected ranged from 0.16 mg/L at Agua Fria River below Waddell Dam to 40.0 mg/L at San Pedro River below Aravaipa Creek. The largest median concentration was found

Surface-water segment	State quality standard for total phosphorus as P, in milligrams per liter			
	Annual mean	90 percentile	Single sample maximum	Maximum
Salt River and its tributaries except Pinal Creek, from confluence of White and Black Rivers to Theodore Roosevelt Lake	0.12	0.30	1.00	
Apache, Canyon, Saguaro, and Theodore Roosevelt Lakes	[1].03			[2]0.60
Salt River below Stewart Mountain Dam to confluence with the Verde River	.05		.20	

[1]Annual mean of representative composite samples collected from the surface and the 2- and 5-meter depths.

[2]Maximum for any set of representative composite samples collected from the surface and the 2- and 5-meter depths.



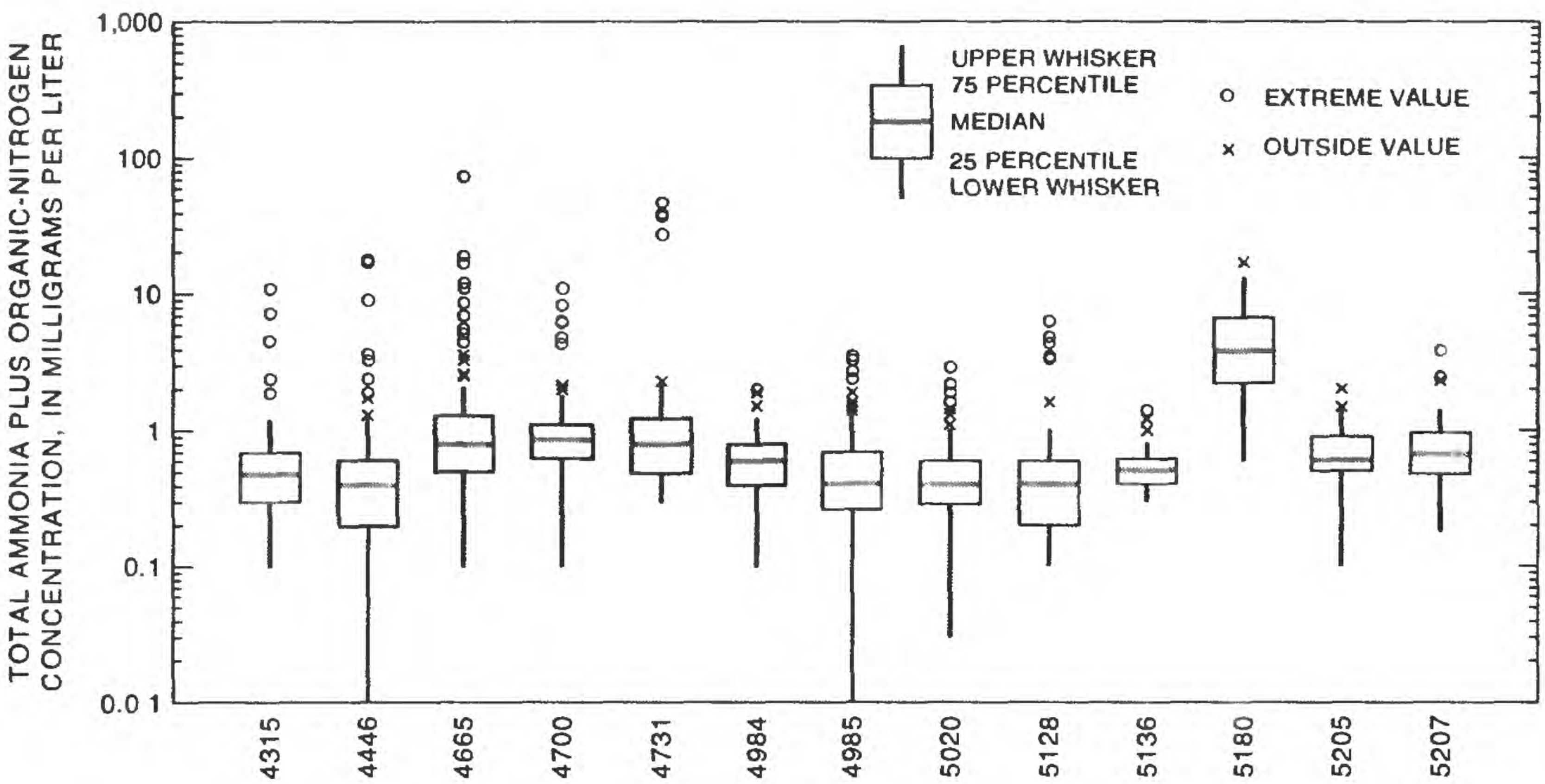


Figure 11. Total ammonia plus organic nitrogen and direction of temporal trend.

at Gila River above diversions, at Gillespie Dam (1.7 mg/L). Water in the Gila River downstream from Phoenix is predominantly effluent from the Phoenix metropolitan area and has been classified by the State as effluent dominated. The State quality standard for a single sample of 1.0 mg/L of total phosphorus for the Salt River and its tributaries was exceeded at Salt River near Roosevelt (3.8 mg/L). The maximum concentration of total phosphorus at Salt River below Stewart Mountain Dam (8.3 mg/L) exceeded the State quality standard for that river segment (0.2 mg/L for a single sample).

Trend analysis for concentrations of total phosphorus showed three decreasing trends (fig. 12). Decreasing trends were found at San Francisco River near Clifton (-0.05 (mg/L)/yr), Gila River at Calva (-0.06 (mg/L)/yr), and Gila River at Winkelman (-0.13 (mg/L)/yr). A trend was not established at Gila River at Gillespie Dam, which is dominated by effluent. Concentrations for 12 of the 13 data sets were flow adjusted (table 19, at the end of this report). Only data collected at Salt River below Stewart Mountain Dam were not flow adjusted. The value of r^2 ranged from 13.4 at Salt River near Roosevelt to 68.1 at Gila River near Dome.

Dissolved Arsenic

Arsenic is used as a component in pesticides and can enter the environment from waste disposal, agricultural drainage, mine runoff, and atmospheric deposition. Dissolved arsenic is considered an undesirable impurity in water because it is a possible carcinogen and mutagen (Sax and Lewis, p. 98, 1987). The MCL under review for arsenic in drinking water is 50 μg/L (U.S. Environmental Protection Agency, 1993). The State quality standards for surface water are 360 μg/L for acute aquatic and wildlife and 190 μg/L for chronic aquatic and wildlife (State of Arizona, 1992).

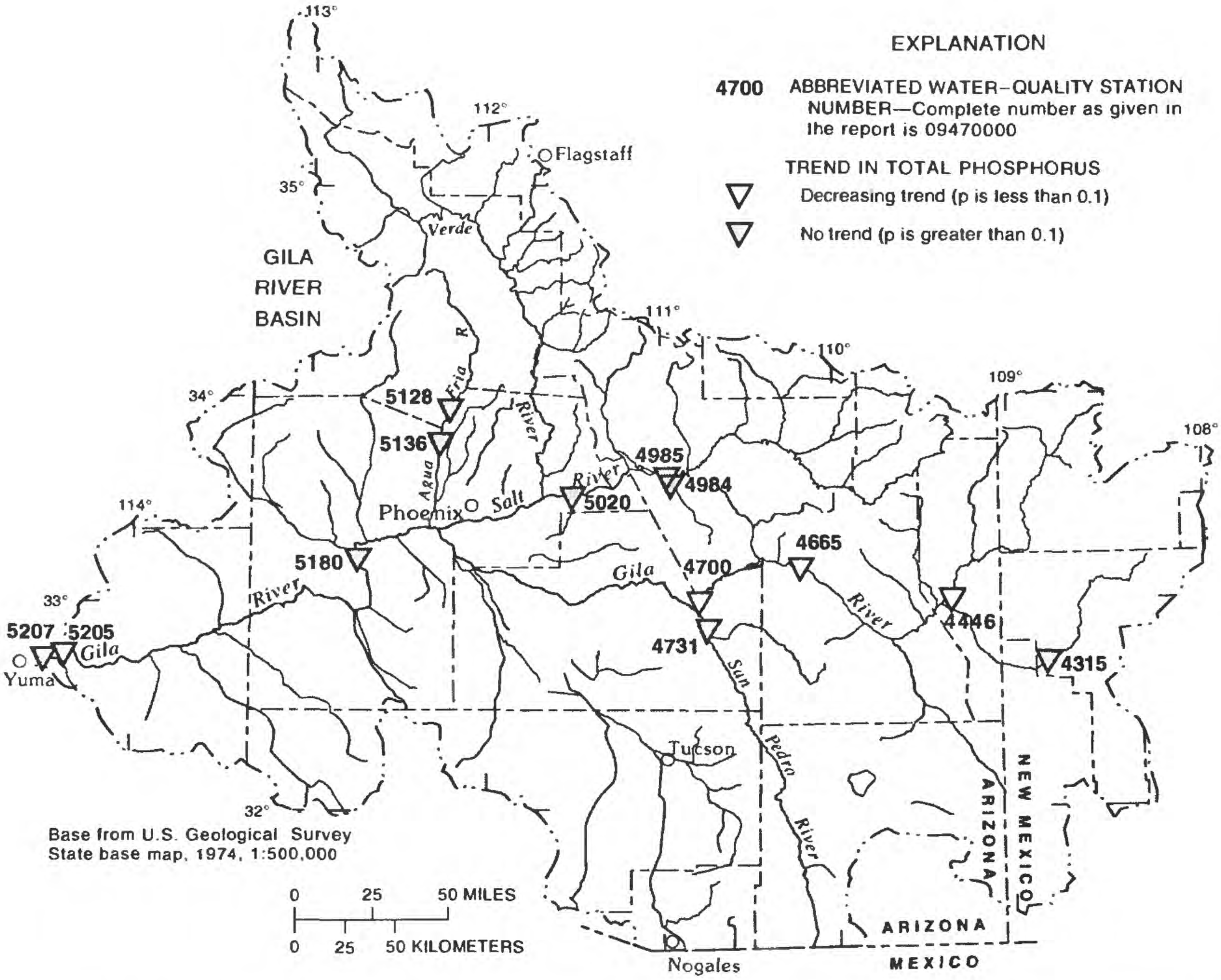
Summary statistics for concentrations of dissolved arsenic were compiled for 10 of 13 sites (table 20, at the end of this report). Concentrations of dissolved arsenic generally were greater at sites downstream from Gila River above diversions, at Gillespie Dam (fig. 13). Minimum concentrations of dissolved arsenic ranged from <1.0 μg/L at five sites to 7.0 μg/L at two sites. Median concentrations of dissolved arsenic were significantly below the MCL and State drinking water standard of 50 μg/L. The greatest median concentration was 11 μg/L at Agua Fria River below Waddell Dam, which could have been caused by the natural occurrence of arsenic in the rocks of the area. The maximum concentration for dissolved arsenic for a single sample (20 μg/L) was recorded at Gila River near mouth, near Yuma. Many of the larger median concentrations of dissolved arsenic were recorded where farming practices may have had an influence on water chemistry. A median concentration of 9.0 μg/L was recorded at Gila River above diversions, at Gillespie Dam, which may have been a result of irrigation-return flows above Gillespie Dam.

Trends in concentrations of dissolved arsenic were not observed for any of the 10 sites for which flow-adjustment procedures could be applied (table 21, at the end of this report). Flow-adjustment equations were used for data collected at 7 of the 10 sites. Streamflow correlated best with concentrations of dissolved arsenic at San Pedro River below Aravaipa Creek (r^2=68.3) and Salt River near Roosevelt (r^2=65.6).

Dissolved Barium

Barium occurs in nature chiefly as barite and witherite, which are highly insoluble salts. Soluble barium salts are reported to be poisonous; however, barium ions generally are rapidly precipitated or removed from solution by absorption and sedimentation (U.S. Environmental Protection Agency, 1986). Barium also enters the environment from industrial wastes and mining runoff. The MCL for barium in drinking water is 2,000 μg/L (U.S. Environmental Protection Agency, 1993). The State quality standard for dissolved barium in surface water is 1,000 μg/L (State of Arizona, 1992).

Summary statistics for concentrations of dissolved barium were compiled from data sets varying from 11 to 75 samples that had been collected at 11 of the 13 sites (table 22, at the end of this report). Samples for determination of concentrations of dissolved barium were not collected at the Gila River at Winkelman or Agua Fria River near Rock Springs sites. Boxplots of data



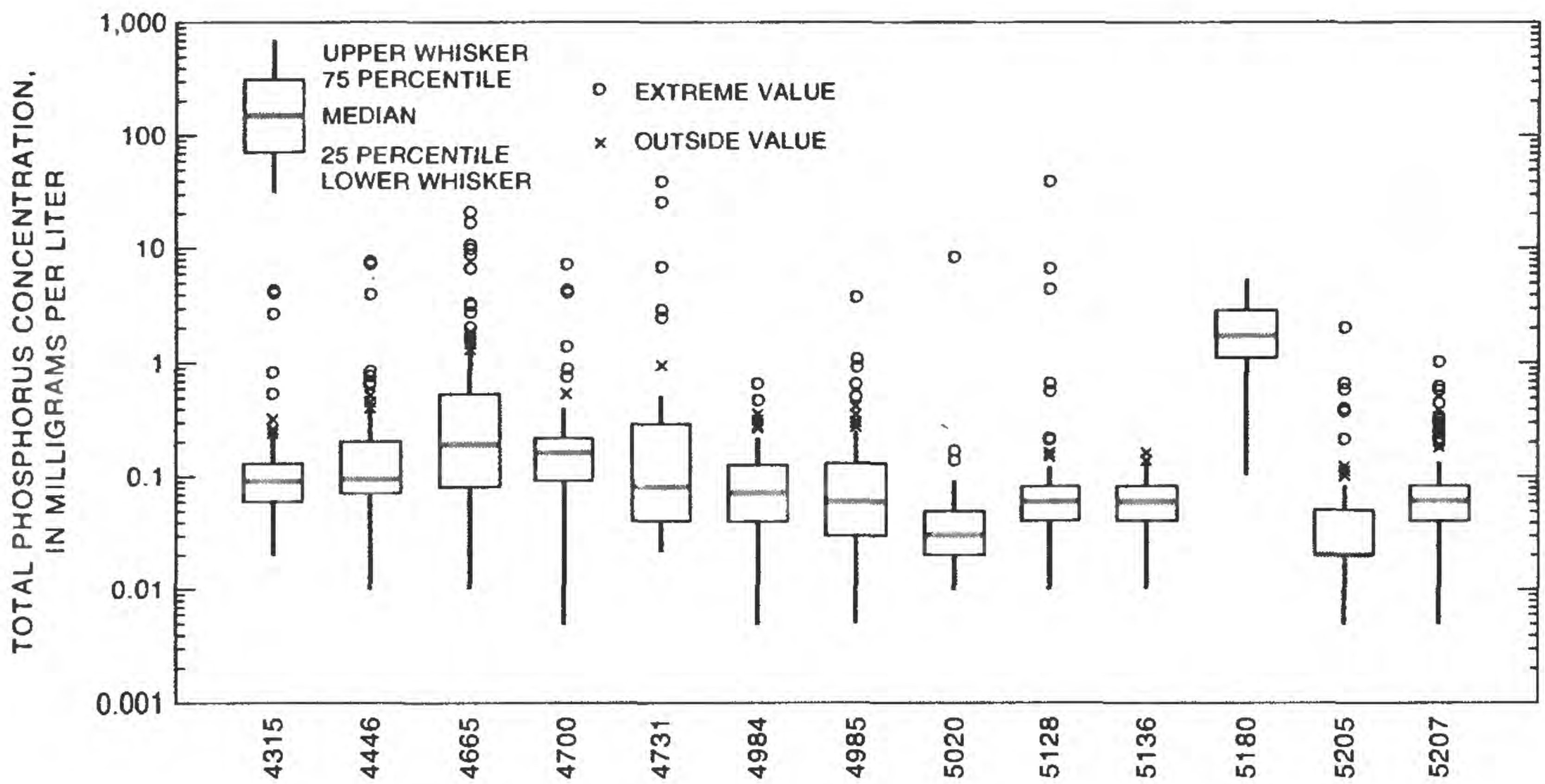
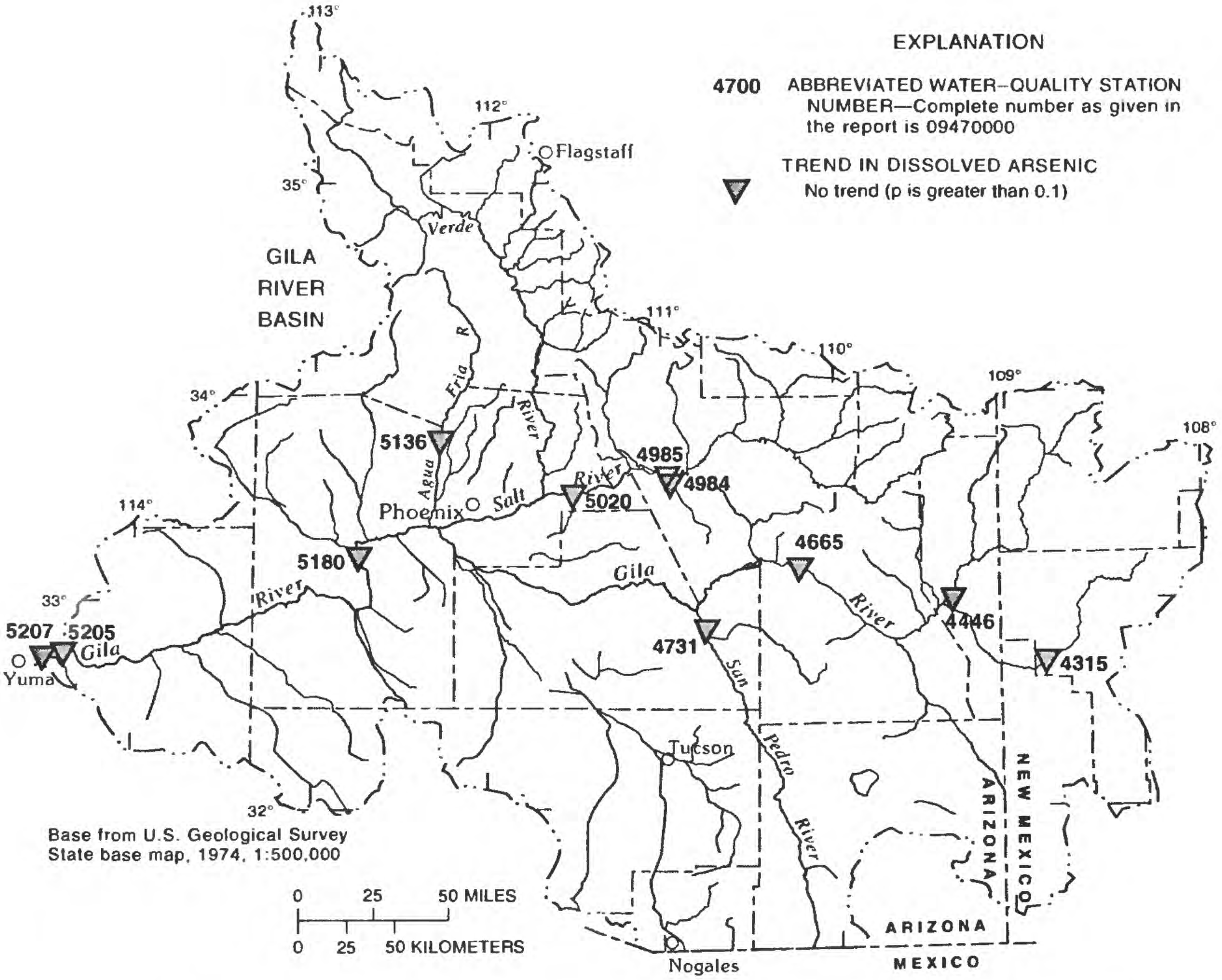


Figure 12. Total phosphorus and direction of temporal trend.



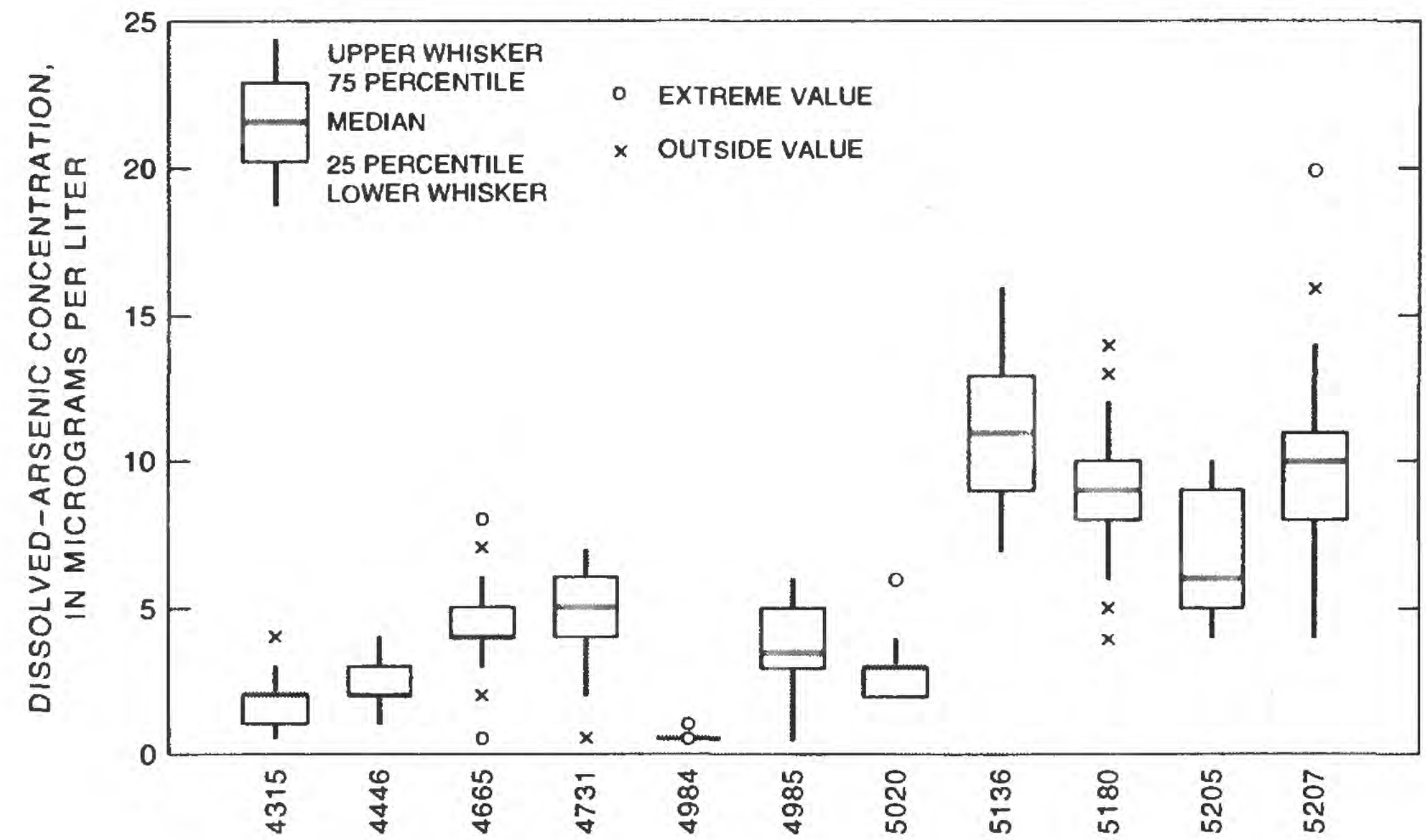


Figure 13. Dissolved arsenic and direction of temporal trend.

for dissolved barium show that the two largest interquartile ranges were for data collected at the Gila River near Dome and at Gila River near mouth, near Yuma (fig. 14). Minimum concentrations of dissolved barium ranged from less than 1.0 μg/L at Gila River above diversions, at Gillespie Dam to 60.0 μg/L at Gila River near mouth, near Yuma. Median concentrations of dissolved barium ranged from 20.0 μg/L at Gila River near Redrock to 100 μg/L at the three downstream sites on the Gila River—above diversions, at Gillespie Dam; near Dome; and near mouth, near Yuma. Maximum concentrations of dissolved barium ranged from 50.0 μg/L at Gila River near Redrock to 600 μg/L at Gila River at Calva. All these concentrations are well below the State quality standard of 1,000 μg/L (State of Arizona, 1992).

Decreasing trends in concentrations of dissolved barium were found for two sites, Salt River near Roosevelt (-0.20 (μg/L)/yr) and Gila River above diversions, at Gillespie Dam (-3.57 (μg/L)/yr; table 23, at the end of this report). Increasing trends were not found at significant levels for the rest of the study sites. Of the nine sites where the flow-adjustment procedure was used, the most effective result was for the data set for San Francisco River near Clifton (r^2=83.3).

Total Boron

Boron, when not found in its elemental form in nature, generally occurs as a sodium- or calcium-borate salt from volcanic gases and geothermals (Hem, 1985). Total boron can enter the environment through sewage and industrial wastes. Small amounts of boron are essential to plant growth; however, greater amounts in soil and irrigation water are harmful and are toxic, especially to orange and lemon trees where concentrations of 1 mg/L (1,000 μg/L) can be toxic (Hem, 1985). The Federal criterion for long-term irrigation on sensitive crops is 750 μg/L (U.S. Environmental Protection Agency, 1991). The State quality standard for total boron is 1,000 μg/L for surface water used for irrigation of agricultural lands (State of Arizona, 1992).

Summary statistics for concentrations of total boron were compiled from data collected at 12 of the 13 sites (table 24, at the end of this report). Boron analyses were not available at Gila River near Dome. Boxplots of the data show that concentrations of total boron were larger at Gila River at Calva; at Gila River above diversions, at Gillespie Dam; and Gila River near mouth, near Yuma than at other study sites (fig. 15). Minimum concentrations of total boron ranged from less than 10.0 μg/L at Agua Fria River near Rock Springs to 270 μg/L at Gila River near mouth, near Yuma. Median concentrations of total boron ranged from 40 μg/L at Gila River near Redrock to 2,000 μg/L at Gila River above diversions, at Gillespie Dam. The Federal criterion and State standard were exceeded for samples collected at several sites. The median concentration at Gillespie Dam (2,000 μg/L) is above the Federal criterion (750 μg/L) and State quality standard for surface water (1,000 μg/L). The maximum concentration of total boron was recorded at Gila River above diversions, at Gillespie Dam (22,000 μg/L).

Decreasing trends in concentrations of total boron were determined for Gila River at Winkelman (-0.30 (μg/L)/yr) and Agua Fria River near Rock Springs (-0.29 (μg/L)/yr; table 25, at the end of this report). Median total boron concentrations were within State standards at the two sites where decreasing trends were noted. Trends were not found in total boron concentrations at the remaining 13 study sites including Gila River at Gillespie Dam, which had the largest median concentration (2,000 μg/L). Flow-adjustment procedures were not applied to data sets for Gila River near Redrock, San Pedro below Aravaipa Creek, Pinal Creek at Inspiration Dam, and Salt River below Stewart Mountain Dam because an insufficient number of samples were collected for trend analysis. Of the eight sites where flow-adjustment procedures were used, the r^2 values ranged from 10.5 to 87.6.

Dissolved Chromium

Dissolved chromium species analyzed in this study included a combination of trivalent chromium and hexavalent chromium. Concentrations of trivalent chromium generally are small (less than 1 μg/L). Concentrations of chromium in natural waters that have not been affected by waste disposal commonly are less than 10 μg/L (Hem, 1985).

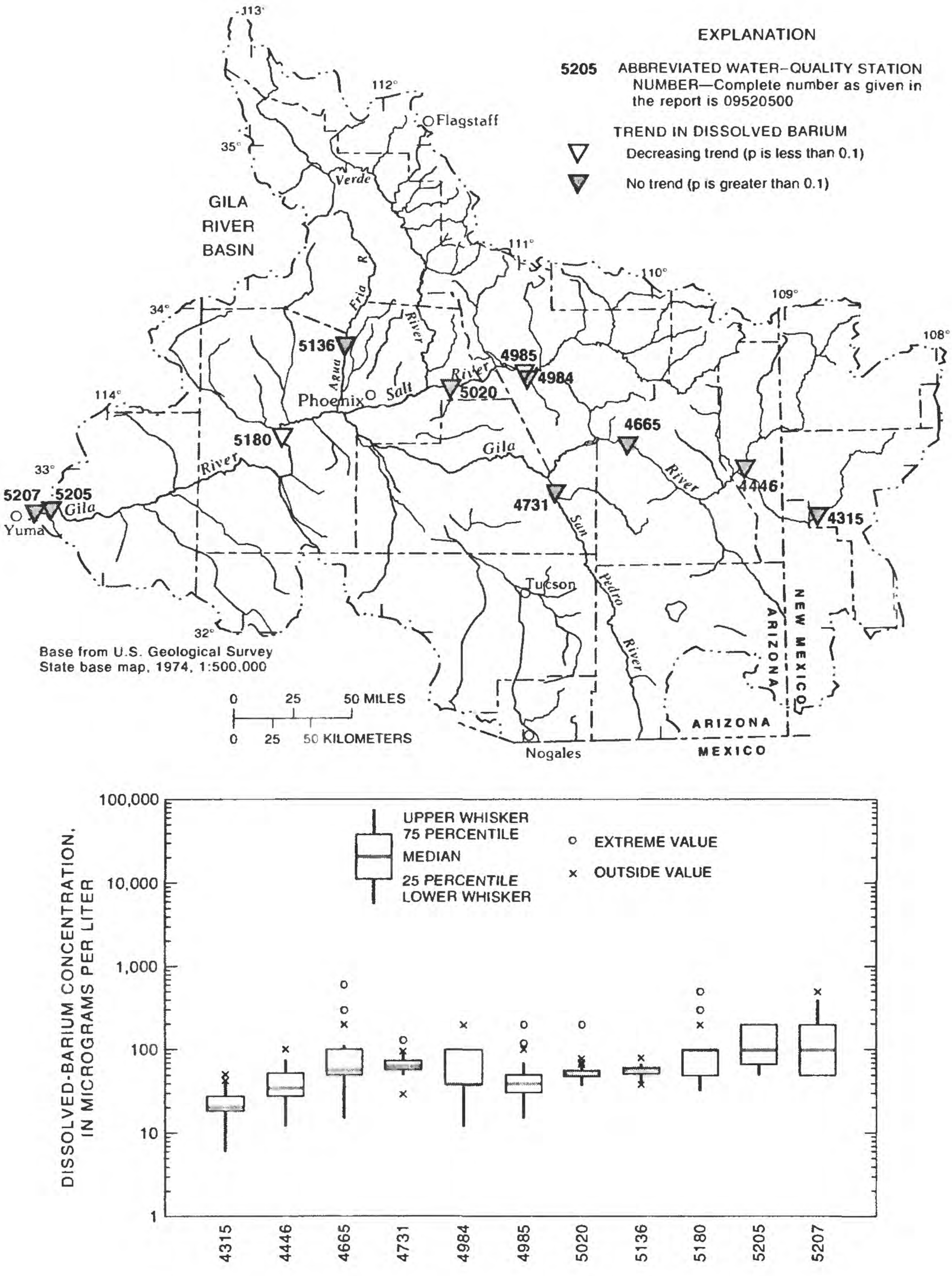


Figure 14. Dissolved barium and direction of temporal trend.

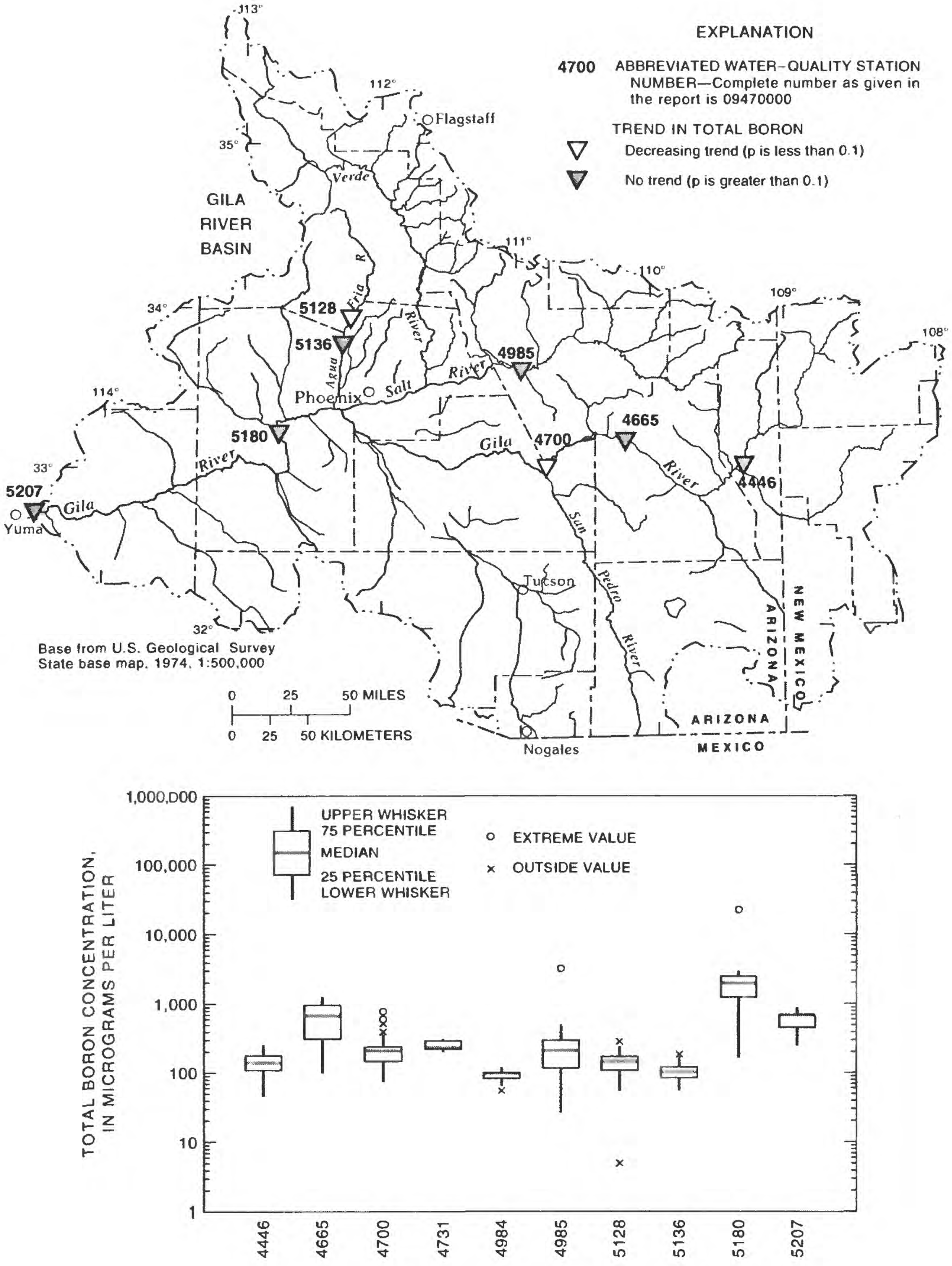


Figure 15. Total boron and direction of temporal trend.

Dissolved chromium, primarily hexavalent chromium, generally enters the environment from industrial and mining activities. Studies by Robertson (1975, 1991), however, show that hexavalent chromium of natural origin is present in ground water in the central and western parts of the study area in concentrations as large as 200 µg/L. Hexavalent chromium can be toxic to aquatic and human life, causing ulcers and dermatitis from prolonged contact (U.S. Environmental Protection Agency, 1986). The drinking-water MCL (100 µg/L) is for total chromium, not dissolved chromium. The State quality standard for total chromium in surface water is 100 µg/L (State of Arizona, 1992).

Summary statistics for concentrations of dissolved chromium were calculated using the logarithmic-probability regression methods at all sites from data sets containing more than 50-percent censored data (table 26, at the end of this report). Boxplots of the data show that the range of concentrations of dissolved chromium at Gila River near mouth, near Yuma was the largest and most widespread of the study sites (fig. 16). Data were not collected at Agua Fria River near Rock Springs. Maximum concentrations for dissolved chromium ranged from 2.0 µg/L at San Francisco River near Clifton to 20.0 µg/L at Gila River above diversions, at Gillespie Dam and Gila River near mouth, near Yuma. Minimum concentrations for all sites where dissolved chromium was collected were less than 1.0 µg/L. The median concentration ranged from 0.02 µg/L at Gila River near Redrock to 3.98 µg/L at Gila River near mouth, near Yuma.

Increasing trends in concentrations of dissolved chromium were reported for 3 of the 10 sites—Pinal Creek at Inspiration Dam; Salt River below Stewart Mountain Dam; and Gila River above diversions, at Gillespie Dam. Trends were not found for dissolved chromium for other sites. Data at three sites—Gila River at Winkelman, Agua Fria River near Rock Springs, and Gila River near Dome—were insufficient to perform the tests. Flow-adjusted equations were used for Pinal Creek data (r^2=21.5; table 27, at the end of this report). The data at the remaining nine sites were adjusted using mean concentrations.

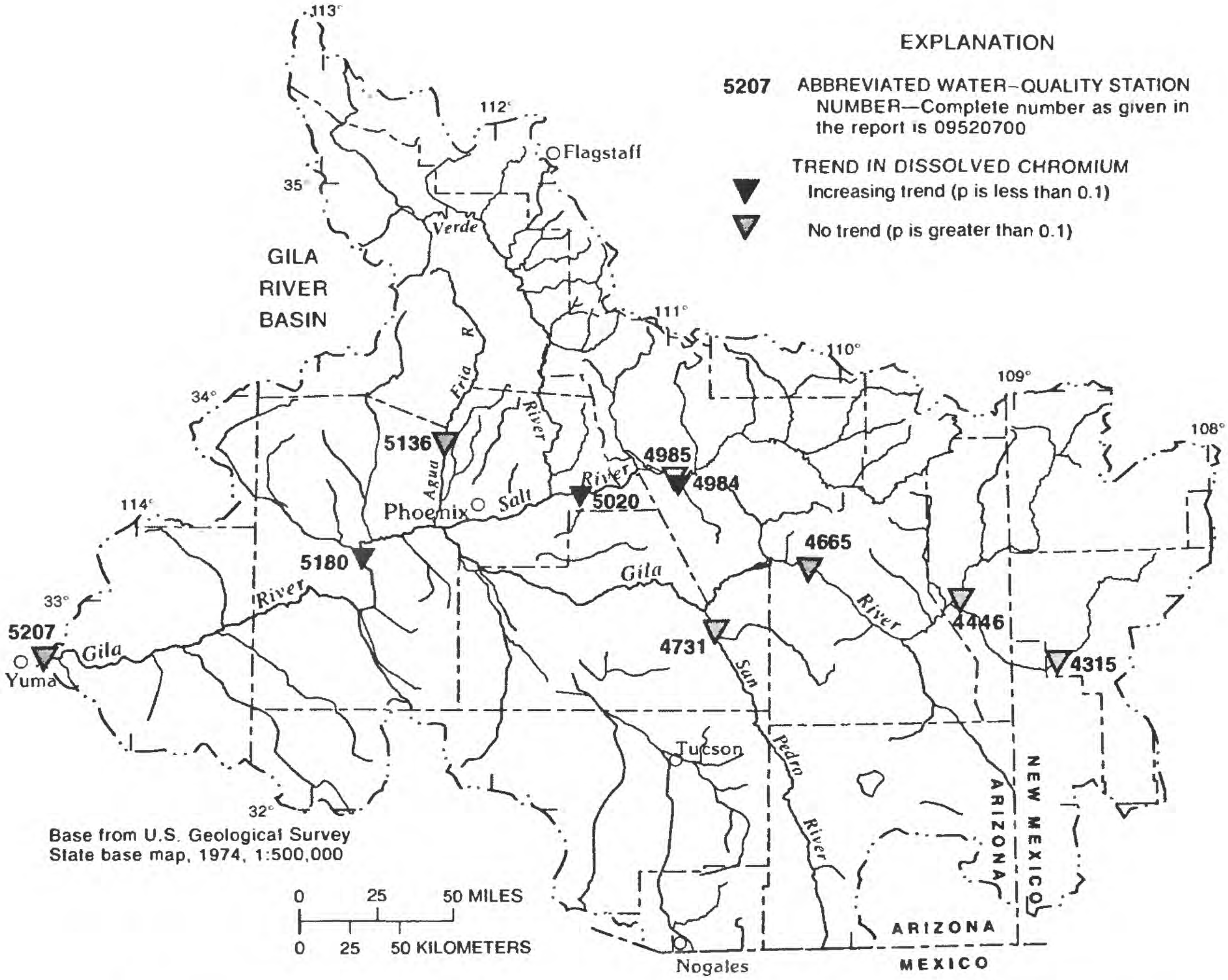
Suspended and Total Copper

Copper is essential for plant and animal metabolism; however, in excess amounts, copper can be toxic to fish and harmful to irrigated crops (U.S. Environmental Protection Agency, 1986). Excess amounts of copper can be detected in the taste of water. Copper enters the environment through rock weathering, acid-mine drainage, the dissolution of copper from water pipes and plumbing fixtures, algal control in reservoirs, and pesticide sprays (Hem, 1985). The SMCL for copper in drinking water is 1,000 µg/L (U.S. Environmental Protection Agency, 1993). The State quality standard for dissolved copper for domestic water sources is 1,000 µg/L (State of Arizona, 1992).

Determinations of summary statistics for suspended copper (table 28, at the end of this report) and total copper (table 30) were done on different size data sets. More data were available for analysis of total copper than for suspended copper. Thirty-one samples—the largest number of samples collected at a site—were collected at Gila River at Calva for determination of concentrations of suspended copper. Conversely, more than 100 total copper concentrations were available for analysis from each of four study sites.

Data for suspended copper were analyzed for summary statistics at 11 study sites. Data were not collected at Agua Fria River near Rock Springs and Gila River near Dome. Maximum concentrations for suspended copper ranged from 16.0 µg/L at San Pedro River below Aravaipa Creek to 1,500 µg/L at Gila River at Calva. Minimum concentrations ranged from less than 1 µg/L at six sites to 40.0 µg/L at Pinal Creek at Inspiration Dam. Median concentrations ranged from 3.0 µg/L at Salt River below Stewart Mountain Dam to 76.0 µg/L at Pinal Creek at Inspiration Dam. Gila River at Calva had a maximum concentration of 1,500 µg/L but a median value of only 20.0 µg/L, which indicates few instances of extremely large concentrations of suspended copper.

Trend analyses for suspended copper were performed at only six study sites because data for suspended copper were insufficient at the other seven sites (fig.17). Flow-adjusted equations were used to adjust the data for suspended copper for three sites—Red Rock, Calva, and Gillespie Dam



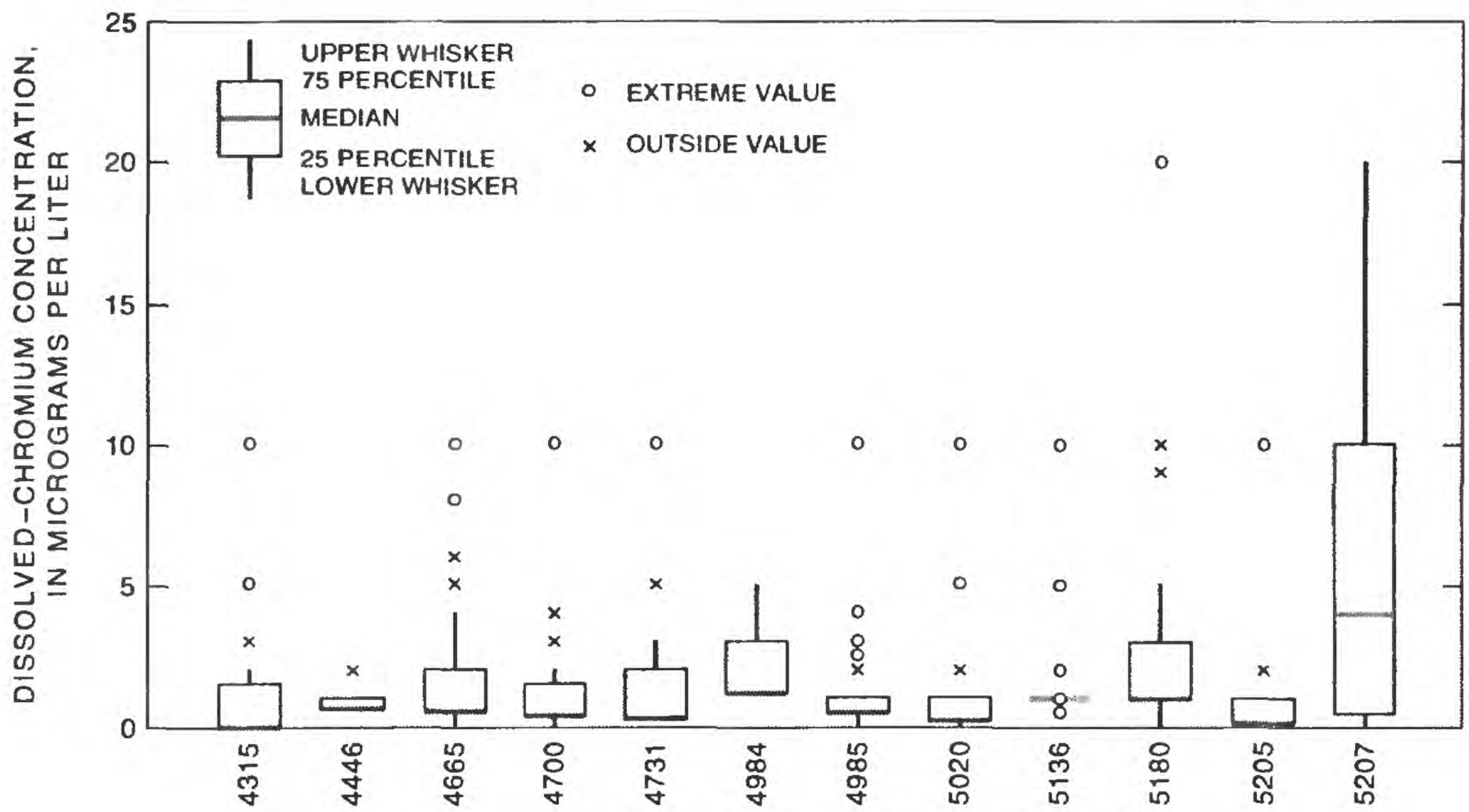
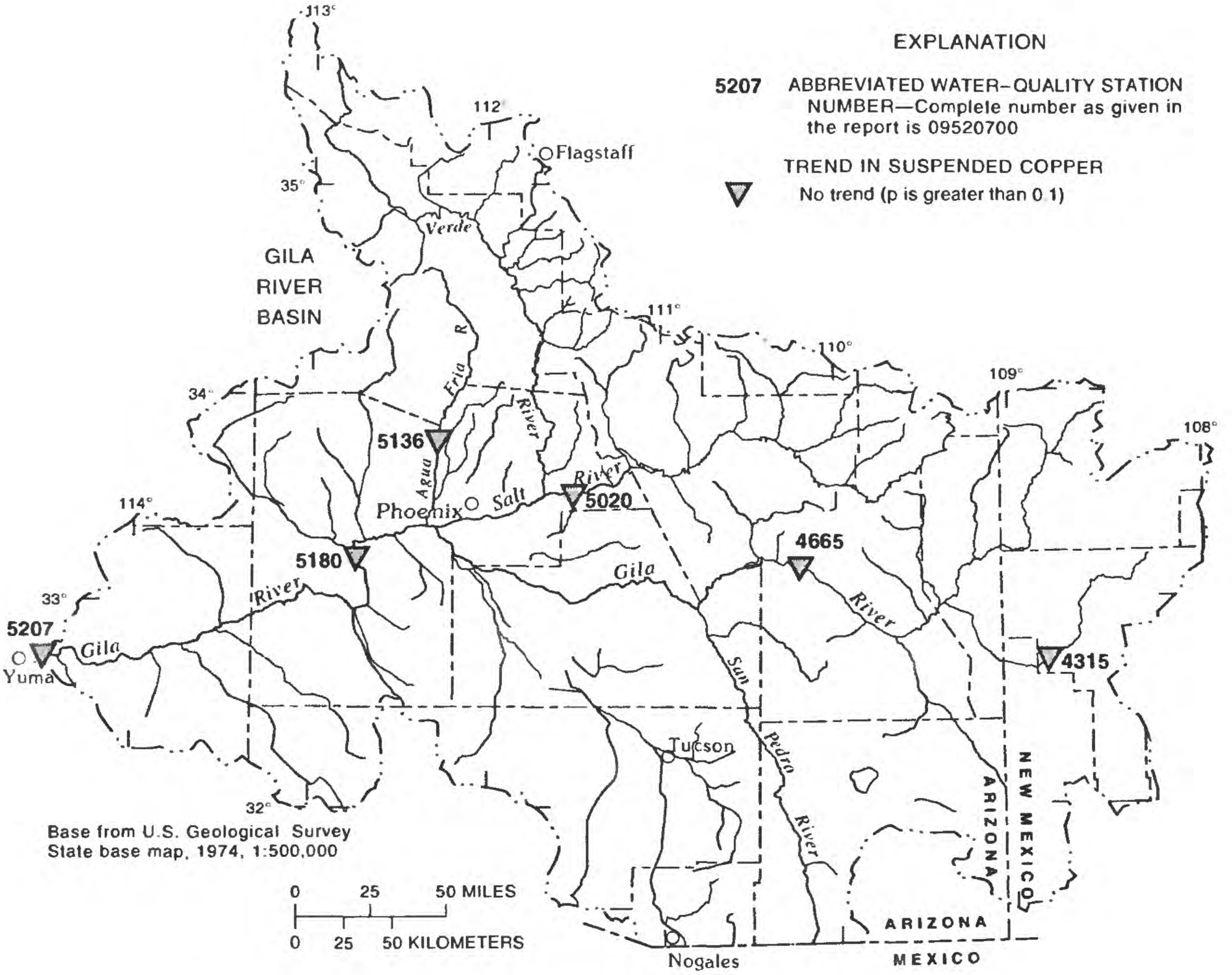


Figure 16. Dissolved chromium and direction of temporal trend.



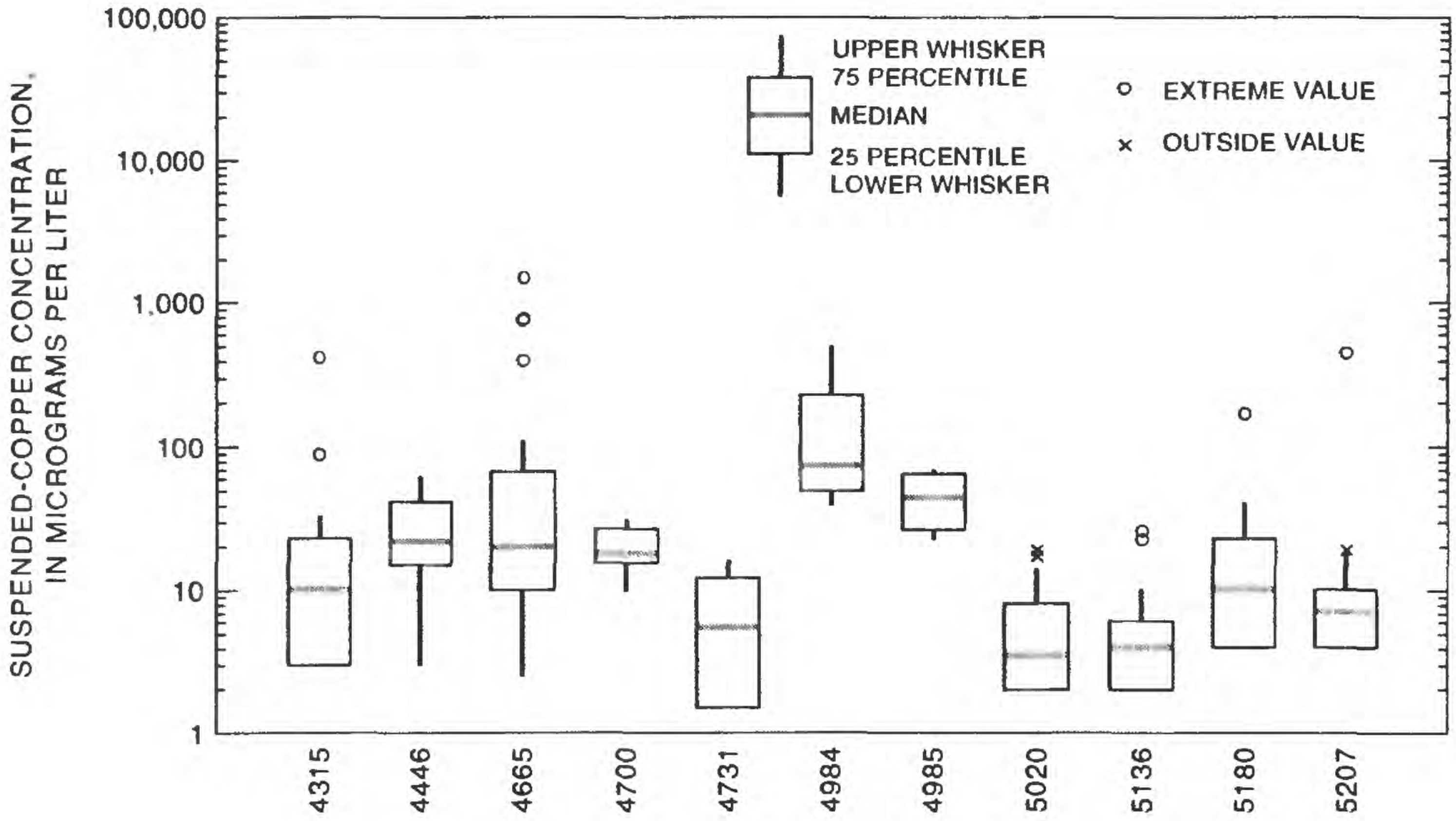


Figure 17. Suspended copper and direction of temporal trend.

(table 29, at end of this report). The r^2 values for these three sites were 10.7, 39.5, and 64.3. Trends were not detected in data for suspended copper collected at any of the six stations.

Summary statistics for total copper were reported for 12 of the 13 study sites (table 30, at the end of this report). Data for total copper were not collected at the Gila River near Dome site. Maximum concentrations for the 12 sites ranged from 22.0 µg/L at Salt River below Stewart Mountain Dam to 10,000 µg/L at San Francisco River near Clifton. Minimum concentrations of total copper ranged from less than 1 µg/L at eight sites to 4.0 µg/L at Agua Fria River below Waddell Dam. Although the highest maximum value for total copper was 10,000 µg/L, the median values ranged from 6.0 µg/L at Salt River below Stewart Mountain Dam to 95.0 µg/L at Pinal Creek at Inspiration Dam. Boxplots of the data show that there are several outliers for most of the stations (fig. 18). Another indication of the variability in total copper at the study sites is the variation between mean value and median concentrations. Median concentrations ranged from 6.0 to 95.0 µg/L; mean concentrations ranged from 7.86 to 269 µg/L.

Three of the study sites—Pinal Creek at Inspiration Dam (-0.04 (µg/L)/yr), Agua Fria below Waddell Dam (-0.63 (µg/L)/yr), and Gila River near mouth, near Yuma (-1.25 (µg/L)/yr)—have trends of decreasing concentrations of total copper (table 31, at the end of this report). Increasing trends of total copper were not found at the remaining study sites. Flow-adjusted equations were used for 7 of 12 sites to calculate temporal trends. The r^2 values ranged from 14.6 to 48.5 for these sites.

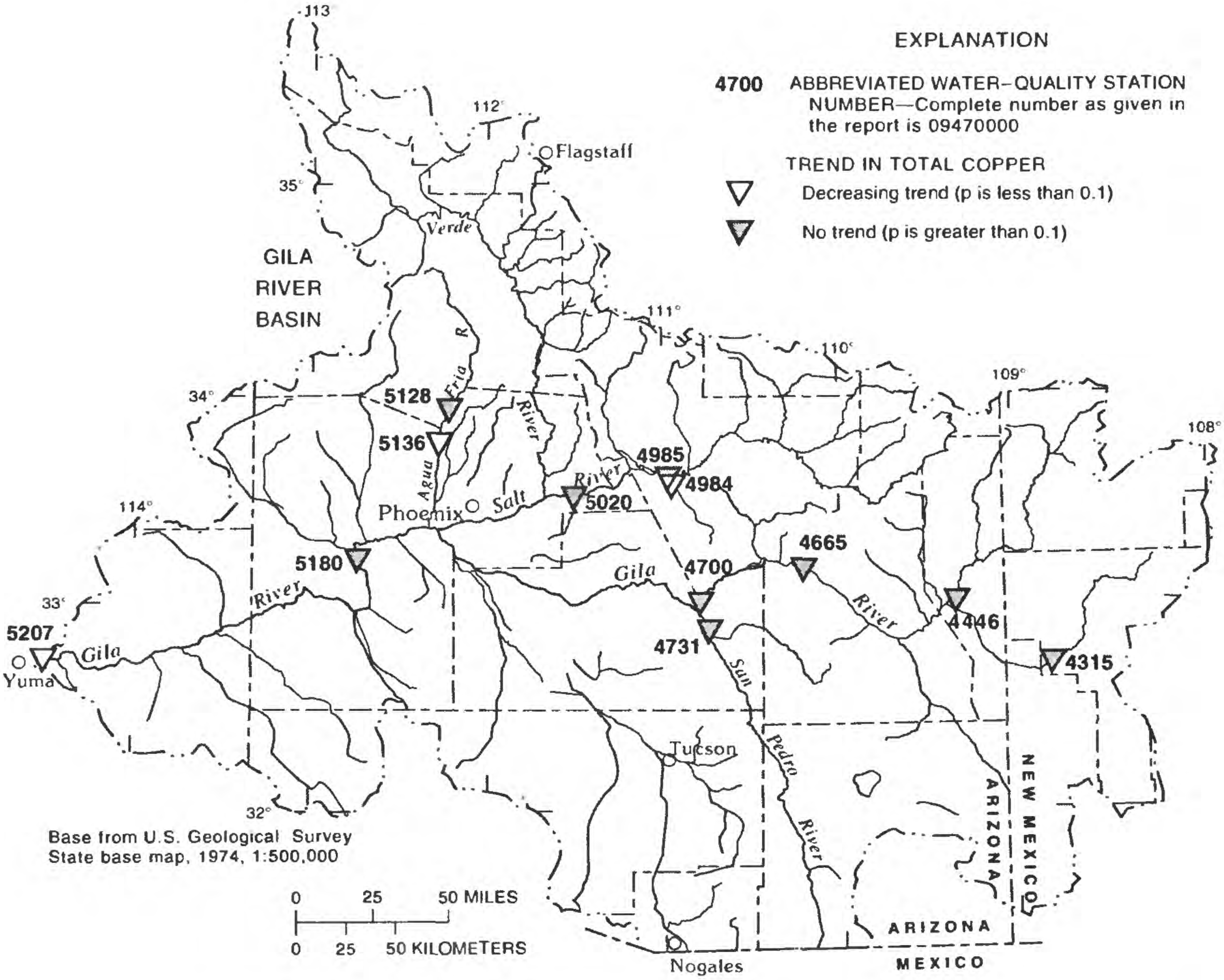
Dissolved and Total Lead

Concentrations of dissolved and total lead were selected for analysis because of their toxic effect on aquatic and human life. Major sources of lead from metropolitan areas are water pipes, paint, and leaded gasoline. Rural sources included atmospheric depositions from sources that may lie outside the study area as well as industrial sources within the area. The principal dissolved inorganic forms of lead are free ion, hydroxide complexes, and the carbonate-ion and sulfate-ion pairs (Hem, 1985). The Federal maximum contaminant level goal (MCLG) for drinking water, which is nonenforceable, is 0 mg/L (U.S. Environmental Protection Agency, 1993). The Federal MCLG for dissolved lead (at tap) is 0 mg/L (U.S. Environmental Protection Agency, 1993). The State quality standard for total lead in surface water is 50 µg/L (State of Arizona, 1992).

Summary statistics for concentrations of dissolved lead were compiled from data sets that ranged in size from 25 to 98 samples and were collected at 11 of the 13 sites (table 32, at the end of this report). Lack of data for dissolved lead from Agua Fria River near Rock Springs and at Gila River near Dome precluded computation of summary statistics. Concentrations of dissolved lead show fairly consistent distributions of data throughout the basin. Minimum concentrations of dissolved lead were at the detection limit of 1.0 µg/L for all stations. Median values ranged from 0.66 µg/L at Gila River above diversions, at Gillespie Dam to 2.0 µg/L at Gila River near mouth, near Yuma. The largest maximum concentration of dissolved lead of 74.0 µg/L was recorded at Gila River near mouth, near Yuma. Large concentrations of dissolved lead also were found at Gila River at Calva (70.0 µg/L) and at Salt River below Stewart Mountain Dam (60.0 µg/L).

Decreasing trends in concentrations of dissolved lead were found at 6 of 11 sites; two on the main stem of the Gila River—at Calva and above diversions, at Gillespie Dam; and two on the Salt River—Roosevelt and Stewart Mountain Dam (fig. 19). The other two decreasing trends were measured at San Francisco River near Clifton and Pinal Creek at Inspiration Dam. Increasing trends in concentrations of dissolved lead were not found; in five instances, no trends were determined. Slope-estimate values were not reported because of the large amount of censored data except for Gila River at Calva (r^2=12.0). Flow-adjustment procedures were not used except for Gila River at Calva (table 33, at the end of this report) because of the lack of correlation between discharge and concentrations of dissolved lead at the individual sites.

Summary statistics for concentrations of total lead were compiled from data sets of 14 to 121 samples that had been collected at 12 of the 13 sites



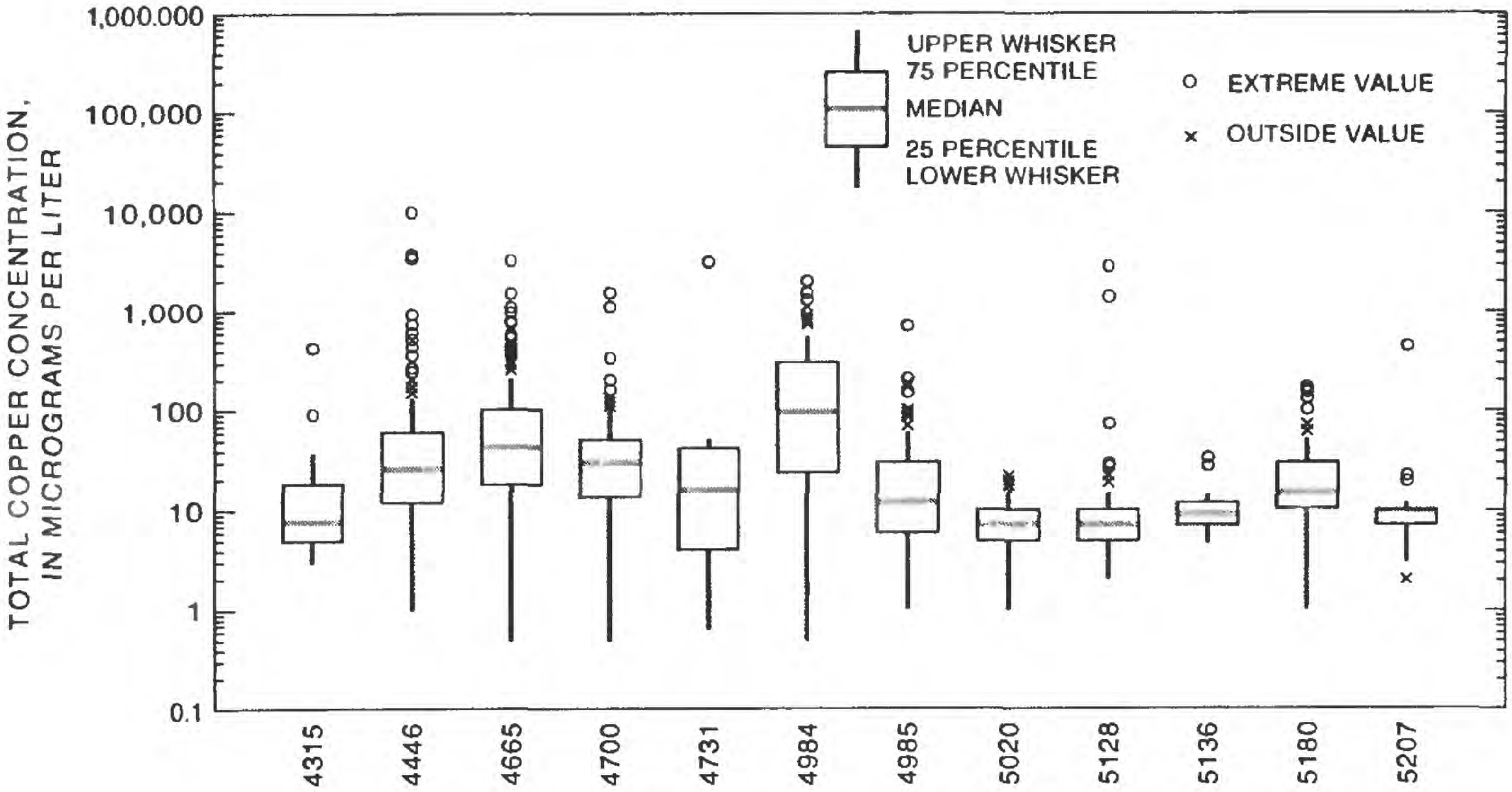


Figure 18. Total copper and direction of temporal trend.

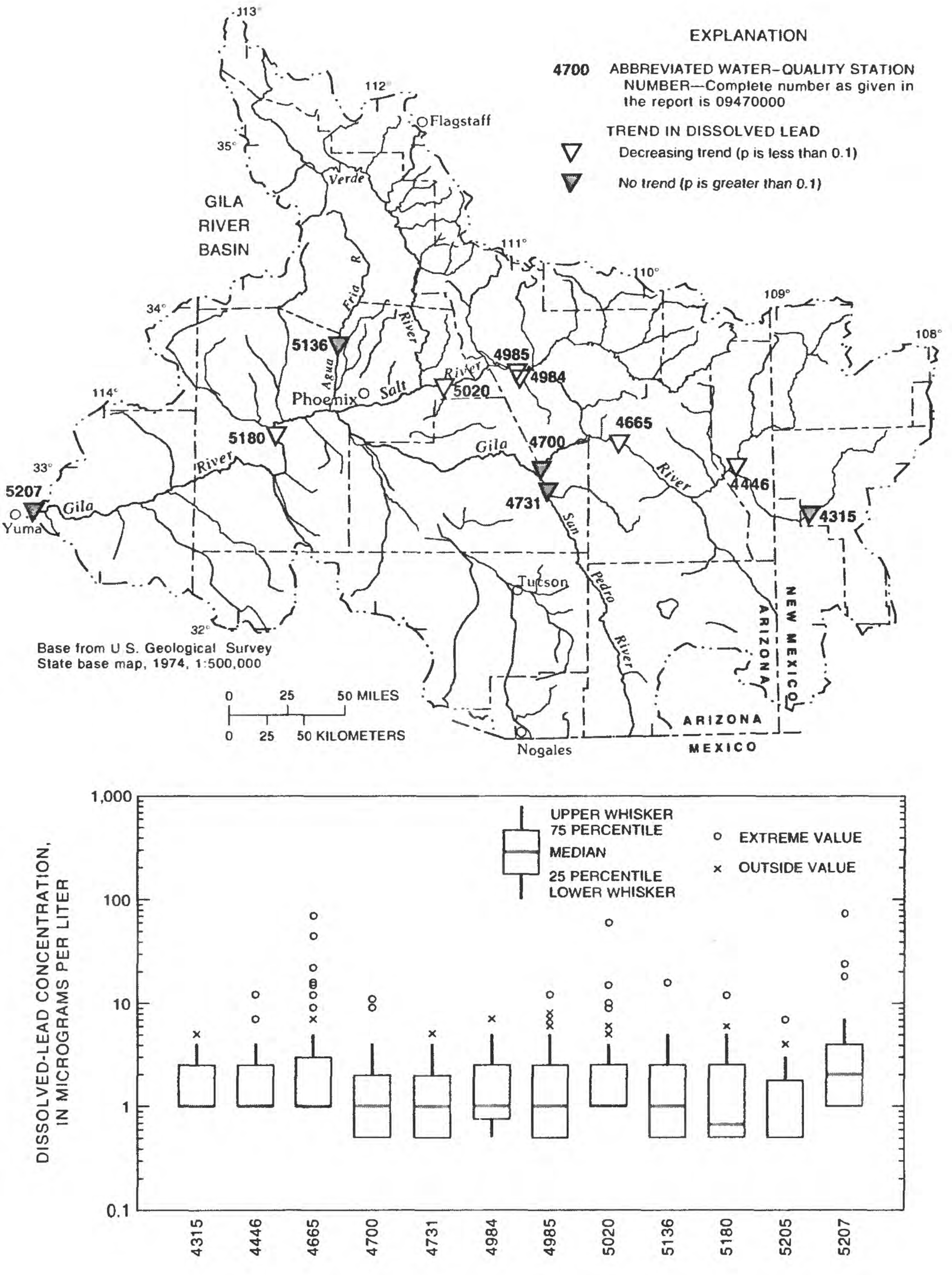


Figure 19. Dissolved lead and direction of temporal trend.

(table 34, at the end of this report). Summary statistics were not calculated at Gila River near Dome because samples were not collected for the determination of total lead concentrations. Median concentrations of total lead ranged from 2.0 μg/L at Agua Fria River near Rock Springs to 8.0 μg/L at Gila River at Calva and Gila River at Winkelman. The maximum concentrations of total lead ranged from 60.0 μg/L at Pinal Creek at Inspiration Dam to 930 μg/L at Agua Fria River near Rock Springs. Boxplots of the data show that the concentrations appear to be larger on the eastern part of the Gila River compared with the concentrations on the Salt River, Agua Fria River, and western part of the Gila River excluding Gila River near mouth, near Yuma (fig. 20).

Of the 12 sites where trends were calculated, increasing trends in concentrations of total lead were calculated for 2 sites—Gila River near Redrock (0.19 (μg/L)/yr) and Gila River near mouth, near Yuma (0.41 (μg/L)/yr; table 35, at the end of this report). Decreasing trends in concentrations of total lead were reported at Pinal Creek at Inspiration Dam (-0.06 (μg/L)/yr). Flow-adjustment procedures were used for 9 of the 12 sites, and the r^2 values ranged from 13.9 to 62.6.

Total Manganese

Manganese, a metallic element, is essential for plants and animals. Manganese is typically associated with iron compounds naturally occurring in the Earth's crust in various salts and minerals and has low solubility in water. Manganese is an undesirable impurity in large concentrations in water because it has a tendency to deposit black oxide stains. In large doses, manganese can cause liver damage (U.S. Environmental Protection Agency, 1986). Total manganese was selected for analysis because of the abnormally large concentrations found in samples collected from Pinal Creek in a separate study (Eychaner and others, 1989). The SMCL for manganese in drinking water is 50 μg/L (U.S. Environmental Protection Agency, 1993). The State quality standard is 10,000 μg/L for total manganese in waters used for agricultural irrigation.

Summary statistics were computed from data sets ranging from 8 samples at San Pedro River below Aravaipa Creek to 116 samples at Gila River at Calva (table 36, at the end of this report). Data for total manganese were not collected at Gila River near Dome. Maximum concentrations ranged from 170 μg/L at Salt River below Stewart Mountain Dam to 41,000 μg/L at Pinal Creek at Inspiration Dam. The Pinal Creek site, influenced by a mine-drainage contaminant plume (Eychaner and others, 1989), recorded the highest minimum value (680 μg/L). Boxplots of data for total manganese show that concentrations of total manganese at the Pinal Creek site are significantly larger than those at other study sites (fig. 21). Minimum concentrations ranged from 8.0 μg/L at Gila River near Redrock and at Gila River at Calva to 680 μg/L at Pinal Creek at Inspiration Dam. Median concentrations ranged from 30.0 μg/L at Salt River below Stewart Mountain Dam and at Agua Fria River near Rock Springs to 21,500 μg/L at Pinal Creek at Inspiration Dam. The second highest median value is 730 μg/L at Gila River near mouth, near Yuma. The maximum concentrations for Gila River near Redrock (11,000 μg/L), Gila River at Calva (11,000 μg/L), Gila River at Winkelman (11,000 μg/L), San Pedro River below Aravaipa Creek (13,000 μg/L), Pinal Creek at Inspiration Dam (41,000 μg/L), and Agua Fria River near Rock Springs (35,000 μg/L) exceed the State water-quality standards (10,000 μg/L). The only median concentration for total manganese that exceeds the State standard is for Pinal Creek at Inspiration Dam (21,000 μg/L).

Trend analyses indicated that total manganese concentrations are increasing at three sites—Pinal Creek at Inspiration Dam, Salt River near Roosevelt, and Agua Fria River near Rock Springs (table 37, at the end of this report). Total manganese concentrations are decreasing at five sites—San Francisco River near Clifton; Gila River at Calva; Salt River below Stewart Mountain Dam; Gila River above diversions, at Gillespie Dam; and Gila River near mouth, near Yuma. Trend tests were not done for San Pedro River below Aravaipa Creek because of insufficient data. The slope estimate at Salt River near Roosevelt (35.0 (μg/L)/yr) was much larger than those at Pinal Creek at Inspiration Dam (0.70 (μg/L)/yr) and Agua Fria River near Rock Springs (0.01 (μg/L)/yr). At nine of the 11

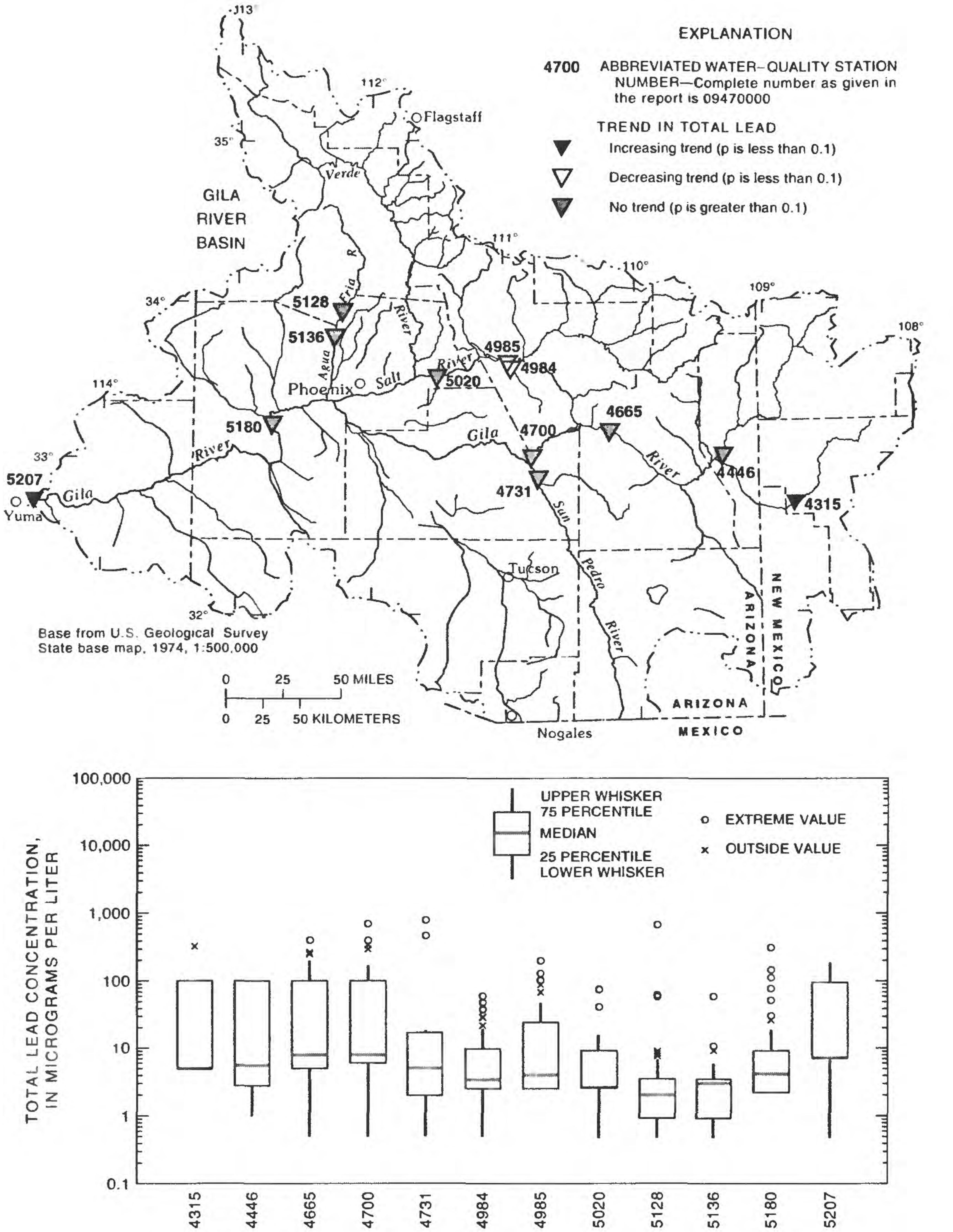
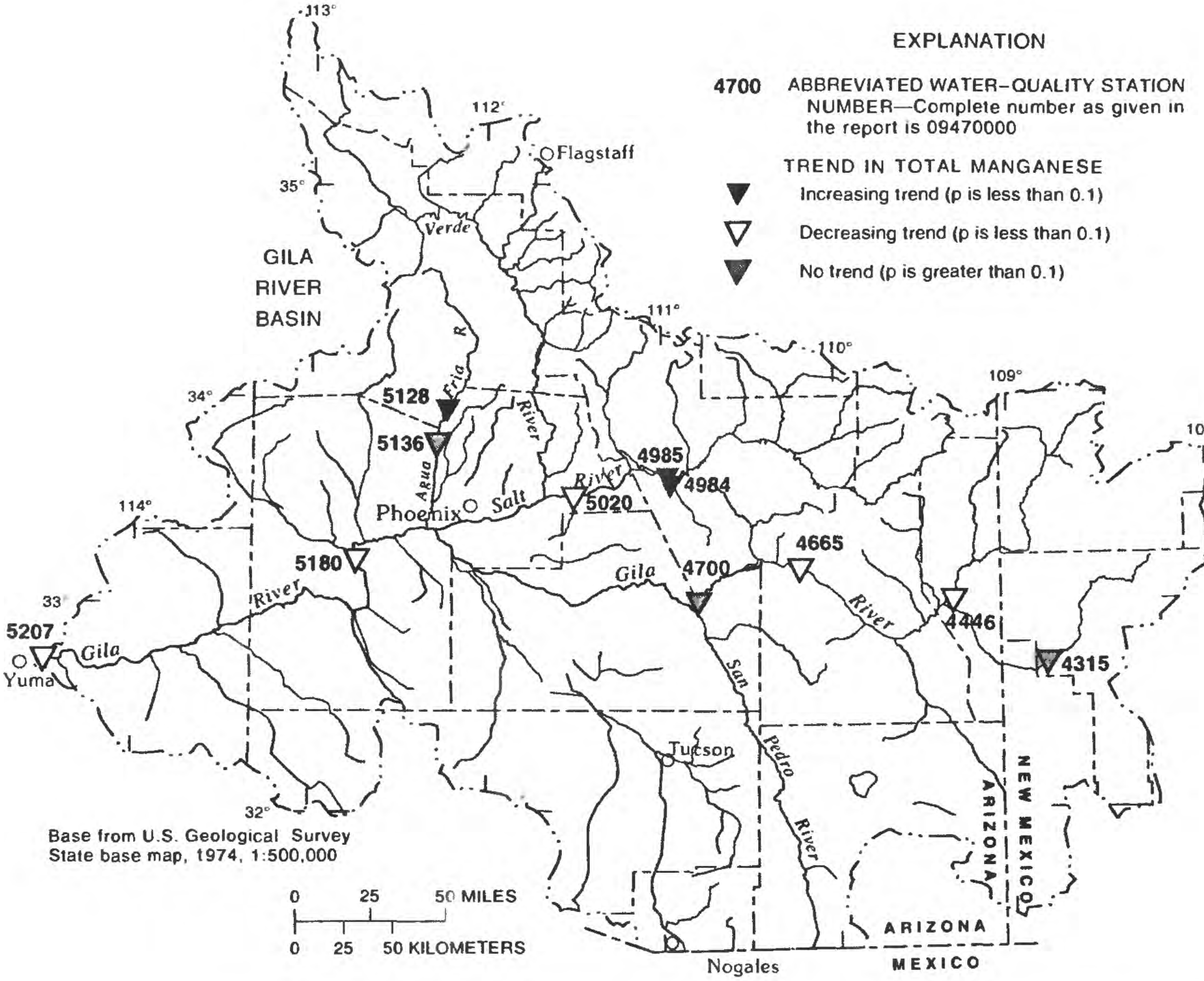


Figure 20. Total lead and direction of temporal trend.



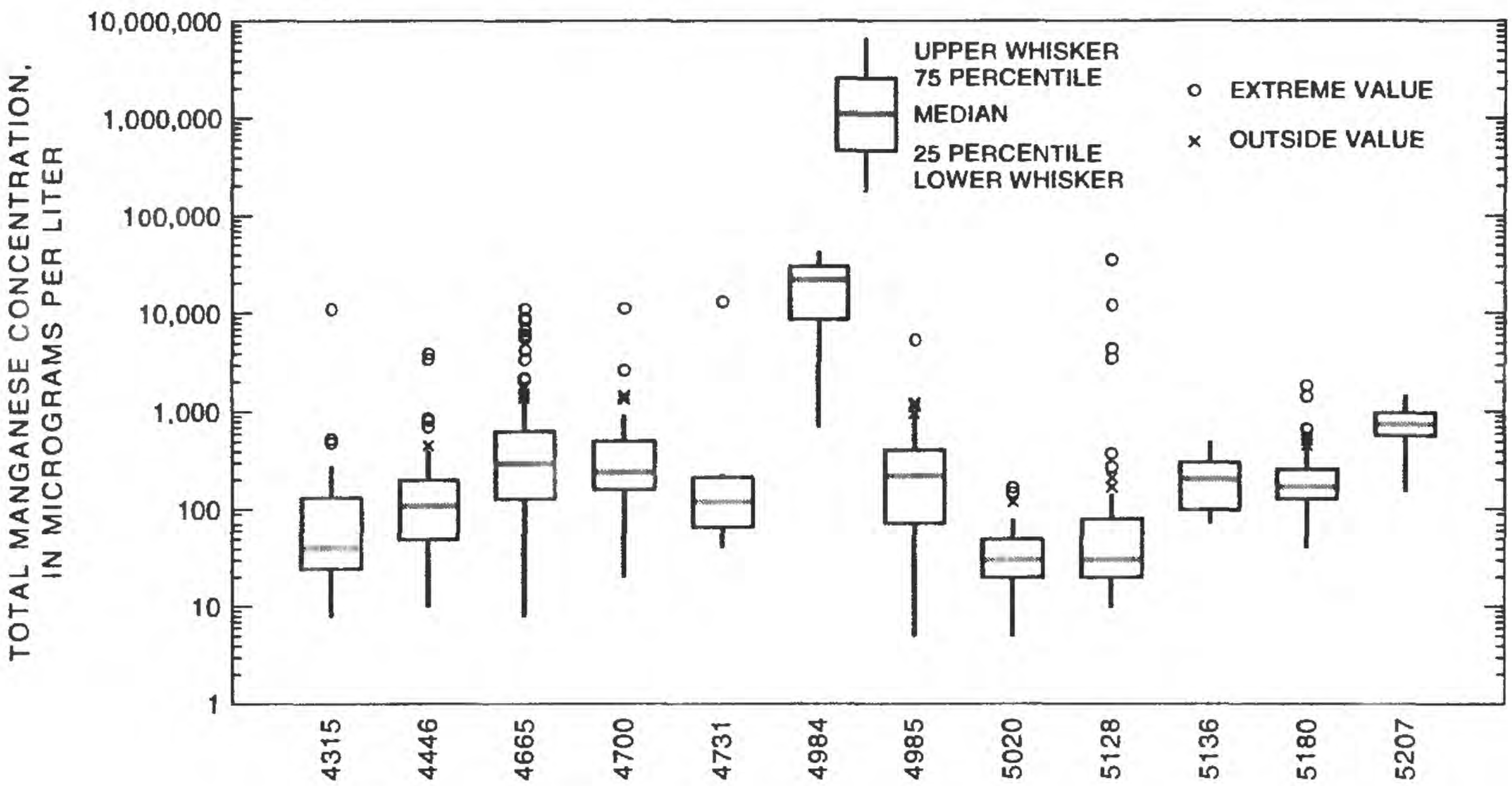


Figure 21. *Total manganese and direction of temporal trend.*

sites, flow-adjusted procedures were used that resulted in r^2 values ranging from 10.9 to 74.5.

Dissolved Zinc

Dissolved zinc is essential for plant and animal metabolism; however, large concentrations can be toxic to aquatic life. The SMCL for zinc in drinking water is 5,000 µg/L (U.S. Environmental Protection Agency, 1993). The State quality standard for total zinc is 5,000 µg/L in water used as domestic-water sources (State of Arizona, 1992).

Summary statistics were computed for 12 of the 13 study sites (table 38, at the end of this report). Data for dissolved zinc were not collected at Agua Fria River near Rock Springs. Maximum concentrations of dissolved zinc ranged from 40.0 µg/L at Agua Fria River below Waddell Dam to 1,280 µg/L at Gila River near Redrock. Of the 12 sites, 10 had a minimum concentration below the analytical reporting limit. The median concentration of dissolved zinc ranged from 8.0 µg/L at two sites to 20.0 µg/L at two sites. Boxplots show that the data for Gila River at Calva; Gila River near mouth, near Yuma; and Gila River near Redrock (maximum 1,280 µg/L) contain several extreme values (fig. 22); however, median concentrations were well within the State quality standard for surface water.

Decreasing trends in concentrations of dissolved zinc were found at three sites—San Francisco River near Clifton (-0.53 (µg/L)/yr); San Pedro River below Aravaipa Creek (-2.50 (µg/L)/yr); and Salt River near Roosevelt (-1.67 (µg/L)/yr; table 39, at the end of this report). Analyses for trends in concentrations of dissolved zinc at Agua Fria River near Rock Springs were not done because samples for dissolved zinc were not collected. Trends in concentrations of dissolved zinc were not found at the remaining study sites. Flow-adjusted equations were used for 6 of the 12 data sets, and r^2 values ranged from 10.3 to 15.3 µg/L.

Total Organic Carbon

The measurement of total organic-carbon concentrations allows an approximate determination of the total concentration of organic material in aqueous systems (Hem, 1985). Organic matter can have significant effects on the chemical properties of aqueous systems. Water containing certain organic solutes can be unsuitable for use by human, aquatic, and other life forms. Federal and State regulations for total organic-carbon concentrations have not been established.

Summary statistics for concentrations of total organic carbon were compiled for 10 of the 13 sites (table 40, at the end of this report). Minimum concentrations of total organic carbon ranged from 0.50 mg/L at San Francisco River near Clifton to 5.40 mg/L at Gila River above diversions, at Gillespie Dam (excluding the one sample collected at Gila River near Dome). Median total organic-carbon concentrations ranged from 2.40 mg/L at San Francisco River near Clifton to 11.0 mg/L at Gila River above diversions, at Gillespie Dam. The maximum total organic-carbon concentration (300 mg/L) was recorded at Gila River at Calva. More values above 50 mg/L occurred at sites in the upper half of the basin than in the lower half (fig. 23). Statistics were not compiled at Agua Fria River near Rock Springs and Agua Fria River below Waddell Dam because total organic-carbon data were not collected. Only one sample was collected at Gila River near Dome; therefore, summary statistics were not computed for this site.

Trend analyses were not performed for 5 of the 13 sites because of insufficient data. Total organic-carbon concentrations were found to be increasing at a rate of 0.26 (mg/L)/yr at Salt River below Stewart Mountain Dam. The remaining seven sites showed no trend (table 41, at the end of this report). Streamflow is poorly correlated with total organic-carbon concentrations at all the study sites; the r^2 values ranged from 12.5 to 51.1. The flow-adjustment procedure was effective only at Gila River near mouth, near Yuma (r^2=51.1).

SUMMARY

Water-resources managers are concerned with effectively evaluating and understanding short- and long-term trends of water quality in streams in the Gila River basin. The Gila River basin is a valuable source of water for agricultural, industrial, and

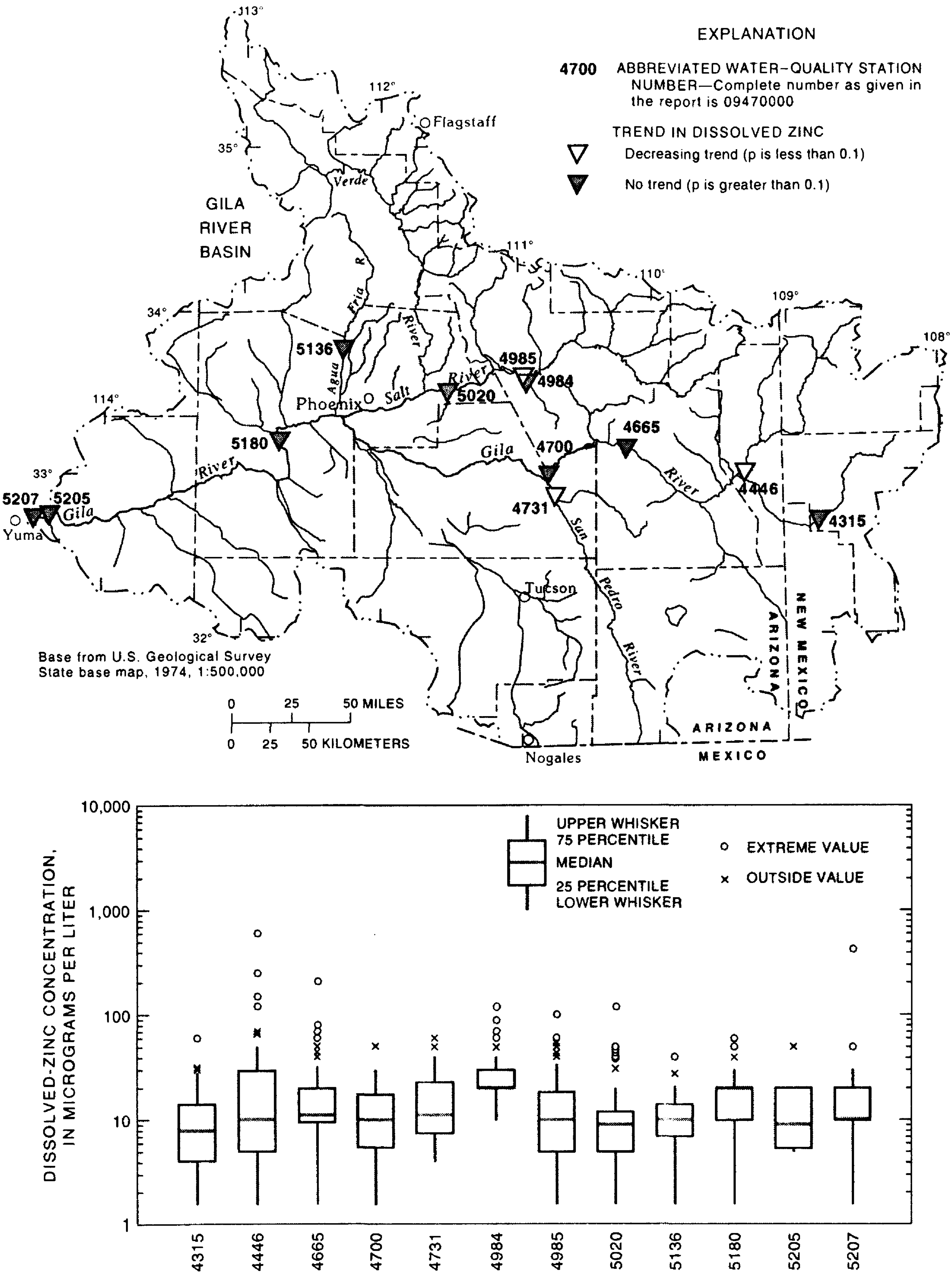
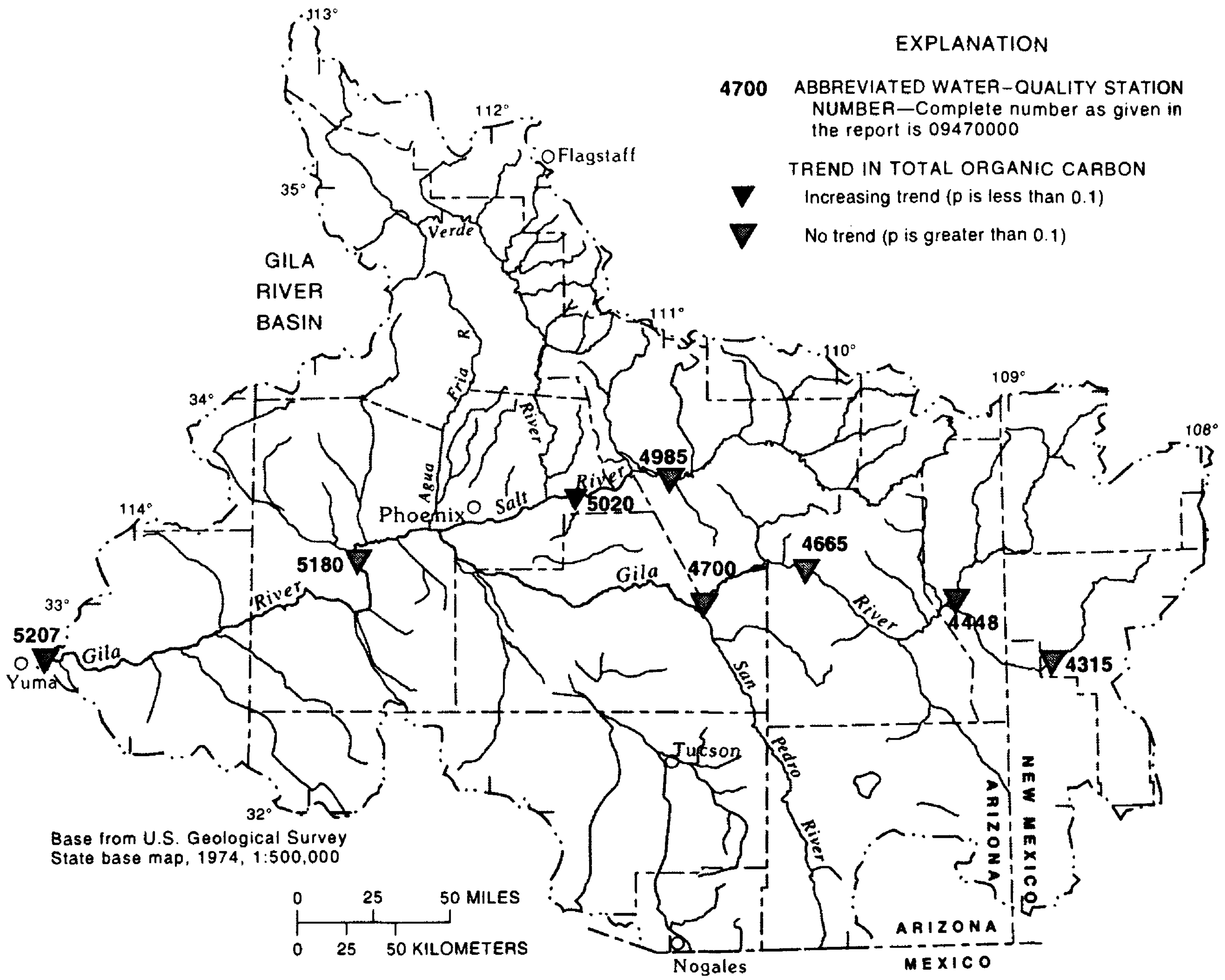


Figure 22. Dissolved zinc and direction of temporal trend.



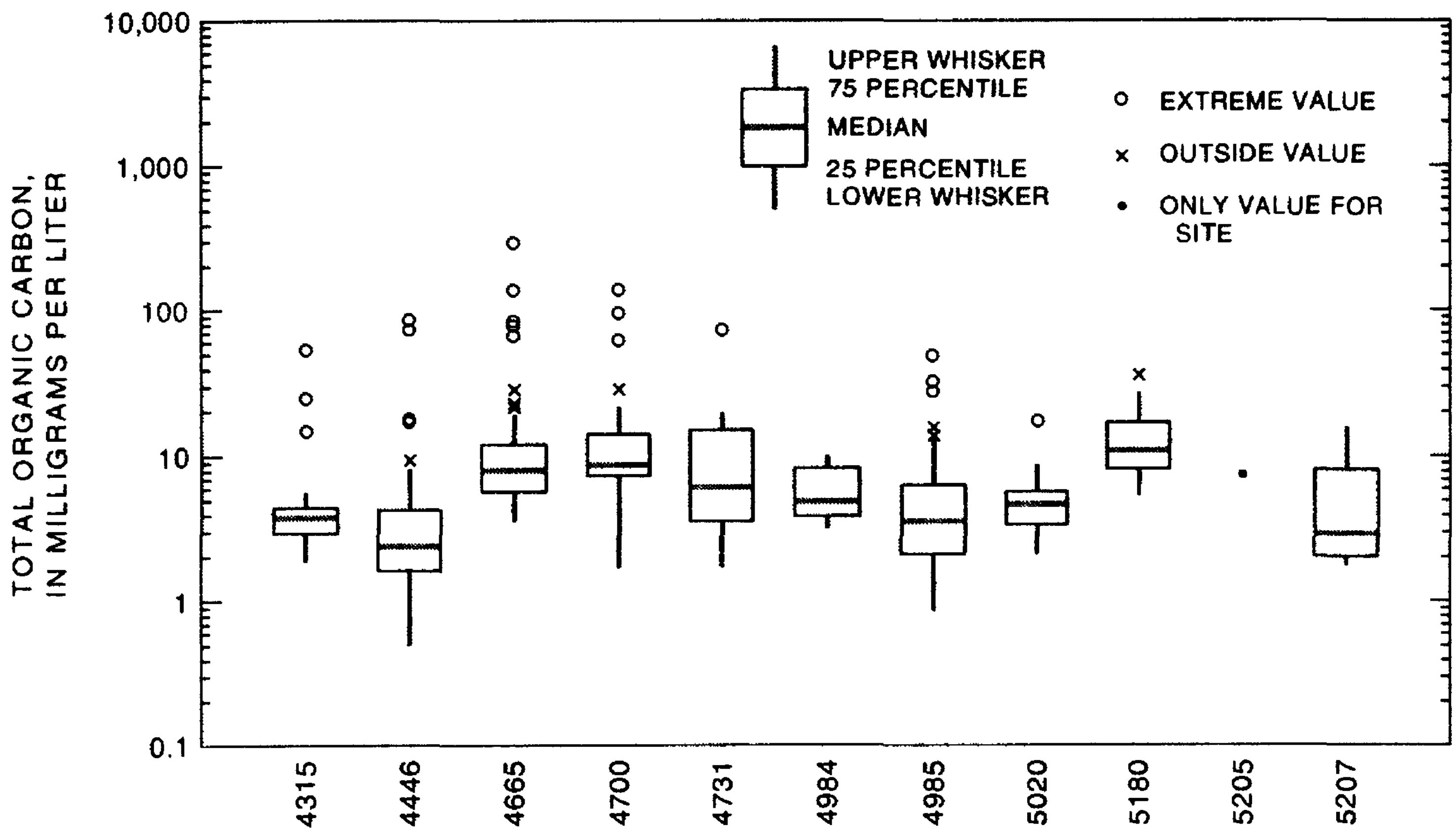


Figure 23. Total organic carbon and direction of temporal trend.

municipal uses throughout central Arizona and western New Mexico. In Arizona, the population increase from 499,261 in 1940 to 3,605,700 in 1988 (Valley National Bank, 1988) has resulted in increased demands on surface-water and ground-water resources. Resource managers and planners are concerned that the quality of water is degrading with time as a result of stresses on the hydrologic system.

Nonparametric trend-analysis techniques were used to assess temporal changes in water-chemistry data collected at 13 sites in the Gila River basin. A nonparametric technique, the seasonal Kendall tau test for flow-adjusted data, was selected as the method used for trend analysis. Water-chemistry data collected at several sites in the Gila River basin, mostly by the ADEQ and the USGS, were available for trend analysis. This report describes temporal and areal variability of water-chemistry constituents collected from sampling sites at 13 streamflow-gaging stations in the Gila River basin.

From approximately 110 constituents sampled at each site, 19 constituents and turbidity were selected for trend analysis: pH, hardness, dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, total ammonia plus organic nitrogen, total phosphorus, dissolved arsenic, dissolved barium, total boron, dissolved chromium, suspended copper, total copper, dissolved lead, total lead, total manganese, dissolved zinc, and total organic carbon. Six of the 13 gaging stations are on the main stem of the Gila River. The remaining seven stations are on major tributaries to the Gila River—one on the San Francisco River, one on the San Pedro River, two on the Agua Fria River, two on the Salt River, and one on Pinal Creek, which is tributary to the Salt River.

Increasing trends generally were found in three areas in the basin—at Pinal Creek above Inspiration Dam, at sites above reservoirs, and at sites on the main stem of the Gila River from Gillespie Dam to the mouth. Median concentrations of hardness, dissolved solids, dissolved sodium, dissolved sulfate, and dissolved chloride were larger at sites above reservoirs especially at Gila River at Calva and Salt River near Roosevelt than at downstream sites. Median concentrations of hardness, dissolved solids, dissolved sulfate, suspended and total copper, and total manganese were greater at Pinal Creek than at other sites. The sites at and downstream from Gillespie Dam seem to be affected by irrigation-return flow. Median concentrations of hardness, dissolved solids, dissolved sodium, dissolved chloride, dissolved arsenic, dissolved barium, and total boron were greatest at these sites. In addition, the Gila River at Gillespie Dam site, which is affected by sewage effluent, had the greatest median concentrations of ammonia plus organic nitrogen and total phosphorus. The median concentration of dissolved chromium was greatest at the Gila River near the mouth, near Yuma.

Increasing trends in concentrations were found for 24 data sets at the 13 study sites. Pinal Creek at Inspiration Dam had the largest number (six) of increasing trends: dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, dissolved chromium, and total manganese. Gila River near mouth, near Yuma had three increasing trends: dissolved sulfate, total ammonia plus organic nitrogen, and total lead. The largest number of increasing trends measured for a constituent was for pH (four), dissolved sulfate (three), dissolved chromium (three), and total manganese (three).

Decreasing trends were found for 49 data sets at the 13 study sites. Gila River at Calva and Gila River above diversions, at Gillespie Dam (eight each) had the most decreasing trends for individual sites. Data for Gila River at Calva indicated decreasing concentrations of hardness, dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, total phosphorus, dissolved lead, and total manganese. Data for Gila River above diversions, at Gillespie Dam indicate decreasing concentrations of hardness, dissolved solids, dissolved sodium, dissolved sulfate, dissolved chloride, dissolved barium, dissolved lead, and total manganese. The largest number of decreasing trends measured for a constituent was six for dissolved lead. The next largest number of decreasing trends for a constituent was for dissolved solids and total manganese (five each). Decreasing trends were found in concentrations of hardness, dissolved sodium, and dissolved chloride at four of the study sites.

For the 19 selected constituents and turbidity, decreasing trends outnumbered increasing trends by almost two to one. Possible explanations for the increasing trends are that Pinal Creek is influenced by mine drainage, Gila River near Calva is influenced by irrigation-return flows, and the reach of the Gila River from Gillespie Dam to the mouth, near Yuma is influenced by irrigation-return flows, and effluent from near Gillespie Dam is influenced by municipal wastewater-treatment plants. Increasing trends in concentrations were not found for constituents whose median concentrations were larger than the quality standards for surface waters set by the State of Arizona.

SELECTED REFERENCES

Alley, W.M., 1987, A note on stagewise regression: The American Statistician, May 1987, v. 41, no. 2, p. 132–134.

_____1988, Using exogenous variables in testing for nontoxic trends in hydrologic time series: Water Resources Research, v. 24, no. 11, p. 1955–1961.

Arizona Atomic Energy Commission, 1977, Rules and regulations, Title 12: Phoenix, State of Arizona report, Supplement 77–3, p. 1–133.

Arizona Bureau of Mines, 1969, Mineral and water resources of Arizona: Tucson, University of Arizona Bulletin 180, 638 p.

Arizona Department of Health Services, 1976, Water quality in Arizona: Phoenix, Arizona Department of Health Services report, 191 p.

_____1986, Water quality assessment for water years 1984 and 1985: Phoenix, Arizona Department of Health Services report, 98 p.

Baldys, Stanley, III, 1990, Trend analysis of selected water-quality constituents in the Verde River basin, central Arizona: U.S. Geological Survey Water-Resources Investigations Report 90–4128, 55 p.

Brown, J.G., and Pool, D.R., 1989, Hydrogeology of the western part of the Salt River Valley area, Maricopa County, Arizona: U.S. Geological Survey Water-Resources Investigations Report 88–4202, 5 sheets.

Buell, G.R., and Grams, S.C., 1985, The hydrologic bench-mark program—A standard to evaluate time-series trends in selected water-quality constituents for streams in Georgia: U.S. Geological Survey Water-Resources Investigations Report 84–4318, 36 p.

Eychaner, J.H., Rehmann, M.R., and Brown, J.G., 1989, Chemical, geologic, and hydrologic data from the study of acidic contamination in the Miami Wash–Pinal Creek area, Arizona, water years 1984–87: U.S. Geological Survey Open-File Report 89–410, 105 p.

Feth, J.H., and Hem, J.D., 1963, Reconnaissance of headwater springs in the Gila River drainage basin, Arizona: U.S. Geological Survey Water-Supply Paper 1619–H, 54 p.

Garrett, J.M., and Gellenbeck, D.J., 1991, Basin characteristics and streamflow statistics in Arizona as of 1989: U.S. Geological Survey Water-Resources Investigations Report 91–4041, 612 p.

Goetz, C.L., Abeyta, C.G., and Thomas, E.V., 1987, Application of techniques to identify coal-mine and power-generation effects on surface-water quality, San Juan River basin, New Mexico and Colorado: U.S. Geological Survey Water-Resources Investigations Report 86–4076, 79 p.

Helsel, D.R., and Cohn, T.A., 1988, Estimation of descriptive statistics for multiple censored water quality data: Water Resources Research, v. 24, no. 12, p. 1997–2004.

Hem, J.D., 1950, Quality of water of the Gila River basin above Coolidge Dam, Arizona: U.S. Geological Survey Water-Supply Paper 1104, 230 p.

_____1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hirsch, R.M., 1981, Techniques of trend analysis for monthly water-quality data: U.S. Geological Survey Open-File Report 81–488, 30 p.

Iman, R.L., and Conover, W.J., 1983, A modern approach to statistics: New York, Wiley and Sons, 497 p.

Kendall, M.G., 1975, Rank correlation methods: London, Charles Griffin and Company, 202 p.

Kister, L.R., and Hardt, W.F., 1966, Salinity of the ground water in western Pinal County, Arizona: U.S. Geological Survey Water-Supply Paper 1819–E, 21 p.

Laney, R.L., 1972, Chemical quality of water in the Tucson basin, Arizona: U.S. Geological Survey Water-Supply Paper 1939–D, 46 p.

McClennan, J.J., 1984, Official compilation of administrative rules and regulations: Phoenix, State of Arizona report, Supplement 84–3, p. 68–84.

_____1986, Official compilation of administrative rules and regulations: Phoenix, State of Arizona report, Advance Supplement 86–4, p. 1–49.

McDougall, W.B., 1973, Seed plants of northern Arizona: Flagstaff, Arizona, The museum of northern Arizona, 594 p.

McLeod, A.I., Hipel, K., and Camancho, F., 1984, Trend assessment of water quality time series: Water Resources Bulletin 19, p. 537–547.

Owen-Joyce, S.J., 1984, Hydrology of a stream-aquifer system in the Camp Verde area, Yavapai County, Arizona: Phoenix, Arizona Department of Water Resources Bulletin 3, 60 p.

Owen-Joyce, S.J., and Bell, C.K., 1983, Appraisal of water resources in the upper Verde River area, Yavapai and Coconino Counties, Arizona: Phoenix, Arizona Department of Water Resources Bulletin 2, 219 p.

Robertson, F.N., 1975, Hexavalent chromium in the ground water in Paradise Valley, Maricopa County, Arizona: Ground Water, v. 13, no. 6, p. 516–527.

_____1991, Geochemistry of ground water in alluvial basins of Arizona and adjacent parts of Nevada, New Mexico, and California: U.S. Geological Survey Professional Paper 1406–C, 90 p.

Sax, I.N., and Lewis, R.J., Sr., 1987, Hawleys condensed chemical dictionary: New York, Van Nostrand Reinhold Co., 1,288 p.

Sellers, W.D., Hill, R.H., and Sanderson-Rae, Margaret, eds., 1985, Arizona climate—The first hundred years: Tucson, University of Arizona Press, 143 p.

Smith, R.A., Alexander, R.B., and Wolman, M.G., 1987, Analysis and interpretation of water-quality trends in major U.S. rivers, 1974–81: U.S. Geological Survey Water-Supply Paper 2307, 25 p.

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

Smith, S.A, Small, Gary, Phillips, T.S., and Clester, Michael, 1982b, Water quality in the Salt River Project—A preliminary report: Phoenix, Salt River Project, Water Resources Operations, Groundwater Planning Division, 360 p.

State of Arizona, 1992, Arizona Administrative Code, 1992: Phoenix, Arizona, Title 18, Chapter 11, Article 1, p. 1–34, Article 4, p. 36–40.

Thomsen, B.W., and Baldys, Stanley, III, 1985, Ground-water conditions in and near the Gila River Indian Reservation, south-central Arizona: U.S. Geological Survey Water-Resources Investigations Report 85–4073, 2 sheets.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: U.S. Environmental Protection Agency report, 256 p.

_____1986, Quality criteria for water, 1986: U.S. Environmental Protection Agency Report EPA 440/5–86–001, v.p.

_____1990, Drinking water regulations and health advisories: U.S. Environmental Protection Agency Office of Drinking Water report, 10 p.

_____1991, Drinking water regulations and health advisories: Washington, D.C., U.S. Environmental Protection Agency report, 21 p.

_____1993, Drinking water regulations and health advisories: Washington, D.C., U.S. Environmental Protection Agency report, 11 p.

Valley National Bank, 1988, Arizona statistical review: Phoenix, Valley National Bank of Arizona, 44th edition, 89 p.

Wilson, E.D., Moore, R.T., and Cooper, J.R., 1969, Geologic map of Arizona: Tucson, Arizona Bureau of Mines map, scale 1:500,000.

Wilson, R.P., 1988, Water resources of the northern part of the Agua Fria area, Yavapai County, Arizona: Phoenix, Arizona Department of Water Resources Bulletin 5, 109 p.

SUMMARY STATISTICS AND RESULTS OF SEASONAL KENDALL TAU TEST

(page 47 follows)

Table 2. Summary statistics for pH data used in time-trend analysis

[Dashes, no value computed]

Statlon name snd number	Number of ssmples	pH, in stsndard units				Standsrd deviation	Stsndard error of the mean
		Mean	Medisn	Mini-mum	Msxi-mum		
Gila River near Redrock, N. Mex. (09431500)	191	---	8.20	6.90	9.10	---	---
San Francisco River near Clifton (09444600)	105	---	8.20	6.90	9.60	---	---
Gila River at Calva (09466500)	133	---	8.20	6.80	9.80	---	---
Gila River at Winkelman (09470000)	84	---	8.20	7.30	8.80	---	---
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	38	---	8.30	7.80	8.90	---	---
Pinal Creek at Inspiration Dam, near Globe (09498400)	98	---	8.00	5.70	8.40	---	---
Salt River near Roosevelt (09498500)	149	---	8.20	6.90	9.20	---	---
Salt River below Stewart Mountain Dam (09502000)	130	---	8.00	6.40	8.70	---	---
Agua Fria River near Rock Springs (09512800)	81	---	8.35	6.90	8.70	---	---
Agua Fria River below Waddell Dam (09513600)	38	---	8.10	7.10	8.60	---	---
Gila River above diversions, at Gillespie Dam (09518000)	146	---	8.10	6.50	9.20	---	---
Gila River near Dome (09520500)	69	---	7.90	7.30	8.30	---	---
Gila River near mouth, near Yuma (09520700)	180	---	7.90	7.40	8.40	---	---

Table 3. Results of seasonal Kendall tau test on flow-adjusted pH

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c) = ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between pH and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent; <, less than; dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using pH as s function of dischsrge		Seasonal Kendall tau test on flow-adjusted pH data		
	f(c)/f(Q)	r^2, in percent	Medisn, in stan-dsrd units	Stan-dard units per year	p vslue
Gila River near Redrock, N. Mex. (09431500)	LOG/HYP	12.8	8.20	0.056	0.1310
San Francisco River near Clifton (09444600)	LOG/NR	-----	8.20	<.001	1.000
Gila River at Calva (094665000	LOG/NR	------	8.20	.029	.0234
Gila River at Winkelman (09470000)	LOG/NR	------	8.20	.040	.0012
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/NR	-----	8.30	<.001	1.000
Pinal Creek at Inspiration Dam, near Globe (09498400)	LOG/NR	-----	7.98	.013	.3371
Salt River near Roosevelt (09498500)	LOG/NR	-----	8.21	.013	.2335
Salt River below Stewart Mountain Dam (09502000)	LOG/NR	-----	8.00	.044	.0017
Agua Fria River near Rock Springs (09512800)	LOG/NR	-----	8.35	-.010	.4818
Agua Fria River below Waddell Dam (09513600)	LOG/NR	-----	8.10	<.001	.8283
Gila River above diversions, at Gillespie Dam (09518000)	LOG/LOG	12.7	8.10	.058	.0940
Gila River near Dome (09520500)	LOG/NR	-----	7.90	<.001	1.000
Gila River near mouth, near Yuma (09520700)	LOG/LOG	12.5	7.90	<.001	1.000

Table 4. Summary statistics for turbidity used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Turbidity, in nephelometric turbidity units				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	64	158	10	<0.01	6,500	819	102
San Francisco River near Clifton (09444600)	31	87.7	5.5	.60	1,500	272	48.8
Gila River at Calva (09466500)	101	472	40	.00	21,000	2,310	230
Gila River at Winkelman (09470000)	29	216	24	6.00	4,800	888	165
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	38	631	10	<.01	12,000	2,280	370
Pinal Creek at Inspiration Dam, near Globe (09498400)	64	20.6	3.2	.20	140	32.9	4.12
Salt River near Roosevelt (09498500)	69	86.6	9.0	.50	2,400	315	37.9
Salt River below Stewart Mountain Dam (09502000)	89	5.45	3.0	.40	54.0	7.55	.80
Agua Fria River near Rock Springs (09512800)	80	283	1.0	.00	17,000	1,920	215
Agua Fria River below Waddell Dam (09513600)	38	7.61	5.8	.60	31.0	6.03	.98
Gila River above diversions, at Gillespie Dam (09518000)	94	44.9	26	1.60	480	68.8	7.10
Gila River near Dome (09520500)	39	13.7	3.0	.50	140	27.0	4.33
Gila River near mouth, near Yuma (09520700)	42	38.5	5.0	.10	720	112	17.3

Table 5. Results of seasonal Kendall tau test on flow-adjusted turbidity

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. NTU, nephelometric turbidity units. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using turbidity as a function of discharge		Seasonal Kendall tau test on flow-adjusted turbidity data		
	f(c)/f(Q)	r^2, in percent	Median, in NTU	Turbidity, in NTU per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/LOG	16.4	10	-0.04	0.3418
San Francisco River near Clifton (09444600)	LOG/LIN	70.8	5.5	.14	.2301
Gila River at Calva (09466500)	LOG/LOG	45.0	40	-.02	.9470
Gila River at Winkelman (09470000)	LOG/LIN	21.0	24	-.06	.3502
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/LOG	63.9	10	.26	.5085
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/HYP	54.9	3.2	-.01	.8191
Salt River near Roosevelt (09498500)	LIN/NR	----	9.0	-.38	.3177
Salt River below Stewart Mountain Dam (09502000)	LIN/LIN	61.0	3.0	-.12	.0325
Agua Fria River near Rock Springs (09512800)	LOG/HYP	23.2	1.0	.09	.0849
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	14.6	5.8	.06	.7527
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LIN	57.6	26	-.01	.5255
Gila River near Dome (09520500)	LIN/HYP	69.2	3.0	.03	.8345
Gila River near mouth, near Yuma (09520700)	LOG/LOG	70.8	5.0	.38	.3567

Table 6. Summary statistics for hardness used in time-trend analysis

Station name and number	Number of samples	Hardness, in milligrams per liter as calcium carbonate				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	141	115	120	46.0	180	25.7	2.16
San Francisco River near Clifton (09444600)	109	221	230	70.0	440	68.8	6.58
Gila River at Calva (09466500)	142	521	420	63.0	1,300	330	27.7
Gila River at Winkelman (09470000)	85	255	220	110	650	93.5	10.1
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	311	330	160	390	64.8	10.6
Pinal Creek at Inspiration Dam, near Globe (09498400)	96	1,860	1,900	830	2,400	231	23.6
Salt River near Roosevelt (09498500)	145	242	250	70.0	440	93.8	7.79
Salt River below Stewart Mountain Dam (09502000)	130	165	170	130	220	21.0	1.84
Agua Fria River near Rock Springs (09512800)	80	228	230	130	280	30.0	3.36
Agua Fria River below Waddell Dam (09513600)	38	180	180	130	230	20.5	3.32
Gila River above diversions, at Gillespie Dam (09518000)	127	745	750	81.0	1,400	269	23.9
Gila River near Dome (09520500)	44	628	540	190	2,000	369	55.6
Gila River near mouth, near Yuma (09520700)	183	573	610	190	890	153	11.3

Table 7. Results of seasonal Kendall tau test on flow-adjusted hardness

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using hardness as a function of discharge		Seasonal Kendall tau test on flow-adjusted hardness data		
	f(c)/f(Q)	r^2, in percent	Median, in milligrams per liter	Hardness, in milligrams per liter per year as calcium carbonate	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/HYP	73.1	120	-0.03	0.2332
San Francisco River near Clifton (09444600)	LIN/INV	84.3	230	-.04	.3486
Gila River at Calva (09466500)	LIN/HYP	69.4	420	-.07	.0088
Gila River at Winkelman (09470000)	LOG/HYP	48.7	220	-.18	.0041
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/HYP	60.9	330	1.56	.1229
Pinal Creek at Inspiration Dam, near Globe (09498400)	LOG/HYP	67.7	1,900	.18	.4463
Salt River near Roosevelt (09498500)	LOG/LOG	80.5	250	.08	.3847
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	170	.00	.7990
Agua Fria River near Rock Springs (09512800)	LIN/HYP	53.9	230	-.13	.0199
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	21.4	180	-.05	.5995
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LOG	63.4	750	-.07	.0072
Gila River near Dome (09520500)	LIN/LOG	65.7	540	-.10	.7500
Gila River near mouth, near Yuma (09520700)	LOG/LIN	81.4	610	.16	.2064

Table 8. Summary statistics for dissolved solids used in time-trend analysis

Station name and number	Number of samples	Dissolved solids, in milligrams per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	89	221	229	68.0	349	51.6	5.47
San Francisco River near Clifton (09444600)	109	676	630	178	1,830	324	31.0
Gila River at Calva (09466500)	142	2,060	1,700	244	4,680	1,360	114
Gila River at Winkelman (09470000)	85	752	628	234	2,890	390	42.3
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	754	838	322	960	214	35.2
Pinal Creek at Inspiration Dam, near Globe (09498400)	100	2,970	3,000	1,310	3,600	355	35.5
Salt River near Roosevelt (09498500)	143	1,070	984	146	2,830	624	52.2
Salt River below Stewart Mountain Dam (09502000)	130	482	464	287	855	135	11.8
Agua Fria River near Rock Springs (09512800)	81	367	380	218	484	52.0	5.78
Agua Fria River below Waddell Dam (09513600)	38	296	298	217	390	38.0	6.17
Gila River above diversions, at Gillespie Dam (09518000)	127	2,560	2,570	202	4,700	974	86.4
Gila River near Dome (09520500)	67	2,300	2,270	546	5,870	1,260	154
Gila River near mouth, near Yuma (09520700)	181	1,870	2,000	528	2,730	521	38.7

Table 9. Results of seasonal Kendall tau test on flow-adjusted dissolved solids

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved solids as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milligrams per liter	Concentrations, in milligram per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LOG	59.4	229	-0.45	0.0492
San Francisco River near Clifton (09444600)	LIN/INV	89.4	630	-.2	.4708
Gila River at Calva (09466500)	LIN/LIN	79.5	1,700	-.5	.0439
Gila River at Winkelman (09470000)	LOG/LIN	27.4	628	-.20	.0279
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/HYP	72.7	838	.22	.1393
Pinal Creek at Inspiration Dam, near Globe (09498400)	LOG/HYP	66.2	3,000	.49	<.0001
Salt River near Roosevelt (09498500)	LOG/LOG	91.2	984	.01	.9337
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	464	-.30	.9824
Agua Fria River near Rock Springs (09512800)	LIN/HYP	56.4	380	-.30	<.0001
Agua Fria River below Waddell Dam (09513600)	LOG/LIN	23.4	298	-.01	.9164
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LOG	71.1	2,570	-.08	.0366
Gila River near Dome (09520500)	LOG/HYP	49.4	2,270	.14	.6178
Gila River near mouth, near Yuma (09520700)	LOG/LIN	83.6	2,000	.13	.1840

Table 10. *Summary statistics for dissolved sodium used in time-trend analysis*

Station name and number	Number of samples	Dissolved sodium, in milligrams per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	139	28.7	31.0	7.80	44.0	8.00	0.68
San Francisco River near Clifton (09444600)	83	142	130	17.0	420	84.5	9.27
Gila River at Calva (09466500)	142	525	425	2.50	1,200	364	30.6
Gila River at Winkelman (09470000)	49	184	160	16.0	790	138	19.7
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	125	140	29.0	170	42.9	7.05
Pinal Creek at Inspiration Dam, near Globe (09498400)	96	67.5	67.0	2.50	89.0	10.6	1.09
Salt River near Roosevelt (09498500)	114	286	240	2.50	950	202	19.0
Salt River below Stewart Mountain Dam (09502000)	130	106	100	43.0	230	44.4	3.89
Agua Fria River near Rock Springs (09512800)	81	42.0	45.0	17.0	56.0	8.44	.94
Agua Fria River below Waddell Dam (09513600)	38	33.3	34.0	23.0	43.0	5.45	.88
Gila River above diversions, at Gillespie Dam (09518000)	127	598	610	2.50	1,100	245	21.7
Gila River near Dome (09520500)	45	425	400	82.0	920	225	33.4
Gila River near mouth, near Yuma (09520700)	183	437	470	110	610	12.5	9.27

Table 11. *Results of seasonal Kendall tau test on flow-adjusted dissolved sodium*

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \bullet f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved sodium as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milli-grams per liter	Concen-trations, in milli-grams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LOG	79.6	31.0	-0.05	0.0002
San Francisco River near Clifton (09444600)	LOG/LOG	94.6	130	-.10	.2648
Gila River at Calva (09466500)	LIN/HYP	81.3	425	-.04	.0725
Gila River at Winkelman (09470000)	LOG/LIN	26.2	160	-.08	.4863
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/HYP	75.9	140	.17	.0778
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/LIN	21.2	67.0	.18	<.0001
Salt River near Roosevelt (09498500)	LIN/INV	84.8	240	.01	.3367
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	100	<.01	1.000
Agua Fria River near Rock Springs (09512800)	LIN/HYP	70.9	45.0	-.28	<.0001
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	15.8	34.0	.32	.1152
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LOG	69.6	610	-.05	.0776
Gila River near Dome (09520500)	LOG/HYP	57.8	400	-.21	.6569
Gila River near mouth, near Yuma (09520700)	LIN/HYP	69.4	470	.04	.2848

Table 12. Summary statistics for dissolved sulfate used in time-trend analysis

Station name and number	Number of samples	Dissolved sulfate, in milligrams per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	141	32.8	34.0	<1.0	49.0	8.07	0.68
San Francisco River near Clifton (09444600)	109	30.6	30.0	2.0	79.0	9.91	.95
Gila River at Calva (09466500)	142	341	280	30.0	810	236	19.8
Gila River at Winkelman (09470000)	85	138	120	56.0	530	70.6	7.65
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	38	314	350	99.0	450	102	16.6
Pinal Creek at Inspiration Dam, near Globe (09498400)	100	1,790	1,800	760	2,200	232	23.2
Salt River near Roosevelt (09498500)	145	94.5	94.0	6.0	200	45.4	3.77
Salt River below Stewart Mountain Dam (09502000)	130	55.8	55.0	38.0	220	16.5	1.44
Agua Fria River near Rock Springs (09512800)	80	74.9	72.0	38.0	120	18.1	2.03
Agua Fria River below Waddell Dam (09513600)	38	57.3	56.0	40.0	80.0	9.04	1.47
Gila River above diversions, at Gillespie Dam (09518000)	126	556	555	22.0	1,100	246	21.9
Gila River near Dome (09520500)	46	415	415	83.0	830	207	30.5
Gila River near mouth, near Yuma (09520700)	183	444	480	100	650	132	9.77

Table 13. Results of seasonal Kendall tau test on flow-adjusted dissolved sulfate

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$ NR=No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved sulfate as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milligrams per liter	Concentrations, in milligrams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)..	LIN/HYP	30.6	34.0	-0.09	0.0013
San Francisco River near Clifton (09444600) ...	LIN/HYP	10.0	30.0	-.02	.6058
Gila River at Calva (09466500)	LIN/HYP	75.5	280	-.05	.0679
Gila River at Winkelman (09470000)	LOG/LOG	25.7	120	-.05	.2139
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/HYP	72.0	350	1.34	.0153
Pinal Creek at Inspiration Dam, near Globe(09498400)	LOG/LIN	60.5	1,800	.55	.0023
Salt River near Roosevelt (09498500)	LOG/LOG	74.0	94.0	.10	.2322
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	---	55.0	-.07	.8286
Agua Fria River near Rock Springs (09512800)	LIN/HYP	22.5	72.0	-.44	<.0001
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	13.6	56.0	-.19	.4623
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LOG	70.8	555	-.08	.0202
Gila River near Dome (09520500)	LOG/HYP	80.8	415	.02	.9032
Gila River near mouth, near Yuma (09520700)	LIN/LOG	77.5	480	.12	.0572

Table 14. Summary statistics for dissolved chloride used in time-trend analysis

Station name and number	Number of samples	Dissolved chloride, in milligrams per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	141	11.8	12.0	2.0	44.0	5.02	0.42
San Francisco River near Clifton (09444600)	83	257	230	16.0	870	172	18.8
Gila River at Calva (09466500)	145	786	590	31.0	2,200	606	50.3
Gila River at Winkelman (09470000)	49	255	210	11.0	1,200	218	31.1
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	41.1	48.0	9.6	59.0	15.3	2.52
Pinal Creek at Inspiration Dam, near Globe (09498400)	99	75.3	77.0	31.0	110	20.4	2.05
Salt River near Roosevelt (09498500)	113	465	390	33.0	1,500	324.0	30.5
Salt River below Stewart Mountain Dam (09502000)	130	164	160	37.0	360	71.1	6.24
Agua Fria River near Rock Springs (09512800)	80	31.8	33.5	12.0	50.0	8.66	.97
Agua Fria River below Waddell Dam (09513600)	38	24.7	24.0	16.0	40.0	5.31	.86
Gila River above diversions, at Gillespie Dam (09518000)	128	903	920	20.0	1,600	348	30.7
Gila River near Dome (09520500)	45	689	610	70.0	1,600	436	65.0
Gila River near mouth, near Yuma (09520700)	184	597	630	150	1,200	192	14.1

Table 15. Results of seasonal Kendall tau test on flow-adjusted dissolved chloride

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved chloride as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milligrams per liter	Concentrations, in milligrams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/HYP	47.1	12.0	-0.07	0.0220
San Francisco River near Clifton (09444600)	LIN/INV	88.2	230	-.01	.8491
Gila River at Calva (09466500)	LIN/HYP	76.7	590	-.07	.0054
Gila River at Winkelman (09470000)	LOG/LOG	15.6	210	-.12	.2653
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/HYP	67.1	48.0	.11	.5085
Pinal Creek at Inspiration Dam, near Globe (09498400)	LOG/HYP	21.4	77.0	1.76	<.0001
Salt River near Roosevelt (09498500)	LIN/INV	83.0	390	.03	.0123
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	160	.00	1.0000
Agua Fria River near Rock Springs (09512800)	LIN/HYP	48.2	33.5	-.36	<.0001
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	14.1	24.0	.06	1.000
Gila River above diversions, at Gillespie Dam (09518000)	LIN/LOG	69.5	920	-.05	.0241
Gila River near Dome (09520500)	LIN/HYP	48.7	610	-.02	.7972
Gila River near mouth, near Yuma (09520700)	LOG/LIN	77.1	630	.16	.1805

Table 16. Summary statistics for total ammonia plus organic nitrogen used in time-trend analysis

[<, less than]

Station name snd number	Number of aamplea	Total ammonia piua organic nitrogen (ss nitrogen), in miiligrama per iiter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	77	0.80	0.47	0.10	11.0	1.52	0.17
San Francisco River near Clifton (09444600)	83	1.08	.40	.01	18.0	2.82	.31
Gila River at Calva (09466500)	142	2.01	.80	.10	74.0	6.62	.56
Gila River at Winkelman (09470000)	81	1.32	.85	.10	11.0	1.72	.19
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	4.80	.80	.30	47.0	11.8	1.94
Pinal Creek at Inspiration Dam, near Globe (09498400)	84	.64	.60	<.01	2.00	.35	.04
Salt River near Roosevelt (09498500)	148	.57	.40	.01	3.50	.53	.04
Salt River below Stewart Mountain Dam (09502000)	119	.50	.40	.03	2.90	.43	.04
Agua Fria River near Rock Springs (09512800)	81	.64	.40	.10	6.20	1.04	.12
Agua Fria River below Waddell Dam (09513600)	38	.60	.50	.30	1.40	.26	.04
Gila River above diversions, at Gillespie Dam (09518000)	125	4.56	3.70	.60	17.0	2.94	.26
Gila River near Dome (09520500)	62	.72	.60	.10	2.00	.36	.05
Gila River near mouth, near Yuma (09520700)	82	.77	.67	.18	3.80	.52	.06

Table 17. Results of seasonal Kendall tau test on flow-adjusted total ammonia plus organic nitrogen

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \bullet f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR = No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data is not flow adjusted]

Statlon nsme and number	Ordinary least-squares regression analysis using concentrstion of total ammonia plus organic nitrogen (as nitrogen) aa a function of disoharge		Sessonsl Kendall tsu test on flow-adjusted concentrstion data		
	f(c)/f(Q)	r^2, in percent	Median, in milli-grsms per liter	Concen-trations, in milli-grsms per liter per year	p vslue
Gila River near Redrock, N. Mex. (09431500)..	LIN/LIN	10.6	0.47	-.01	0.7041
San Francisco River near Clifton (09444600)....	LIN/NR	----	.40	.02	.0660
Gila River at Calva (09466500)	LIN/NR	-----	.80	<.01	.9095
Gila River at Winkelman (09470000)	LIN/NR	-----	.85	-.02	.5273
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/HYP	49.3	.80	.05	.2843
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/NR	-----	.60	-.03	.4786
Salt River near Roosevelt (09498500)	LIN/NR	-----	.40	<.01	.7527
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	-----	.40	<.01	.7356
Agua Fria River near Rock Springs (09512800)	LIN/HYP	12.5	.40	-.02	.8159
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	.50	-.05	.0281
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	----	3.70	-.04	.5287
Gila River near Dome (09520500)	LIN/LOG	13.3	.60	.06	.2963
Gila River near mouth, near Yuma (09520700)	LIN/HYP	14.6	.67	.10	.0639

Table 18. Summary statistics for total phosphorus used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Total phosphorus, in milligrams per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	77	0.25	0.09	0.02	4.40	0.73	0.08
San Francisco River near Clifton (09444600)	82	.50	.10	.01	7.90	1.48	.16
Gila River at Calva (09466500)	146	.98	.19	.01	21.0	2.75	.23
Gila River at Winkelman (09470000)	85	.37	.16	<.01	7.30	1.00	.11
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	37	2.25	.08	.02	40.0	7.73	1.27
Pinal Creek at Inspiration Dam, near Globe (09498400)	84	.10	.07	<.01	.66	.10	.01
Salt River near Roosevelt (09498500)	149	.14	.06	<.01	3.80	.34	.03
Salt River below Stewart Mountain Dam (09502000)	120	.11	.03	.01	8.30	.75	.07
Agua Fria River near Rock Springs (09512800)	81	.69	.06	.01	39.0	4.39	.49
Agua Fria River below Waddell Dam (09513600)	38	.06	.06	.01	.16	.03	.01
Gila River above diversions, at Gillespie Dam (09518000)	130	1.93	1.70	.10	5.00	1.03	.09
Gila River near Dome (09520500)	62	.10	.02	<.01	2.00	.28	.04
Gila River near mouth, near Yuma (09520700)	86	.10	.06	<.01	1.00	.15	.02

Table 19. Results of seasonal Kendall tau test on flow-adjusted total phosphorus

[Results follow the general linear model form $f(c)=b_0+ b_1 \cdot f(Q)+e$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), f(Q)=1/(1+ b Q) NR=No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of total phosphorus as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milli-grams per liter	Concen-trations, in milligrams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LIN	42.6	0.09	-0.01	0.1043
San Francisco River near Clifton (09444600)	LOG/LOG	14.6	.10	-.05	.0266
Gila River at Calva (09466500)	LOG/HYP	39.1	.19	-.06	.0333
Gila River at Winkelman (09470000)	LOG/LOG	17.6	.16	-.13	.0447
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/LOG	63.2	.08	-.22	.1220
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/LIN	48.5	.07	-.06	.1140
Salt River near Roosevelt (09498500)	LOG/LOG	13.4	.06	-.05	.1948
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	-----	.03	<-.01	.1017
Agua Fria River near Rock Springs (09512800)	LOG/LOG	14.5	.06	-.01	.9073
Agua Fria River below Waddell Dam (09513600)	LIN/LIN	23.6	.06	.03	.7527
Gila River above diversions, at Gillespie Dam (09518000)	LOG/HYP	22.8	1.70	-.05	.1139
Gila River near Dome (09520500)	LIN/LIN	68.1	.02	-.05	.5309
Gila River near mouth, near Yuma (09520700)	LIN/LIN	49.5	.06	.01	.7442

Table 20. Summary statistics for dissolved arsenic used in time-trend analysis

[Dashes, no value computed]

Station name and number	Number of samples	Dissolved arsenic, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	45	1.74	2.0	<1.0	4.0	1.02	0.15
San Francisco River near Clifton (09444600)	25	2.40	2.0	1.0	4.0	.76	.15
Gila River at Calva (09466500)	88	4.38	4.0	<1.0	8.0	1.27	.14
Gila River at Winkelman (09470000)	1	----	----	7.0	7.0	----	----
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	22	4.47	5.0	<1.0	7.0	1.53	.33
Pinal Creek at Inspiration Dam, near Globe (09498400)	24	([1])	([1])	<1.0	1.0	([1])	([1])
Salt River near Roosevelt (09498500)	48	3.55	3.5	<1.0	6.0	1.56	.22
Salt River below Stewart Mountain Dam (09502000)	70	2.93	3.0	2.0	6.0	.75	.09
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	38	11.1	11	7.0	16	2.54	.41
Gila River above diversions, at Gillespie Dam (09518000)	80	9.02	9.0	4.0	14	1.86	.21
Gila River near Dome (09520500)	11	6.91	6.0	4.0	10	2.21	.67
Gila River near mouth, near Yuma (09520700)	35	6.63	10	4.0	20	3.28	.56

[1]Data set consists of more than 50 percent of values reported as less than values.

Table 21. Results of seasonal Kendall tau test on flow-adjusted dissolved arsenic

[Results follow the general linear model form $f(c)=\beta_0= \beta_1 \cdot f(Q)+\varepsilon$, where f(c) (LIN) or f(c)=ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$ NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved arsenic as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/NR	----	2.0	<0.01	0.4328
San Francisco River near Clifton (09444600)	LOG/LOG	47.3	2.0	.37	.5403
Gila River at Calva (09466500)	LIN/LIN	15.2	4.0	.04	.1003
Gila River at Winkelman (09470000)	Insufficient data.				
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/LIN	68.3	5.0	-.57	.2207
Pinal Creek at Inspiration Dam, near Globe (09498400)	([1])	([1])	([1])	([1])	([1])
Salt River near Roosevelt (09498500)	LOG/LOG	65.6	3.5	-.14	.5482
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	3.0	<.01	.2189
Agua Fria River near Rock Springs (09512800)	No data collected at this site.				
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	11	.50	.1304
Gila River above diversions, at Gillespie Dam (09518000)	LOG/LOG	24.2	9.0	.01	.9604
Gila River near Dome (09520500)	LIN/LIN	18.1	6.0	.50	.3261
Gila River near mouth, near Yuma (09520700)	LOG/INV	36.8	10	-.15	.4831

[1]Data set consists of more than 50 percent of values reported as less than values.

Table 22. Summary statistics for dissolved barium used in time-trend analysis
[<, less than]

Station name and number	Number of samples	Dissolved barium, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	41	23.5	20.0	6.0	50.0	10.1	1.58
San Francisco River near Clifton (09444600)	24	40.0	34.0	12.0	100	21.1	4.30
Gila River at Calva (09466500)	75	95.9	56.0	15.0	600	92.1	10.6
Gila River at Winkelman (09470000)	No data collected at this site.						
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	22	66.4	63.0	29.0	130	21.6	4.61
Pinal Creek at Inspiration Dam, near Globe (09498400)	24	47.8	26.8	12.0	200	48.9	9.98
Salt River near Roosevelt (09498500)	47	47.7	39.4	15.0	200	32.6	4.76
Salt River below Stewart Mountain Dam (09502000)	61	57.5	52.0	37.0	240	31.4	4.03
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	38	56.4	57.0	38.0	81.0	8.98	1.46
Gila River above diversions, at Gillespie Dam (09518000)	72	100	100	<1.0	500	84.7	9.98
Gila River near Dome (09520500)	11	128	100	55.0	200	69.6	21.0
Gila River near mouth, near Yuma (09520700)	20	137	100	60.0	500	121	27.1

Table 23. Results of seasonal Kendall tau test on flow-adjusted dissolved barium

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved barium as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/HYP	16.9	20.0	-0.10	0.1830
San Francisco River near Clifton (09444600)	LIN/INV	83.3	34.0	.23	.2888
Gila River at Calva (09466500)	LOG/LOG	58.9	56.0	-.01	.9712
Gila River at Winkelman (09470000)	No data collected at this site.				
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/HYP	30.1	63.0	<.01	1.000
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/NR	----	26.8	<.01	.2482
Salt River near Roosevelt (09498500)	LOG/LOG	18.3	39.4	-.20	.0461
Salt River below Stewart Mountain Dam (09502000)	LOG/HYP	17.1	52.0	-.06	.1458
Agua Fria River near Rock Springs (09512800)	No data collected at this site.				
Agua Fria River below Waddell Dam (09513600)	LOG/LIN	13.1	57.0	-.20	.1722
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	----	100	-3.57	.0485
Gila River near Dome (09520500)	LIN/HYP	63.4	100	<.01	1.000
Gila River near mouth, near Yuma (09520700)	LOG/LIN	12.3	100	-.16	.4473

Table 24. Summary statistics for total boron used in time-trend analysis

[Dashes, no value computed]

Station name and number	Number of samples	Total boron, in micrograms per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	2	40	40	40	40.0	-----	-----
San Francisco River near Clifton (09444600)	45	151	150	50	270	47.6	7.09
Gila River at Calva (09466500)	64	674	705	110	1,300	355	44.4
Gila River at Winkelman (09470000)	43	249	230	80	810	144	21.9
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	7	273	250	220	330	43.1	16.3
Pinal Creek at Inspiration Dam, near Globe (09498400)	12	99	105	60	130	20.2	5.83
Salt River near Roosevelt (09498500)	65	275	230	30	3,300	398	49.4
Salt River below Stewart Mountain Dam (09502000)	2	185	185	140	230	-----	-----
Agua Fria River near Rock Springs (09512800)	79	155	160	<10.0	300	51.6	5.81
Agua Fria River below Waddell Dam (09513600)	38	115	110	60	200	29.8	4.84
Gila River above diversions, at Gillespie Dam (09518000)	38	2,310	2,000	180	22,000	3,380	548
Gila River near Dome (09520500)	No data collected at this site.						
Gila River near mouth, near Yuma (09520700)	11	618	710	270	930	226	68.0

Table 25. Results of seasonal Kendall tau test on flow-adjusted total boron

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. <, less than. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of total boron as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)			Insufficient data.		
San Francisco River near Clifton (09444600)	LIN/INV	51.4	150	-0.24	0.5163
Gila River at Calva (09466500)	LIN/HYP	65.0	705	-.02	.6235
Gila River at Winkelman (09470000)	LOG/LIN	24.2	230	-.30	.0315
San Pedro River below Aravaipa Creek, near Mammoth (09473100)			Insufficient data.		
Pinal Creek at Inspiration Dam, near Globe (09498400)			Insufficient data.		
Salt River near Roosevelt (09498500)	LOG/LOG	55.4	230	-.12	.2450
Salt River below Stewart Mountain Dam (09502000)			Insufficient data.		
Agua Fria River near Rock Springs (09513800)	LIN/HYP	19.9	160	-.29	<.0001
Agua Fria River below Waddell Dam (09513600)	LIN/LOG	10.5	110	-.11	.1722
Gila River above diversions, at Gillespie Dam (09518000)	LOG/LOG	61.2	2,000	.06	.6692
Gila River near Dome (09520500)			No data collected at this site.		
Gila River near mouth, near Yuma (09520700)	LIN/LIN	87.6	710	-.17	.7728

Table 26. Summary statistics for dissolved chromium used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Dissolved chromium, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	36	0.41	0.02	<1.0	10.0	1.65	0.28
San Francisco River near Clifton (09444600)	24	.78	.67	<1.0	2.0	.45	.09
Gila River at Calva (09466500)	85	1.59	.56	<1.0	10.0	2.81	.30
Gila River at Winkelman (09470000)	24	1.32	.42	<1.0	10.0	2.20	.45
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	30	1.22	.31	<1.0	10.0	2.50	5.48
Pinal Creek at Inspiration Dam, near Globe (09498400)	36	1.81	1.20	<1.0	5.0	1.30	.32
Salt River near Roosevelt (09498500)	72	.94	.53	<1.0	10.0	1.35	.16
Salt River below Stewart Mountain Dam (09502000)	55	.68	.24	<1.0	10.0	1.50	.20
Agua Fria River near Rock Springs (09512800)		No data collected at this site.					
Agua Fria River below Waddell Dam (09513600)	38	1.99	1.01	<1.0	10.0	2.62	.43
Gila River above diversions, at Gillespie Dam (09518000)	83	2.19	1.00	<1.0	20.0	3.17	.35
Gila River near Dome (09520500)	11	1.32	.14	<1.0	10.0	2.95	.89
Gila River near mouth, near Yuma (09520700)	20	5.70	3.98	<1.0	20.0	4.53	1.01

Table 27. Results of seasonal Kendall tau test on flow-adjusted dissolved chromium

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c) = ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), f(Q) = 1/(1+ β Q); NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved chromium as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/NR	----	0.02	None[1]	0.8445
San Francisco River near Clifton (09444600)	LIN/NR	----	.67	None[1]	.1336
Gila River at Calva (09466500)	LIN/NR	----	.56	None[1]	.9542
Gila River at Winkelman (09470000)			Insufficient data.		
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/NR	----	.31	None[1]	.8700
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/HYP	21.5	1.20	Increasing[1]	.0005
Salt River near Roosevelt (09498500)	LIN/NR	----	.53	None[1]	.8030
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	.24	Increasing[1]	.0592
Agua Fria River near Rock Springs (09512800)			No data collected at this site.		
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	1.01	None[1]	.2644
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	-----	1.00	Increasing[1]	.0549
Gila River near Dome (09520500)			Insufficient data.		
Gila River near mouth, near Yuma 09520700)	LIN/NR	----	3.98	None[1]	.7303

[1]Trend-slope estimate not reported because of more than 50 percent less than values in the data set.

Table 28. Summary statistics for suspended copper used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Suspended copper, in micrograms per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	16	40.4	10.0	<1	410	101	25.2
San Francisco River near Clifton (09444600)	6	27.7	22.0	3.0	63.0	21.5	8.77
Gila River at Calva (09466500)	31	137	20.0	<5	1,500	317	56.9
Gila River at Winkelman (09470000)	8	20.2	18.0	10.0	31.0	7.34	2.60
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	8	6.75	5.5	<1	16.0	6.09	2.15
Pinal Creek at Inspiration Dam, near Globe (09498400)	8	155	76.0	40.0	490	171	60.5
Salt River near Roosevelt (09498500)	4	45.7	45.0	23.0	70.0	22.8	11.4
Salt River below Stewart Mountain Dam (09502000)	26	5.31	3.0	<1	19.0	5.26	1.03
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	17	6.58	4.0	<1	26.0	7.20	1.75
Gila River above diversions, at Gillespie Dam (09518000)	26	19.2	10.0	<1	170	33.8	6.63
Gila River near Dome (09520500)	No data collected at this site.						
Gila River near mouth, near Yuma (09520700)	27	23.6	7.0	<1	440	83.4	16.1

Table 29. Results of seasonal Kendall tau test on flow-adjusted suspended copper

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c) = ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q) = Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of suspended copper as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LIN	39.5	10.0	0.01	1.000
San Francisco River near Clifton (09444600)		Insufficient data.			
Gila River at Calva (09466500)	LOG/HYP	64.3	20.0	.06	.8882
Gila River at Winkelman (09470000)		Insufficient data.			
San Pedro River below Aravaipa Creek, near Mammoth (09473100)		Insufficient data.			
Pinal Creek at Inspiration Dam, near Globe (09498400)		Insufficient data.			
Salt River near Roosevelt (09498500)		Insufficient data.			
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	3.0	<.01	.7237
Agua Fria River near Rock Springs (09512800)		No data collected at this site.			
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	4.0	-.75	.4884
Gila River above diversions, at Gillespie Dam (09518000)	LOG/HYP	10.7	10.0	-.11	.4636
Gila River near Dome (09520500)		No data collected at this site.			
Gila River near mouth, near Yuma (09520700)	LIN/NR	----	7.0	-.88	.2587

Table 30. Summary statistics for total copper used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Total copper, in micrograms per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	19	37.2	7.76	3.0	420	94.9	21.8
San Francisco River near Clifton (09444600)	110	229	26.5	<1	10,000	1,060	101
Gila River at Calva (09466500)	124	152	43.0	<1	3,200	361	32.4
Gila River at Winkelman (09470000)	83	71.2	30.0	<1	1,500	202	22.2
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	22	159	14.5	<1	3,100	657	140
Pinal Creek at Inspiration Dam, near Globe (09498400)	98	269	95.0	<1	2,000	411	41.5
Salt River near Roosevelt (09498500)	147	32.3	12.0	<1	700	67.6	5.58
Salt River below Stewart Mountain Dam (09502000)	62	7.86	6.0	<1	22.0	4.78	.61
Agua Fria River near Rock Springs (09512800)	80	63.0	7.0	2.0	2,900	357	39.9
Agua Fria River below Waddell Dam (09513600)	38	10.3	9.0	4.0	33.0	5.90	96
Gila River above diversions, at Gillespie Dam (09518000)	128	25.8	15.0	<1	170	30.9	2.73
Gila River near Dome (09520500)	No data collected at this site.						
Gila River near mouth, near Yuma (09520700)	29	23.7	7.0	2.0	440	80.3	14.9

Table 31. Results of seasonal Kendall tau test on flow-adjusted total copper

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR = No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration total copper as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LIN	41.3	7.76	0.01	0.6674
San Francisco River near Clifton (09444600)	LOG/LOG	17.0	26.5	.05	.3266
Gila River at Calva (09466500)	LOG/HYP	43.4	43.0	-.04	.4196
Gila River at Winkelman (09470000)	LOG/LOG	14.6	30.0	.05	.7701
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/HYP	48.5	14.5	.63	.6056
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/HYP	35.3	95.0	-.04	.0597
Salt River near Roosevelt (09498500)	LIN/NR	----	700	-.15	.6184
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	6.0	.08	.5815
Agua Fria River near Rock Springs (09512800)	LOG/HYP	23.7	7.0	<.01	.9073
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	9.0	-.63	.0327
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	----	15.0	-.04	.1001
Gila River near Dome (09520500)	No data collected at this site.				
Gila River near mouth, near Yuma (09520700)	LIN/NR	----	7.0	-1.25	.0001

Table 32. Summary statistics for dissolved lead used in time-trend analysis

[<, less than. Dashes, no value computed]

Station name and number	Number of samples	Dissolved lead, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	41	1.39	1.00	<1.0	5.00	1.07	0.17
San Francisco River near Clifton (09444600)	61	1.52	1.00	<1.0	12.0	1.86	.24
Gila River at Calva (09466500)	95	3.41	1.00	<1.0	70.0	8.78	.91
Gila River at Winkelman (09470000)	37	1.69	1.00	<1.0	11.0	2.30	.38
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	33	1.46	1.00	<1.0	5.00	1.20	.21
Pinal Creek at Inspiration Dam, near Globe (09498400)	60	1.53	1.00	<1.0	7.00	1.59	.20
Salt River near Roosevelt (09498500)	84	1.76	1.00	<1.0	12.0	2.04	.22
Salt River below Stewart Mountain Dam (09502000)	64	2.92	1.00	<1.0	60.0	7.69	.96
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	38	1.62	1.00	<1.0	16.0	2.66	.43
Gila River above diversions, at Gillespie Dam (09518000)	98	1.27	.66	<1.0	12.0	1.73	.17
Gila River near Dome (09520500)	11	-----	-----	<1.0	7.00	-----	-----
Gila River near mouth, near Yuma (09520700)	25	6.30	2.0	<1.0	74.0	15.2	3.04

Table 33. Results of seasonal Kendall tau test on flow-adjusted dissolved lead

[Results follow the general linear model form f(c) = β_o + β_1•f(Q) + ε, where f(c) (LIN) or f(c) = ln(c) (LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q) = Q; logarithmic (LOG), f(c) = ln(Q); inverse (INV), f(Q) = 1/Q; hyperbolic (HYP), f(Q) = 1/(1 + β Q) NR = No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved lead as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/NR	----	1.00	None[1]	0.3580
San Francisco River near Clifton (09444600)	LIN/NR	----	1.00	Decreasing[1]	.0005
Gila River at Calva (09466500)	LOG/LOG	12.0	1.00	Decreasing[1]	.0095
Gila River at Winkelman (09470000)	LIN/NR	----	1.00	None[1]	1.000
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/NR	----	1.00	None[1]	.8918
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/NR	----	1.00	Decreasing[1]	.0003
Salt River near Roosevelt (09498500)	LIN/NR	----	1.00	Decreasing[1]	.0190
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	1.00	Decreasing[1]	.0320
Agua Fria River near Rock Springs (09512800)	No data collected at this site				
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	1.00	None[1]	.9087
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	----	.66	Decreasing[1]	.0171
Gila River near Dome (09520500)	Insufficient data.				
Gila River near mouth, near Yuma (09520700)	LIN/NR	----	2.00	None[1]	.1007

[1]Trend-slope estimate not reported because of more than 50 percent less than values in the data set.

Table 34. Summary statistics for total lead used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Total lead, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	23	20.1	5.0	<1.0	330	67.8	14.1
San Francisco River near Clifton (09444600)	75	11.8	5.5	<2.0	84.0	16.4	1.89
Gila River at Calva (09466500)	121	26.6	8.0	<1.0	400	54.5	4.95
Gila River at Winkelman (09470000)	49	48.5	8.0	<1.0	700	128	18.3
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	14	94.6	5.0	<1.0	790	234	62.5
Pinal Creek at Inspiration Dam, near Globe (09498400)	64	8.68	3.4	<1.0	60.0	12.9	1.61
Salt River near Roosevelt (09498500)	113	13.3	4.1	<1.0	200	26.7	2.51
Salt River below Stewart Mountain Dam (09502000)	62	6.04	2.7	<1.0	98.0	14.0	1.78
Agua Fria River near Rock Springs (09512800)	81	17.1	2.0	<1.0	930	104	11.6
Agua Fria River below Waddell Dam (09513600)	38	4.89	3.0	<1.0	77.0	12.3	2.00
Gila River above diversions, at Gillespie Dam (09518000)	100	14.9	4.2	<1.0	440	50.0	5.00
Gila River near Dome (09520500)	No data collected at this site.						
Gila River near mouth, near Yuma (09520700)	29	15.0	7.2	<1.0	200	36.4	6.76

Table 35. Results of seasonal Kendall tau test on flow-adjusted total lead

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c) = ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data is not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of total lead as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/LOG	13.9	5.0	0.19	0.0610
San Francisco River near Clifton (09444600)	LOG/LOG	27.0	5.5	.05	.7056
Gila River at Calva (09466500)	LOG/HYP	36.0	8.0	.05	.6662
Gila River at Winkelman (09470000)	LOG/LIN	23.6	8.0	.04	.7115
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LOG/LOG	62.6	5.0	-.41	.1017
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/LIN	44.8	3.4	-.06	.0395
Salt River near Roosevelt (09498500)	LIN/NR	----	4.1	-.29	.1921
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	2.7	None[1]	.3241
Agua Fria River near Rock Springs (09512800)	LOG/HYP	17.6	2.0	-.05	.4150
Agua Fria River below Waddell Dam (09513600)	LIN/NR	----	3.0	-.32	.5216
Gila River above diversions, at Gillespie Dam (09518000)	LOG/LIN	31.4	4.2	-.07	.1393
Gila River near Dome (09520500)	No data collected at this site.				
Gila River near mouth, near Yuma (09520700)	LOG/HYP	17.6	7.2	.41	.0178

[1]Trend-slope estimate not reported because of more than 50 percent less than values in the data set.

Table 36. Summary statistics for total manganese used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Total manganese, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	19	685	40	8.0	11,000	2,500	574
San Francisco River near Clifton (09444600)	69	321	110	10.0	3,900	751	90.4
Gila River at Calva (09466500)	116	953	300	8.0	11,000	1,920	178
Gila River at Winkelman (09470000)	36	706	245	20.0	11,000	1,830	305
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	8	1,730	120	40.0	13,000	4,550	1,610
Pinal Creek at Inspiration Dam, near Globe (09498400)	52	19,900	21,500	680	41,000	11,700	1,630
Salt River near Roosevelt (09498500)	101	324	220	<10	5,200	551	54.8
Salt River below Stewart Mountain Dam (09502000)	63	39.1	30.0	<10	170	31.4	3.95
Agua Fria River near Rock Springs (09512800)	81	729	30.0	10.0	35,000	4,120	458
Agua Fria River below Waddell Dam (09513600)	38	214	205	70.0	490	120	19.4
Gila River above diversions, at Gillespie Dam (09518000)	88	237	170	40.0	1,800	247	26.3
Gila River near Dome (09520500)	No data collected at this site.						
Gila River near mouth, near Yuma (09520700)	29	737	730	150	1,400	302	56.1

Table 37. Results of seasonal Kendall tau test on flow-adjusted total manganese

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of total manageae aa a function of diacharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micro-grama per liter	Concen-trations, in micro-grams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/LOG	20.4	40	0.04	0.4818
San Francisco River near Clifton (09444600)	LOG/LIN	21.0	110	-.15	.0971
Gila River at Calva (09466500)	LOG/HYP	30.1	300	-.10	.0050
Gila River at Winkelman (09470000)	LOG/HYP	11.6	245	.04	.6025
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	Insufficient data.				
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/INV	42.6	21,500	.70	<.0001
Salt River near Roosevelt (09498500)	LIN/NR	----	220	35.0	.0076
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	----	30.0	-2.50	.0029
Agua Fria River near Rock Springs (09512800)	LIN/HYP	17.0	30.0	.01	.0074
Agua Fria River below Waddell Dam (09513600)	LIN/HYP	10.9	205	-.03	.7527
Gila River above diversions, at Gillespie Dam (09518000)	LOG/LOG	15.8	170	-.22	.0068
Gila River near Dome (09520500)	No data collected at this site.				
Gila River near mouth, near Yuma (09520700)	LOG/LOG	74.5	730	-.44	.0031

Table 38. Summary statistics for dissolved zinc used in time-trend analysis

[<, less than]

Station name and number	Number of samples	Dissolved zinc, in micrograms per liter				Standard deviation	Standard error of mean
		Mean	Median	Minimum	Maximum		
Gila River near Redrock, N. Mex. (09431500)	44	11.8	8.0	<3.0	1,280	11.4	1.72
San Francisco River near Clifton (09444600)	65	32.7	10.0	<3.0	600	82.2	10.2
Gila River at Calva (09466500)	96	20.5	11.5	<3.0	210	26.0	2.65
Gila River at Winkelman (09470000)	36	12.0	10.0	<3.0	50.0	9.38	1.56
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	31	17.8	11.0	4.0	60.0	14.1	2.53
Pinal Creek at Inspiration Dam, near Globe (09498400)	84	29.2	20.0	10.0	120	16.6	1.81
Salt River near Roosevelt (09498500)	96	13.5	10.0	<3.0	100	15.1	1.54
Salt River below Stewart Mountain Dam (09502000)	67	13.4	8.0	<3.0	120	17.8	2.17
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	38	11.4	10.0	<3.0	40.0	7.20	1.17
Gila River above diversions, at Gillespie Dam (09518000)	77	17.5	20.0	<3.0	60.0	11.2	1.46
Gila River near Dome (09520500)	11	15.3	10.2	<10.0	50.0	12.8	3.86
Gila River near mouth, near Yuma (09520700)	29	28.5	10.0	<3.0	430	77.8	14.4

Table 39. Results of seasonal Kendall tau test on flow-adjusted dissolved zinc

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), f(Q)=1/(1= β Q); NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of dissolved zinc as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in micrograms per liter	Concentrations, in micrograms per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LIN/LOG	13.3	8.0	-0.03	0.4706
San Francisco River near Clifton (09444600)	LOG/LIN	15.3	10.0	-.53	.0014
Gila River at Calva (09466500)	LIN/NR	----	11.5	-.63	.3080
Gila River at Winkelman (09470000)	LIN/NR	----	10.0	1.0	1.0000
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	LIN/NR	----	11.0	-2.50	.0102
Pinal Creek at Inspiration Dam, near Globe (09498400)	LIN/NR	----	20.0	<.01	.3032
Salt River near Roosevelt (09498500)	LIN/NR	----	10.0	-1.67	.0001
Salt River below Stewart Mountain Dam (09502000)	LOG/HYP	10.7	8.0	.23	.1882
Agua Fria River near Rock Springs (09512800)		No data collected at this site.			
Agua Fria River below Waddell Dam (09513600)	LOG/INV	15.0	10.0	-.27	.4623
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	----	20.0	<.01	.5826
Gila River near Dome (09520500)	LOG/HYP	10.3	10.2	.83	.3261
Gila River near mouth, near Yuma (09520700)	LOG/HYP	15.3	10.0	.19	.6568

Table 40. Summary statistics for total organic carbon used in time-trend analysis

[Dashes, no value computed]

Station name and number	Number of samples	Total organic carbon, in milligrams per liter: Mean	Median	Minimum	Maximum	Standard deviation	Standard error of mean
Gila River near Redrock, N. Mex. (09431500)	27	6.64	3.80	1.90	54.0	10.6	2.03
San Francisco River near Clifton (09444600)	43	7.21	2.40	.50	87.0	16.8	2.57
Gila River at Calva (09466500)	59	19.9	8.00	3.60	300	43.7	5.69
Gila River at Winkelman (09470000)	31	18.4	8.70	1.70	140	29.3	5.26
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	7	17.0	6.10	1.70	74.0	25.9	9.78
Pinal Creek at Inspiration Dam, near Globe (09498400)	11	5.84	4.90	3.20	10.0	2.61	.79
Salt River near Roosevelt (09498500)	99	5.92	3.60	.90	50.0	7.23	.73
Salt River below Stewart Mountain Dam (09502000)	36	5.10	4.70	2.20	18.0	2.74	.46
Agua Fria River near Rock Springs (09512800)	No data collected at this site.						
Agua Fria River below Waddell Dam (09513600)	No data collected at this site.						
Gila River above diversions, at Gillespie Dam (09518000)	45	13.4	11.0	5.40	37.0	7.02	1.05
Gila River near Dome (09520500)	1	---	---	7.50	7.50	---	---
Gila River near mouth, near Yuma (09520700)	35	4.99	2.90	1.80	16.0	3.91	.66

Table 41. Results of seasonal Kendall tau test on flow-adjusted total organic carbon

[Results follow the general linear model form $f(c)=\beta_0+\beta_1 \cdot f(Q)+\varepsilon$, where f(c)(LIN) or f(c)=ln(c)(LOG) and f(Q) is one of the following functions of water discharge: linear (LIN), f(Q)=Q; logarithmic (LOG), f(c)=ln(Q); inverse (INV), f(Q)=1/Q; hyperbolic (HYP), $f(Q)=1/(1+\beta Q)$; NR=No relation between concentrations and discharge. The p value is the probability of rejecting the null hypothesis of no trend in the water-chemistry constituent. Dashes, data are not flow adjusted]

Station name and number	Ordinary least-squares regression analysis using concentration of total organic carbon as a function of discharge		Seasonal Kendall tau test on flow-adjusted concentration data		
	f(c)/f(Q)	r^2, in percent	Median, in milligrams per liter	Concentrations, in milligrams per liter per year	p value
Gila River near Redrock, N. Mex. (09431500)	LOG/INV	18.7	3.80	0.14	0.6967
San Francisco River near Clifton (09444600)	LOG/LOG	18.0	2.40	.01	.8984
Gila River at Calva (09466500)	LIN/HYP	16.3	8.00	.02	.2083
Gila River at Winkelman (09470000)	LOG/HYP	12.5	8.70	-.16	.2801
San Pedro River below Aravaipa Creek, near Mammoth (09473100)	Insufficient data.				
Pinal Creek at Inspiration Dam, near Globe (09498400)	Insufficient data.				
Salt River near Roosevelt (09498500)	LIN/NR	---	3.60	.04	.8301
Salt River below Stewart Mountain Dam (09502000)	LIN/NR	---	4.70	.26	.0790
Agua Fria River near Rock Springs (09512800)	No data collected at this site.				
Agua Fria River below Waddell Dam (09513600)	No data collected at this site.				
Gila River above diversions, at Gillespie Dam (09518000)	LIN/NR	---	11.0	.09	.9559
Gila River near Dome (09520500)	Insufficient data.				
Gila River near mouth, near Yuma (09520700)	LOG/LOG	51.1	2.90	<.01	1.000