COMPUTATION AND USE OF VOLUME-WEIGHTED-AVERAGE CONCENTRATIONS TO DETERMINE LONG-TERM VARIATIONS OF SELECTED WATER-QUALITY CONSTITUENTS IN LAKES AND RESERVOIRS

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CONVERSION FACTORS

The inch-pound units of measurements used in this report may be converted to metric units by using the folloiwng conversion factors:

Mulitply inch-pound unit	By	To obtain
foot	0.3048	meter
inch	2.540	millimeter
acre-foot	0.001233	cubic hectometer

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ABSTRACT

A computer program using the Statistical Analysis System has been developed to perform the arithmetic calculations and regression analyses to determine volume-weighted-average concentrations of selected water-quality constituents in lakes and reservoirs. The program has been used in Texas to show decreasing trends in dissolved-solids and total-phosphorus concentrations in Lake Arlington after the discharge of sewage effluent into the reservoir was stopped. The program also was used to show that the August 1978 and October 1981 floods on the Brazos River greatly decreased the volume-weighted-average concentrations of selected constituents in Hubbard Creek Reservoir and Possum Kingdom Lake.

INTRODUCTION

The Texas District of the U.S. Geological Survey, in cooperation with Federal, State, and local agencies operates one of the largest water-quality data-collection programs on lakes or reservoirs in the Nation. As part of the program, comprehensive water-quality surveys of approximately 20 reservoirs are conducted during the winter (January-March), spring (April-June), and summer (July-September).

Primary sampling sites on reservoirs are usually located near the dam, midreservoir, and near the headwaters. Samples for dissolved major inorganic constituents, total nutrients, and dissolved minor elements are usually collected near the water surface and near the reservoir bottom at these sites. Phytoplankton samples usually are collected at a depth corresponding to one-half the Secchi disc reading near the dam and near the headwaters. If thermal stratification exists, additional samples for total nutrients, dissolved iron, and dissolved manganese are collected above and below the metalimnion. *In situ* measurements of dissolved oxygen, temperature, pH, and specific conductance are made at 5- to 10-feet intervals at all primary sampling locations and at numerous secondary measuring sites on each reservoir.

After water-quality data for a reservoir have been collected for 5 to 7 years, the U.S. Geological Survey in Texas usually prepares an interpretive report to evaluate the seasonal variations and long-term trends in water quality. These reports are designed to define the extent of thermal stratification and areal, seasonal and temporal variations in dissolved oxygen, dissolved iron and manganese, total nitrogen and phosphorus, dissolved solids, dissolved chloride, dissolved sulfate, and hardness. During fiscal years 1978-82, seven interpretive reports were prepared using data from the reservoir data-collection program. Volume-weighted-average concentrations of selected constituents were computed for each reservoir and were included in the reports to graphically illustrate long-term variations in water quality.

Long-term variations of constituents in lakes and reservoirs usually are difficult to determine because of the large seasonal and areal variations of these constituents within the lake or reservoir. The computation of volume-weighted-average concentrations allows for each individual measurement of the desired constituent to be weighted on the basis of the volume of water each measurement represents. The volume-weighted-average concentration of the computed constituent then represents the concentration each constituent would be if the lake or reservoir were a thoroughly mixed homogeneous body of water.

COMPUTATION OF VOLUME-WEIGHTED-AVERAGE CONCENTRATIONS

The computation of volume-weighted-average concentrations can be a long and tedious process. The hydrologist must first determine the percentage each individual measurement represents in a cross section and then determine the percentage each cross section represents of the lake or reservoir. Once these determinations are made, numerous mathematical calculations and possible regression analysis are necessary to compute volume-weighted-average concentrations. The U.S. Geological Survey in Texas has developed a computer program using the Statistical Analysis System (SAS)[1/] to perform the necessary calculations and regression analyses to determine volume-weighted-average concentrations of select constituents.

The computer program retrieves data from the U.S. Geological Survey's WATSTORE water-quality file and puts the data into a SAS data set. The user is required to input one data set that requires the following: (1) Percentage of the lake or reservoir that each cross section represents, (2) the percentage of the cross section that each sampling location in the vertical represents, (3) a variable to identify the station as a primary or a secondary sampling location, and (4) a variable that allows the program to compute concentrations of constituents at secondary sampling locations by using regression equations developed at a nearby primary sampling location.

The program uses the SAS General Linear Models Procedure to develop regression equations between specific-conductance values and concentrations of selected major ions at all primary sampling locations. The program then computes constituent concentrations at 5- to 10-foot intervals for these locations. At secondary sampling locations, where only specific-conductance data are available, major ionic concentrations are computed at 5- to 10-foot intervals using regression equations from a nearby primary sampling site.

1/ The use of trade names is for identification only and does not constitute endorsement by the U.S. Geological Survey.

For total nutrients, dissolved iron, and dissolved manganese, volume-weighted-average concentrations need to be determined from analytical data because significant relations do not exist between these constituents and specific conductance. Additional samples collected above and below the metalimnion are vitally important if volume-weighted-average concentrations are to be computed for constituents that do not have a significant relation with specific conductance.

Users of the program need to check the results closely to insure that the data are correct. Sampling locations on lakes or reservoirs may vary depending upon hydrologic conditions, equipment failure, or data-collection changes from year to year. The computer program does make adjustments or notes missing data wherever possible. The program also adjusts or notes if a lake or reservoir survey was made for more than one day.

The program has been used in Texas for several interpretive reservoir studies. Data results from the program have shown a significant decrease in dissolved-solids and total phosphorus concentrations in Lake Arlington after the following discharge of sewage effluent into the reservoir was stopped. The program also was used to determine the effect of floods on water quality in the Brazos River basin. Some of the results of these studies are included here to show the application of the program.

USE OF VOLUME-WEIGHTED-AVERAGE CONCENTRATIONS

Lake Arlington, Texas

Data collected from Lake Arlington, which is located near the western edge of the city of Arlington and the southeastern edge of the city of Fort Worth, showed a decrease in volume-weighted-average concentrations of dissolved solids and total phosphorus. Lake Arlington received effluent discharge from several municipal wastewater-treatment plants until December 1976. From 1967 to 1976, these discharges were periodically diverted downstream from Lake Arlington (Andrews and Gibbons, 1983). A trend of decreasing volume-weighted-average concentrations for dissolved solids and total phosphorus is shown in figure 1. A trend analysis of this data using a modified form of the seasonal Kendall test (SEASKEN) as described by Crawford and others (1983) indicates negative trends at the 95-percent confidence interval for both constituents. The SEASRS procedure (Crawford and others, 1983) was used to test for a shift or differences in the distribution of volume-weighted-average concentrations of dissolved solids and total phosphorus before and after January 1, 1977. The test confirmed at the 95-percent confidence level that the data for the two time periods are from different sample populations.

Hubbard Creek Reservoir and Possum Kingdom Lake, Texas

Computed values of volume-weighted-average concentrations also were used to determine the effects of floods on selected reservoirs in the Brazos River basin. Rainfall in excess of 30 inches during August 1-4, 1978 at Albany, Texas, (Schroeder and others, 1979) and rainfall in excess of 20 inches during October 11-13, 1981, at Breckenridge, Texas, produced severe flooding in the

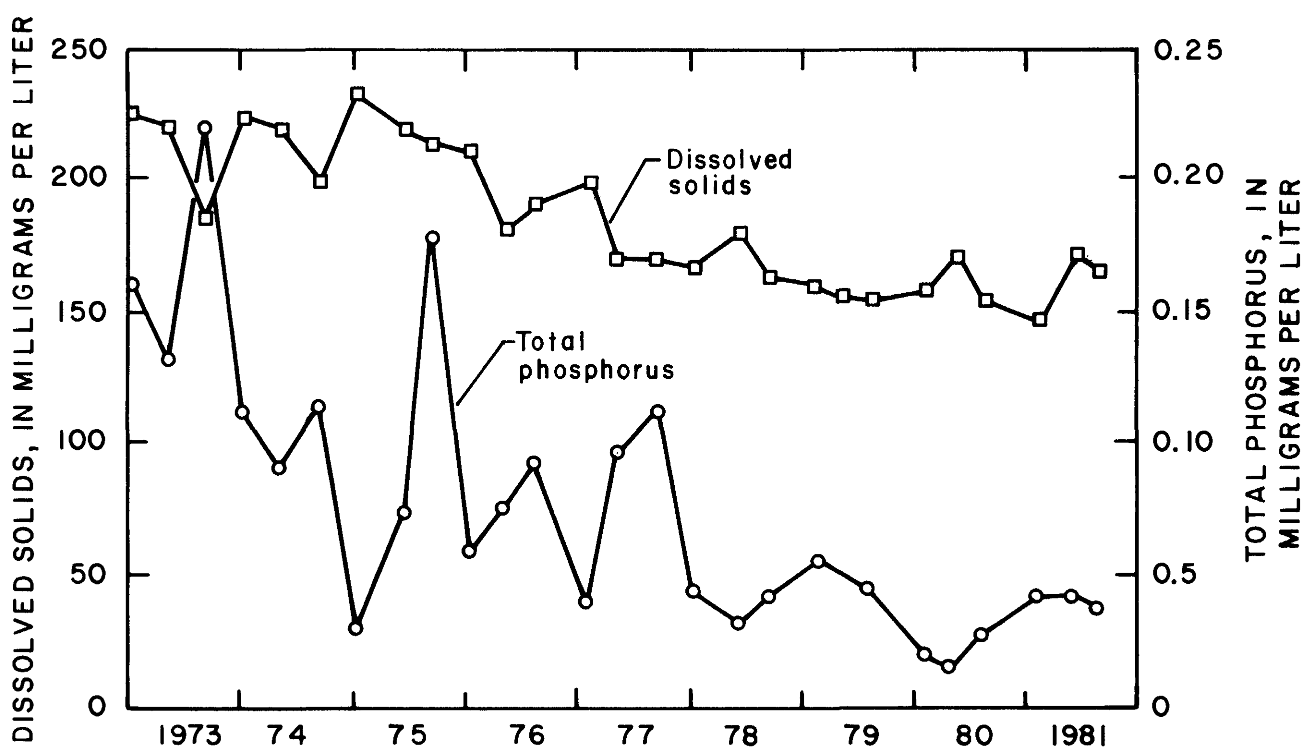

Figure 1.-Variations in volume-weighted-average concentrations of dissolved solids and total phosporus in Lake Arlington, Texas, 1973-81

upper Brazos River basin. These flood waters had a pronounced effect on the quantity and quality of water in both Hubbard Creek Reservoir and Possum Kingdom Lake. For example, the August 1978 flood caused the contents in Hubbard Creek Reservoir to increase from 185,800 acre-feet on August 2 to 401,500 acre-feet on August 5. The October 1981 flood caused the contents of Hubbard Creek Reservoir to increase from 233,000 acre-feet on October 12 to 441,000 acre-feet on October 14.

The change in storage in Possum Kingdom Lake during the August 1978 flood was not as great as that in Hubbard Creek Reservoir. The contents of Hubard Creek Reservoir increased from 465,800 acre-feet on August 2 to 560,400 acre-feet on August 11, 1978. The October 1981 flood caused the storage contents in Possum Kingdom Lake to increase from 505,000 on October 11 to 653,000 acre-feet on October 13.

These large volumes of relatively dilute flood waters had a large effect on the volume-weighted-average concentrations of selected dissolved constituents in both Hubbard Creek Reservoir and Possum Kingdom Lake. Volume-weighted-average concentrations of dissolved constituents for each of the reservoir surveys during the 1978-81 water years were computed to show the effects of the floods of August 1978 and October 1981 (figures 2 and 3). The data clearly illustrate that the floods greatly decreased the volume-weighted-average concentrations of selected constituents in both reservoirs. During the June 9, 1978, water-quality survey, the volume-weighted-average concentration of dissolved-solids in Hubbard Creek Reservoir was 795 mg/L (milligrams per liter). After the flood of August 1978, the volume-weighted-average concentrations of dissolved solids decreased to 436 mg/L. A gradual increase in dissolved solids occurred in the reservoir from August 1978 to August 1981. In August 1981, the volume-weighted-average dissolved-solids concentration was 570 mg/L. After the October 1981 flood, the volume-weighted-average dissolved-solids concentrations decreased to 281 mg/L. As a result of the 1978 and 1981 floods, the volume-weighted-average dissolved-solids concentrations in Hubbard Creek Reservoir had a net decrease of 514 mg/L from June 1978 to October 1981. Similar decreases also were noted in the volume-weighted-average concentrations of dissolved chloride, dissolved sulfate, and hardness.

The data in figure 3 show that the floods of August 1978 and October 1981 also had a pronounced effect on selected dissolved constituents in Possum Kingdom Lake. During the June 1978 water-quality survey, the volume-weighted-average concentration of dissolved solids was 2,380 mg/L. After the August 1981 flood, the volume-weighted-average concentration of dissolved solids was 792 mg/L. A progressive increase in dissolved solids occurred between August 1978 and August 1981 because of the more mineralized water entering the reservoir from the Brazos River. In August 1981, the volume-weighted-average concentrations of dissolved solids was 1,560 mg/L. After the October flood, the volume-weighted-average dissolved solids concentration was 665 mg/L or a net decrease of more than 1,700 mg/L since June 1978. Similar patterns of decreased volume-weighted-average concentrations also occurred for dissolved chloride, sulfate, and hardness.

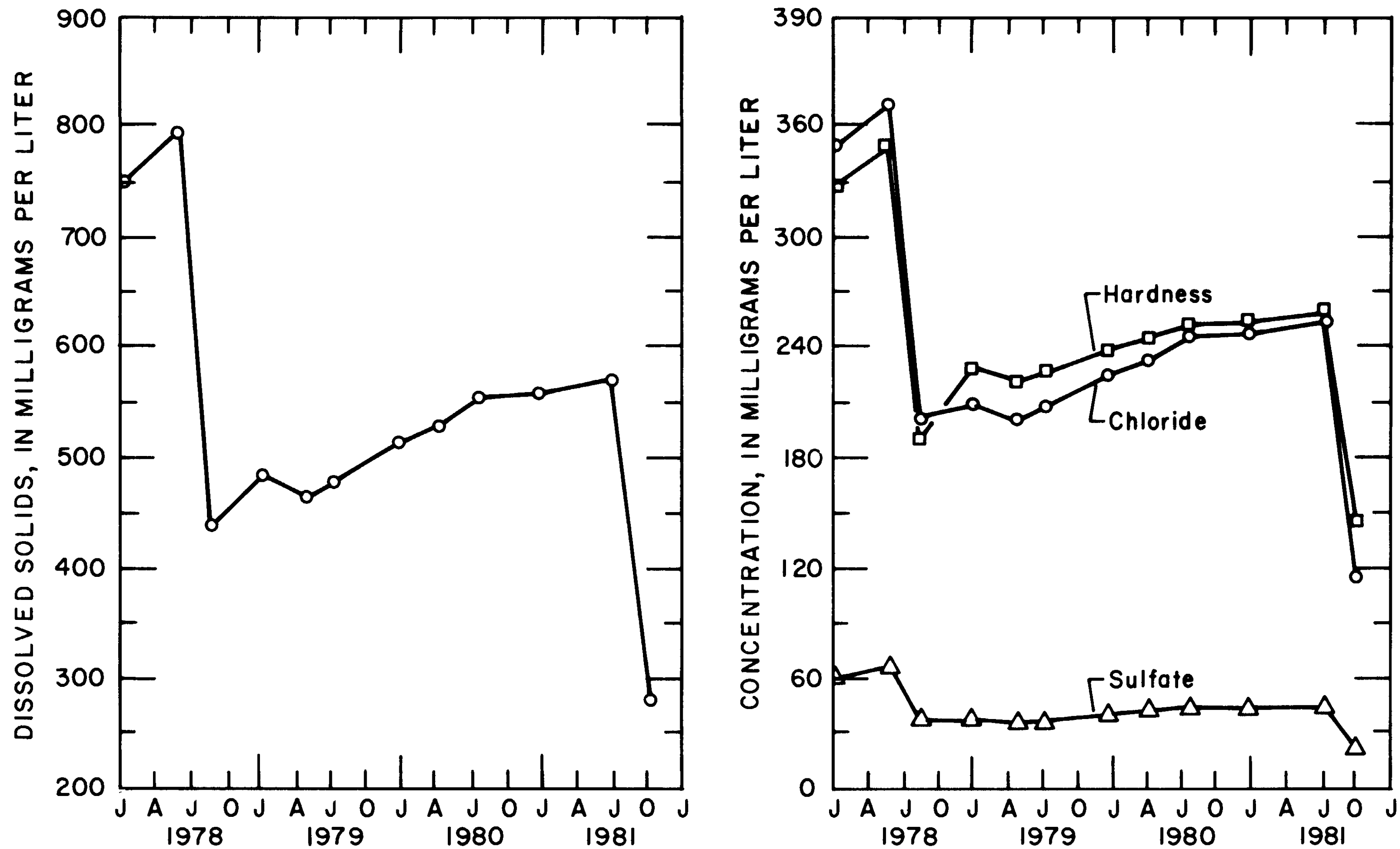

Figure 2.-Variations in volume-weighted-average concentrations of dissolved solids, dissolved chloride, dissolved sulfate, and hardness in Hubbard Creek Reservoir, Texas, 1978-81

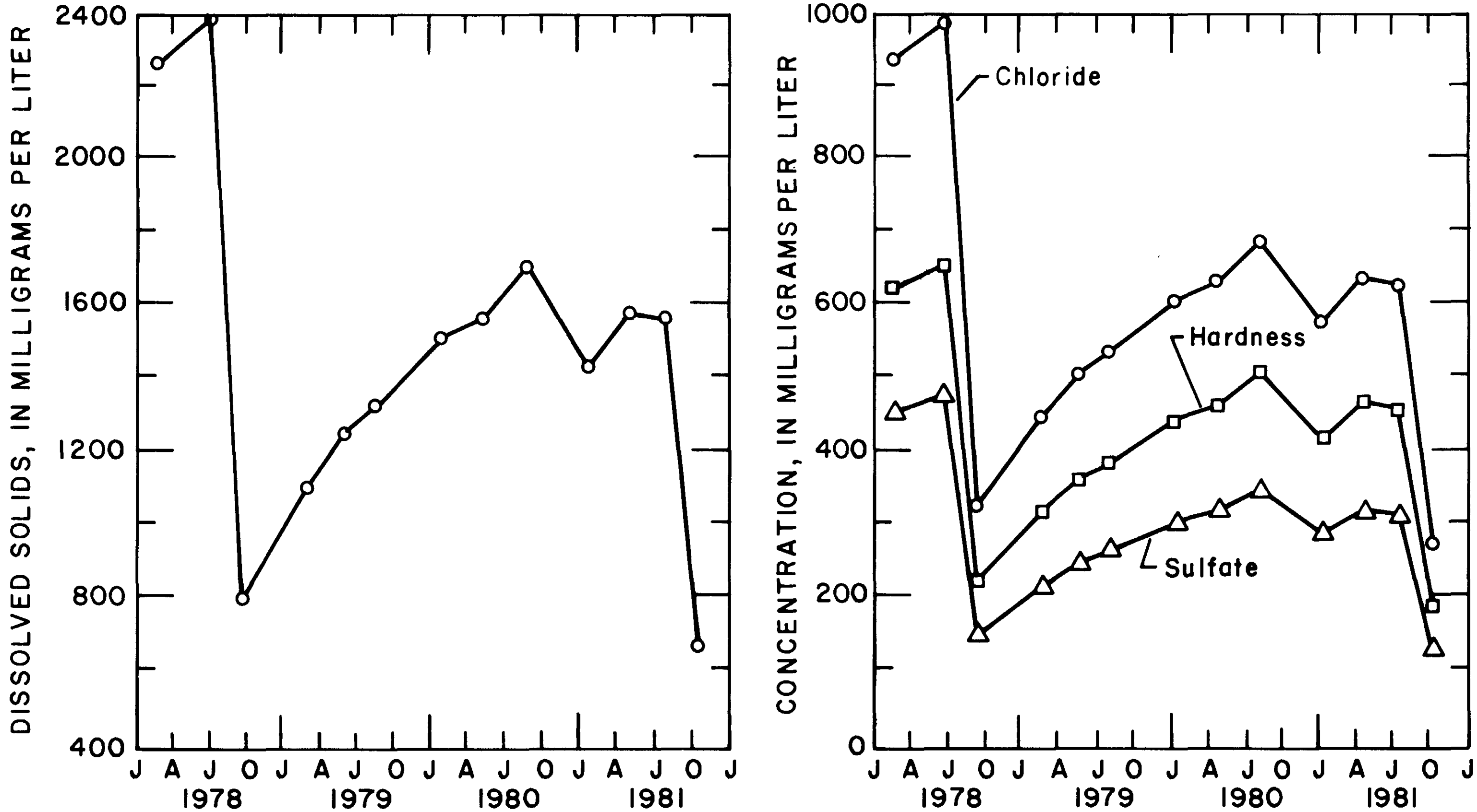

Figure 3.-Variations in volume-weighted-average concentrations of dissolved solids, dissolved chloride, dissolved sulfate, and hardness in Possum Kingdom Lake, Texas, 1978-81

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