HARMONIC ANALYSES OF STREAM TEMPERATURES

IN THE UPPER COLORADO RIVER BASIN

By Timothy Doak Steele

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4290

Lakewood, Colorado
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

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

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey, MS 306
Box 25425, Federal Center
Denver, CO 80225
Telephone: (303) 236-7476

CONTENTS

Illustrations

CONTENTS

Tables

CONVERSION FACTORS AND RELATED INFORMATION

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	*By*	*To obtain*
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

HARMONIC ANALYSIS OF STREAM TEMPERATURES IN THE UPPER COLORADO RIVER BASIN

By Timothy Doak Steele[1]

ABSTRACT

Harmonic analyses were made for available daily water-temperature records for 36 measurement sites on major streams in the Upper Colorado River Basin and for 14 measurement sites on streams in the Piceance basin. Generally (88 percent of the station years analyzed), more than 80 percent of the annual variability of temperatures of streams in the Upper Colorado River Basin was explained by the simple-harmonic function. Significant trends were determined for 6 of the 26 site records having long-term data (8 years or more). In most cases, these trends resulted from construction and operation of upstream surface-water impoundments occurring during the period of record. Regional analysis of water-temperature characteristics at the 14 streamflow sites in the Piceance basin, selected as a specific study area, indicated similarities in water-temperature characteristics for a small range of measurement-site elevations. Evaluation of information content of the daily records indicate that less-than-daily measurement intervals could result in substantial savings in measurement and data-processing costs.

INTRODUCTION

Stream temperature is one of the principal water-quality constituents of concern in water-resources planning and management, because of its dominant effect on aquatic life in streams. Moreover, water temperature influences waste-assimilation rates and is an important variable governing stream management for recreation or for municipal and industrial supplies.

As part of a regional evaluation of water-quality impacts of synfuels development in the Upper Colorado River Basin (Colorado Department of Natural Resources, 1979), available historical water-temperature records were analyzed using a simple-harmonic function to provide a quantitative description of the annual seasonal variability of stream temperatures. Recently renewed interest in constructing commercial-scale oil-shale conversion facilities in the

[1]Water Resources Manager, Engineering and Environmental Science Division, In-Situ, Inc., Lakewood, Colorado.

Piceance basin resulted in a growing need to describe ambient conditions in that specific study area (including water-temperature characteristics), prior to extensive development in that area.

The purpose of this report is to summarize the information provided by many of the available daily water-temperature records in the Upper Colorado River Basin and the Piceance basin and to describe the general water-temperature conditions by major subbasin or specific study area. In this manner, a more objective rationale may evolve for justifying the existing ongoing regional-measurement program or for suggesting modifications to achieve a more efficient operating data-collection network.

Acknowledgments

Initial stages of this study were conducted under the auspices of the U.S. Geological Survey, Water Resources Division, Colorado District Office, Lakewood, Colo. Updated computer analyses were performed by Olivetree Consultants, Inc. Review comments by H. W. Lowham, U.S. Geological Survey, Cheyenne, Wyo., and T. R. Dyar, U.S. Geological Survey, Doraville, Ga., were most appreciated. R. B. Murphy and C. S. Curtis assisted in the final harmonic coefficient tabulations and time-trend analyses. Final computer analyses and preparation of this report were made possible by a research grant from the Professional Development Committee of Woodward-Clyde Consultants, Denver, Colo., and by In-Situ, Inc.

METHODS OF ANALYSIS

A computer program was used to perform harmonic analyses of daily (continuous) temperature records. A complete description of the program operations and of available options is given in a separate program-documentation report (Steele, 1974). This harmonic-function model may be used to interpolate between discrete stream-temperature measurements or record gaps and to assess the effect of various measurement-frequency schemes (Gilroy and Steele, 1972). Resultant harmonic coefficients may be used for summarizing areal variations in annual seasonal stream-temperature characteristics and for detecting and evaluating changes in the coefficients over a period of several years.

In this computer program, a simple sine-function algorithm of the following form is used to define the annual seasonal cycle of water temperature at a streamflow site where stream temperature is measured (Ward, 1963; Collings, 1969):

$$T(t) = A \times [\sin(bt + C)] + M, \qquad (1)$$

where: $T(t)$ = stream temperature, in degrees Celsius, on day t of the annual time increment;
A = amplitude of the harmonic, in degrees Celsius;
b = 0.0172 radians per day = ($2\pi \div 365$ or 366 days);
C = phase angle of the harmonic, in radians; and
M = mean of the harmonic, in degrees Celsius.

With the above notation, stream temperature, T, at a specified site is denoted to vary as a function of time, t. Unless annual stream-temperature characteristics are affected appreciably by economic activity in the catchment upstream from a sampling site, the harmonic coefficients (A, C, and M) are considered to be constant in time (unless a trend is observed), and to vary principally as a function of location.

The rationale for applying a first-order (simple) harmonic function is discussed by Steele (1978), in addition to demonstrating several capabilities of the computer program. Of the harmonic coefficients (A, C, and M), A and M are of principal concern. Areal variations for C (which indicates the phasing of the seasonal cycle for a specified annual increment) generally are small compared with those for A and M, because of its primary dependence upon hemispheric-climatic patterns. These latter coefficients are affected appreciably by such environmental factors as station latitude, altitude, vegetative cover, exposure, and dominant origin of the water (that is, the proportion of ground water contributing to streamflow).

The computer program makes appropriate adjustments for missing values or gaps in a record. However, no attempt is made in this model to account for diel temperature fluctuations in the input-data records; rather, these fluctuations are aggregated with other unaccounted-for noise in the data in the standard error of estimate. Choice of the annual time-increment will affect harmonic coefficient C of equation 1; the water year (October 1 of year n-1 through September 30 of year n) was used throughout this study. The model ignores data values at or below freezing (0°C) temperature (Steele, 1974).

Use of the harmonic-analysis technique for describing water-temperature characteristics has been demonstrated in several studies (Shampine, 1977; Clement, 1978; Lowham, 1978; Wentz and Steele, 1980). Moreover, this procedure has been applied to station records in the U.S. Geological Survey's National Stream Quality Accounting Network (Hawkinson and others, 1977; Briggs and Ficke, 1978; Steele, 1983). For station records of sufficient duration (assumed in this study to be 8 years or more), statistical tests of time trends may be made, using a procedure documented by Conover (1971) and applied by Steele and others (1974).

For main-stem rivers, upstream-downstream profiles of water-temperature harmonic coefficients serve to characterize conditions along the stream reach. Sample case studies are described by Lowham (1978) for the Green River and by Steele and others (1979) for the Yampa River and the Little Snake River.

For purposes of the Upper Colorado River Basin analysis, a total of 751 years of daily water-temperature records at 50 sites were retrieved from the U.S. Geological Survey's WATSTORE data files (Hutchinson, 1975). These records are inventoried in table 1. Station descriptions are given in table 10 in the Supplemental Data section at the end of this report. For the 36 sites in the Upper Colorado River Basin (fig. 1) outside of the Piceance basin, the periods of available record ranged from 2 to 35 years and averaged nearly 19 years for 36 sites. Several records are discontinuous in time, with one or more years of missing record (table 1). Moreover, most daily records fitted to a harmonic-function by annual increments have a number of missing values for a given year. Hence, the annual season-cycle characterization

Table 1.--*Inventory of available daily-water temperature records*

[X = nearly complete to complete year of daily values; I = intermittent measurements see supplemental information and text for station descriptions]

A. Upper Colorado River Basin

USGS Station No.[1)]	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	Number of years
09304200																													X	X	X				X	X	X	6
09304600																																			X	X	X	3
09304800																																			X	X	X	3
09306395																																	X	X	X	X	X	5
09306500							X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X		X	26
09306900																																			X	X	X	3
09071100					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	32
09072500											X	X	X	X																								4
09085000																		X	X	X	X	X	X															6
09093700																														X	X	X	X	X	X	X	X	8
09095500					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33
09152500					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	31
09165300																		X			X	X	X	X	X					X	X	X	X	X	X	X	X	14
09180000						X	X	X	X	X	X	X	X	X	X						X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	26
09180500						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	32
09355500											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													15
09357000															X	X	X	X	X																			5
09364500															X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23
09365000																				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	18
09368000															X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23
09379500	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			I		35
09188500																			X	X																		2
09209400																				X	X	X	X	X	X	X	X	X	X	X	X	X						13
09211200																								X	X	X	X	X	X	X	X	X						9
09217000							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	31
09234500													X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	24
09261000						X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30
09302000						X	X						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			I		23
09307000							X	X		X	X		X	X	X	X	X				X	X																11
09314500							X	X	X		X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X		X				23
09315000					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33
09328500							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					27
09251000							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		I	X	X	X	X	X	X	30
09259950							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													19
09260000																															I	X	X	X	X	X	X	7
09260025																																		X	X	X		3
09380000						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	32

Table 1.--*Inventory of available daily water-temperature records*--Continued

B. Piceance basin USGS Station No.[2]	WATER YEAR 75	76	77	78	79	80	81	Number of years
90902850			X	X	X	X	X	5
09093000	X	X	X	X	X	X		6
09093500	X	X	X	X	X	X		6
09095000	X	X	X	X	X	X		6
09306007	X	X	X	X	X	X	X	7
09306022	X	X	X	X	X	X	X	7
09306025	X	X						2
09306058	X	X	X	X	X	X	X	7
09306061	X	X	X	X	X	X	X	7
09306175	X	X	X	X	X	X	X	7
09306222		X	X	X	X	X	X	6
09306235			X	X	X	X	X	5
09306242	X		X	X	X	X	X	6
09306255	X	X	X	X	X	X	X	7

1See supplemental information and text for station descriptions; sites located in figure 1.

[2]See supplemental information and text for station descriptions; sites located in figure 8.

of water temperature by the harmonic function is a means of standardizing the information contained in the data records of different measurement frequencies, or data records with missing values and gaps (Gilroy and Steele, 1972; Clement, 1978).

In the Piceance basin specific study area, 83 years of daily water-temperature data were available at 14 sites (table 1). Data collection for daily stream temperatures in the Piceance basin generally began in mid-1974, at the earliest. Hence, no more than 7 years of record was available at any given site, and the average period of record was about 6 years for the 14 sites.

Graphic and tabular results of the harmonic analysis are given by subbasin or specific study area (in the case of the Piceance basin). Selected harmonic-function curves are presented, along with stream-reach profiles for main-stem rivers for a particular year of record. Where applicable, causes for significant time trends in annual water-temperature characteristics are discussed. Finally, several observations of the continuing need for daily water-temperature records are summarized, with recommendations for achieving a more user-responsive and cost-effective operating water-temperature network.

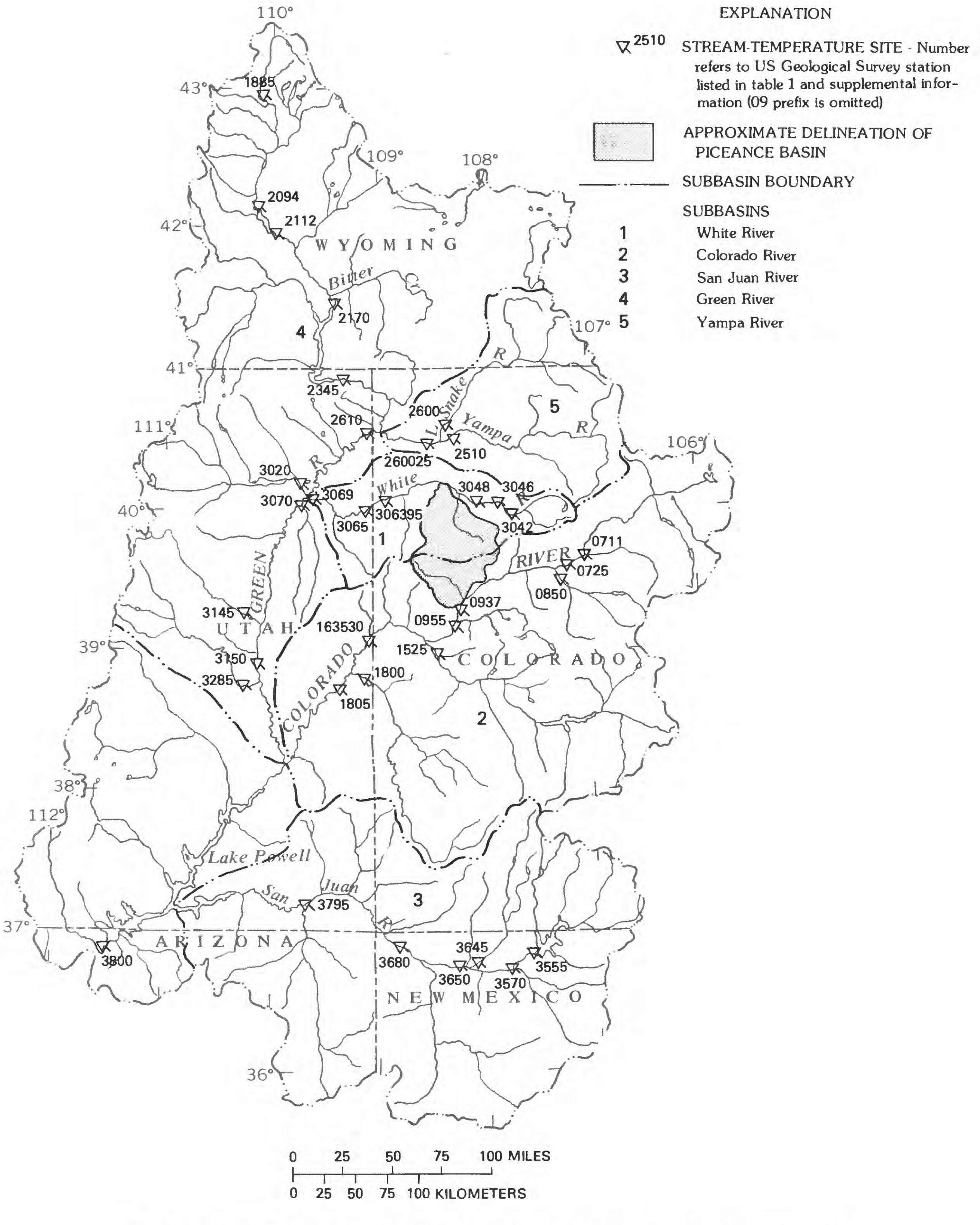


Figure 1.--Location of daily water-temperature measurement sites in the Upper Colorado River Basin.

STREAM-TEMPERATURE ANALYSIS BY SUBBASIN

Results of the harmonic analyses of water-temperature records will be discussed by major subbasin (fig. 1). The sequence order corresponds with the critical-area ordering described by the Colorado Department of Natural Resources (1979). For demonstrating the seasonal cyclical pattern of water temperatures at several sites along a stream reach, harmonic functions for a typical annual increment are displayed graphically. Normally, a year has been selected in which daily records are available for the greatest number of main-stem sampling sites, or sites in a given subbasin or region. For purposes of assessing time trends in the annual time series for harmonic coefficients, a ranking procedure initially proposed and applied by Steele and others (1974) was used. The Kendell's tau ranking test (Conover, 1971) is included in this procedure. Most of the discussion of time trends is deferred to the section on impacts of reservoirs on water temperature.

White River Subbasin

Daily water-temperature data were analyzed for 46 station-years of record at six sites, all located on the main-stem White River (see table 1 and table 10 in the supplemental information section at the end of the report). Harmonic-function coefficients are summarized in table 2. The longest period of record in this subbasin consists of 26 years of record at station 09306500 White River near Watson, Utah. As has been noted in previous studies in nearby regions (Lowham, 1978; Steele and others, 1979), the harmonic mean temperatures increase in a downstream direction from 7.1°C for station 09304200 White River above Coal Creek near Meeker, Colo., to 11.1°C for station 09306900 White River at mouth near Ouray, Utah (fig. 2), using data for the 1979 water year (table 2). Also, for the White River, the harmonic amplitude nearly doubles over the same reach of stream. Significant time trends were detected in the annual time series of the mean-plus-amplitude coefficients for station 09306500 White River near Watson, Utah.

Colorado River Subbasin

A total of 186 years of daily water-temperature records is available at nine sites in the Colorado River subbasin. Six of these sites are located on the main-stem Colorado River (see table 10 in the supplemental information section at the end of the report). The other three are major tributaries in the subbasin. Harmonic-function coefficients for each station-year of record have been tabulated (table 3). Using coefficients for the 1976 water year, mean temperatures in the Colorado River increase from 9.1°C at station 09071100 Colorado River near Glenwood Springs, Colo., to over 11.9°C at station 09163530 Colorado River below Colorado-Utah State line, and 11.6°C station 09180500 Colorado River near Cisco, Utah. However, the 1976 mean temperature is slightly greater than expected at DeBeque (10.2°C for 1976 at station 09093700 Colorado River near De Beque, Colo.) for an increasing stream-reach trend in a downstream direction. For the periods of record, harmonic amplitudes range from 7.9 to 11.5°C at station 09163530 Colorado River below Colorado-Utah State line. Stream-reach patterns during the

Table 2.--*Harmonic-function coefficients, White River subbasin*

[NO = number of daily values; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function]

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9304200.	1973	187	5.83	2.40	11.11	1.77	78
9304200.	1974	255	7.18	2.81	10.08	1.99	86
9304200.	1975	351	7.36	2.68	8.28	1.90	88
9304200.	1979	173	6.87	2.81	7.07	1.30	99
9304200.	1980	229	7.86	2.77	6.81	1.64	99
9304200.	1981	350	7.85	2.84	7.59	1.28	88
9304600.	1979	299	7.63	2.79	7.44	1.77	95
9304600.	1980	274	9.21	2.95	8.36	1.62	99
9304600.	1981	343	7.62	2.83	8.45	1.71	85
9304800.	1979	343	7.99	2.77	8.15	1.93	86
9304800.	1980	310	8.65	2.76	8.26	1.97	88
9304800.	1981	356	9.05	2.87	8.64	1.69	91
9306395.	1977	191	13.22	2.93	10.13	1.70	99
9306395.	1978	265	11.05	2.67	10.34	2.67	99
9306395.	1979	272	11.99	2.72	9.68	2.23	99
9306395.	1980	275	12.10	2.80	9.98	2.16	99
9306395.	1981	365	11.51	2.90	11.24	1.93	94
9306500.	1951	253	10.92	2.70	10.79	2.27	92
9306500.	1952	311	13.08	2.63	9.53	2.94	98
9306500.	1953	306	12.09	2.69	10.02	2.38	99
9306500.	1954	289	12.13	2.77	11.01	2.64	89
9306500.	1956	318	11.51	2.67	11.26	2.58	90
9306500.	1957	362	9.72	2.68	9.00	2.19	89
9306500.	1958	299	10.46	2.66	9.23	2.64	86
9306500.	1959	300	10.46	2.87	10.93	2.39	90
9306500.	1960	316	10.36	2.79	9.58	2.16	91
9306500.	1961	247	12.21	2.87	9.96	2.26	90
9306500.	1962	231	10.83	2.81	9.03	2.33	87
9306500.	1963	259	12.24	2.81	10.01	2.02	92
9306500.	1964	215	12.76	2.65	8.93	2.25	88
9306500.	1965	166	11.24	2.68	8.09	2.39	82
9306500.	1966	225	11.13	2.82	9.94	1.88	93
9306500.	1967	248	10.76	2.72	8.70	2.31	87
9306500.	1968	237	10.53	2.79	8.11	2.07	86
9306500.	1969	267	10.98	2.78	9.10	2.14	89
9306500.	1970	285	7.02	2.75	6.76	2.23	78
9306500.	1971	319	9.90	2.70	8.36	2.23	90
9306500.	1973	197	10.30	2.68	7.58	2.02	83
9306500.	1974	148	11.39	2.77	7.64	2.02	90
9306500.	1975	102	10.37	2.67	7.77	2.56	81

Table 2.--*Harmonic-function coefficient, White River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9306500.	1976	135	11.88	2.82	9.38	2.15	93
9306500.	1979	92	10.19	2.66	10.14	2.52	76
9306500.	1981	90	7.49	2.26	11.58	2.07	75
9306900.	1979	105	12.29	2.87	11.10	2.23	72
9306900.	1980	244	13.01	2.89	10.69	1.86	84
9306900.	1981	331	12.02	2.91	11.57	1.82	87

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description

1976 water year are depicted in figure 3. A general increasing stream-reach trend is observed, on the average, for the six main-stem sites. Mean temperatures at station 09085000 Roaring Fork River near Glenwood Springs, Colo., appears to be slightly greater than at station 09072500 Colorado River at Glenwood Springs, Colo., where the Roaring Fork River flows into the Colorado River. For the six long-term records, significant time trends in the annual series of harmonic coefficients were detected only for the harmonic mean temperature for the Colorado River at station 09095500 Colorado River near Cameo, Colo., using the Kendall's tau test (Conover, 1971).

San Juan River Subbasin

A total of 119 station years of daily water-temperature data was available for five main-stem sites and one major tributary (Animas River) in the San Juan River subbasin. Harmonic-function coefficients are given in table 4. Beginning in 1963, the San Juan River has been regulated by the Navajo Reservoir upstream from Archuleta, N. Mex. at station 09355500 (San Juan River near Archuleta, N. Mex.). Because initial regulation by this reservoir occurred about midway in the historical record at this nearby site, the impacts of streamflow regulation on downstream seasonal-temperature patterns could be readily assessed. In a comparison of harmonic coefficients for the 1963 and 1964 water years at the five main-stem sites, mean-temperature patterns in the stream reach of the San Juan River followed patterns observed for the Colorado River; however, overall temperatures were about 3.0°C greater for the San Juan River relative to the Colorado River. Both mean and amplitude coefficients depicting water-temperature patterns of the San Juan River increased in a downstream direction from station 09355500 San Juan River near Archuleta, N. Mex., to station 09368000 San Juan River at Shiprock, N. Mex. (fig. 4). However, anomalously high coefficients were observed for station 09357000 San Juan River at Bloomfield, N. Mex., for the 1963 water-year record. However, mean water temperatures at station 09364500

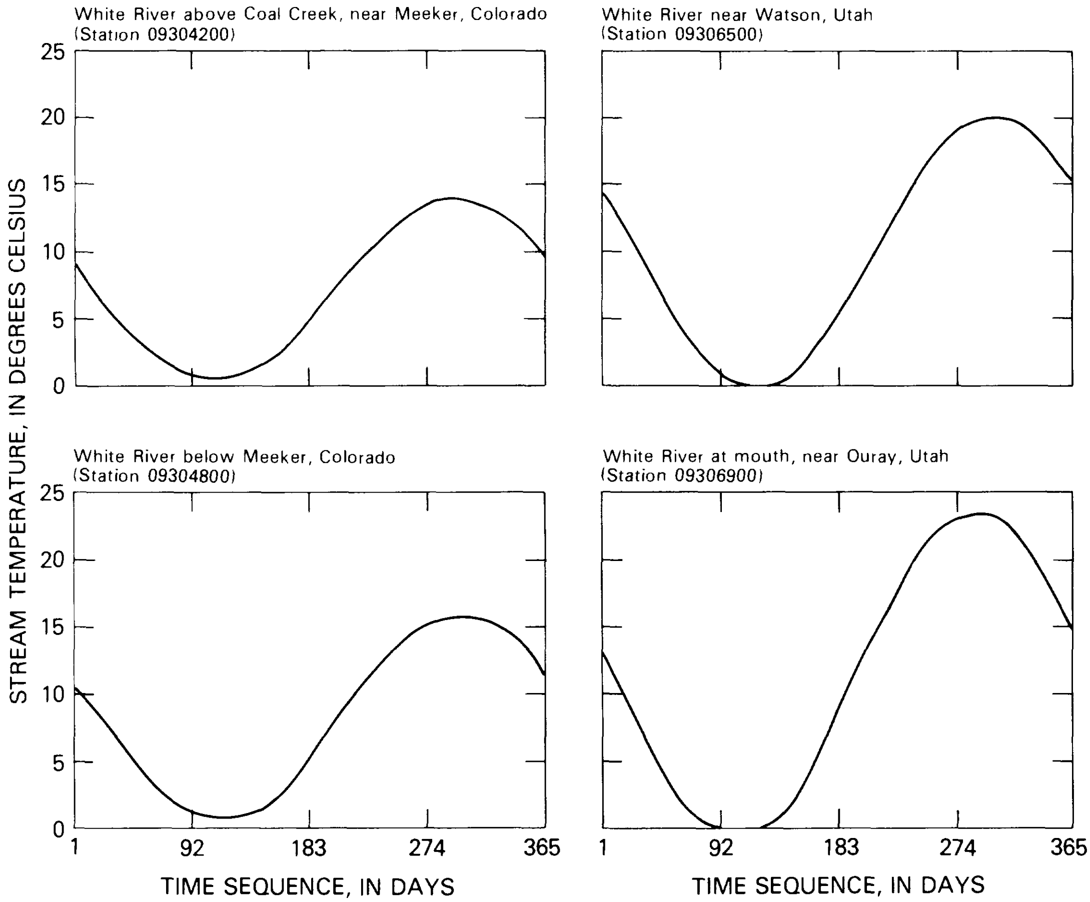


Figure 2.--Stream-reach seasonal water-temperature patterns, White River, 1979 water year.

Table 3.--*Harmonic-function coefficients, Colorado River subbasin*

[NO = number of daily values; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function]

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9071100.	1949	153	7.85	2.42	9.22	1.56	75
9071100.	1950	364	7.74	2.66	8.72	1.53	92
9071100.	1951	355	7.97	2.67	8.50	1.61	92
9071100.	1952	307	8.64	2.66	7.90	1.89	90
9071100.	1953	272	8.61	2.72	7.92	1.69	90
9071100.	1954	303	9.89	2.83	9.02	1.74	92
9071100.	1955	289	9.83	2.70	8.25	1.64	93
9071100.	1956	305	9.09	2.77	8.49	1.54	94
9071100.	1957	273	7.48	2.76	7.34	2.12	81
9071100.	1958	276	8.62	2.70	7.72	1.85	88
9071100.	1959	286	8.97	2.79	8.17	1.77	90
9071100.	1960	269	9.41	2.79	7.64	1.97	87
9071100.	1961	270	9.53	2.83	8.31	2.00	88
9071100.	1962	264	8.39	2.71	7.16	1.85	86
9071100.	1963	294	9.60	2.72	8.68	1.35	95
9071100.	1964	216	9.75	2.63	7.44	1.71	87
9071100.	1965	275	7.60	2.74	7.05	1.67	89
9071100.	1966	275	9.28	2.76	8.55	1.81	91
9071100.	1967	313	8.39	2.75	8.08	1.75	91
9071100.	1968	299	8.55	2.80	7.40	1.69	91
9071100.	1969	291	9.05	2.79	8.32	2.11	88
9071100.	1970	317	8.65	2.76	7.55	2.02	89
9071100.	1972	353	8.64	2.82	9.68	1.86	91
9071100.	1973	356	8.35	2.74	9.18	1.64	92
9071100.	1974	356	8.66	2.73	9.09	1.54	94
9071100.	1975	365	8.27	2.74	8.77	1.61	92
9071100.	1976	339	9.19	2.77	9.08	1.73	93
9071100.	1977	357	9.91	2.82	9.50	1.49	95
9071100.	1978	365	7.95	2.78	9.58	1.93	88
9071100.	1979	365	8.05	2.75	8.95	1.91	89
9071100.	1980	218	8.46	2.36	9.69	1.84	84
9071100.	1981	364	10.52	2.88	10.98	1.82	93
9072500.	1955	290	9.79	2.70	8.30	1.65	93
9072500.	1956	306	8.96	2.78	8.43	1.53	94
9072500.	1957	273	7.61	2.75	7.24	1.94	84
9072500.	1958	276	8.74	2.70	7.66	1.73	90
9085000.	1962	145	7.43	2.27	9.41	1.45	77
9085000.	1963	357	8.36	2.76	10.41	1.97	89
9085000.	1964	361	8.32	2.65	9.75	2.00	89

Table 3.--*Harmonic-function coefficients, Colorado River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9085000.	1965	363	6.56	2.73	9.50	2.24	81
9085000.	1966	362	8.62	2.74	10.55	1.84	91
9085000.	1967	354	7.58	2.75	10.11	2.27	84
9093700.	1974	299	9.39	2.73	10.08	1.90	90
9093700.	1975	264	8.98	2.68	9.48	1.98	87
9093700.	1976	259	10.55	2.78	10.23	2.36	87
9093700.	1977	321	11.70	2.89	11.64	1.69	96
9093700.	1978	224	9.78	2.88	11.67	1.91	92
9093700.	1979	90	8.87	2.48	8.16	1.72	89
9093700.	1980	158	8.42	2.73	10.31	1.91	67
9093700.	1981	292	9.05	2.82	11.74	1.70	90
9095500.	1949	161	5.96	2.35	12.37	1.66	72
9095500.	1950	347	9.18	2.77	9.96	1.70	93
9095500.	1951	332	8.99	2.71	9.94	1.94	91
9095500.	1952	307	9.64	2.71	9.20	1.92	91
9095500.	1953	342	9.56	2.73	10.09	1.93	92
9095500.	1954	352	10.26	2.82	11.25	1.68	94
9095500.	1955	327	10.35	2.64	9.70	1.77	94
9095500.	1956	356	9.54	2.76	10.19	1.97	92
9095500.	1957	340	8.29	2.77	9.26	2.21	87
9095500.	1958	343	9.36	2.76	10.60	1.95	92
9095500.	1959	325	8.66	2.74	10.01	1.98	89
9095500.	1960	303	9.50	2.78	9.27	2.33	87
9095500.	1961	308	9.77	2.82	9.41	2.06	90
9095500.	1962	295	8.44	2.72	8.01	2.16	85
9095500.	1963	308	10.29	2.76	9.80	1.57	94
9095500.	1964	261	10.30	2.61	8.84	1.78	91
9095500.	1965	322	7.90	2.74	8.62	1.93	88
9095500.	1966	282	10.14	2.76	9.72	1.73	92
9095500.	1967	301	8.60	2.70	9.54	2.00	87
9095500.	1968	303	8.41	2.75	8.99	1.81	89
9095500.	1969	304	9.34	2.74	9.60	2.08	90
9095500.	1970	324	8.66	2.78	8.91	2.17	87
9095500.	1971	299	8.70	2.76	8.36	1.91	91
9095500.	1972	303	8.29	2.79	9.66	2.15	85
9095500.	1973	281	7.28	2.67	9.18	1.99	81
9095500.	1974	275	8.44	2.72	9.24	2.01	84
9095500.	1975	307	7.81	2.62	9.10	1.63	91
9095500.	1976	363	8.37	2.76	9.57	1.55	93

Table 3.--*Harmonic-function coefficients, Colorado River subbasin*--Continued

Station no.[2]	Year	NO	A	C	M	SE	PVAR
			Harmonic coefficients[1]				
9095500.	1977	320	10.22	2.91	9.99	1.13	97
9095500.	1978	341	7.24	2.85	9.19	2.04	85
9095500.	1979	254	7.68	2.77	8.91	1.65	88
9095500.	1980	130	11.19	2.47	7.72	1.64	99
9095500.	1981	365	8.64	2.81	11.33	1.56	93
9152500.	1949	149	7.84	2.24	14.24	1.81	81
9152500.	1950	311	10.37	2.71	11.95	2.05	92
9152500.	1951	318	9.83	2.73	12.16	2.14	91
9152500.	1952	317	9.83	2.74	12.15	2.10	91
9152500.	1953	330	11.05	2.71	12.50	2.94	87
9152500.	1954	328	11.10	2.90	13.78	2.41	91
9152500.	1955	335	11.58	2.67	11.58	2.08	93
9152500.	1956	353	10.34	2.80	12.62	2.47	89
9152500.	1957	321	9.02	2.72	10.72	2.87	81
9152500.	1958	351	12.06	2.76	12.55	2.83	90
9152500.	1959	349	11.59	2.81	13.75	2.40	92
9152500.	1960	292	10.49	2.77	10.39	2.04	91
9152500.	1961	254	10.64	2.77	10.09	2.18	88
9152500.	1962	264	9.89	2.72	9.16	2.10	87
9152500.	1963	283	10.22	2.74	10.83	1.64	94
9152500.	1964	281	9.76	2.61	10.19	1.75	92
9152500.	1965	298	8.23	2.68	9.17	2.01	86
9152500.	1966	289	9.95	2.75	10.77	1.82	91
9152500.	1967	318	9.41	2.72	10.82	2.05	90
9152500.	1968	348	7.75	2.74	9.99	2.09	86
9152500.	1969	340	9.97	2.77	10.23	1.93	92
9152500.	1970	354	8.06	2.73	9.74	2.05	88
9152500.	1972	366	9.81	2.86	11.61	1.71	93
9152500.	1973	365	9.52	2.80	11.71	2.23	89
9152500.	1974	297	8.91	2.71	12.06	1.81	90
9152500.	1976	327	10.05	2.79	11.76	1.63	95
9152500.	1977	271	11.16	2.95	11.69	1.91	91
9152500.	1978	305	9.05	2.77	10.76	2.51	85
9152500.	1979	176	8.77	2.65	10.98	2.02	83
9152500.	1980	173	8.64	2.45	11.32	1.95	87
9152500.	1981	365	9.25	2.80	12.69	1.56	94
9163530.	1962	143	11.11	2.46	10.98	.99	91
9163530.	1965	358	9.34	2.78	10.44	2.15	90
9163530.	1966	315	11.12	2.81	12.17	1.82	94

Table 3.--*Harmonic-function coefficients, Colorado River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9163530.	1967	320	9.96	2.79	11.82	2.09	91
9163530.	1968	262	10.26	2.84	11.00	1.91	92
9163530.	1969	173	8.37	2.91	11.70	2.31	81
9163530.	1974	339	10.54	2.71	11.31	1.84	93
9163530.	1975	273	7.87	2.56	12.42	2.03	83
9163530.	1976	360	10.23	2.82	11.91	1.66	95
9163530.	1977	357	11.47	2.91	11.59	1.40	97
9163530.	1978	343	8.41	2.75	11.00	2.09	88
9163530.	1979	341	9.75	2.69	10.42	2.01	92
9163530.	1980	309	10.26	2.78	12.47	2.39	99
9163530.	1981	338	9.58	2.95	12.94	1.86	93
9180000.	1950	256	10.26	2.75	11.33	1.98	99
9180000.	1951	179	8.70	2.79	13.76	2.13	99
9180000.	1952	238	10.10	2.70	11.04	1.87	99
9180000.	1953	200	11.73	2.68	12.12	1.97	99
9180000.	1954	224	11.09	2.87	12.40	1.80	99
9180000.	1955	232	12.54	2.69	11.50	1.87	99
9180000.	1956	228	11.27	2.77	12.20	2.08	99
9180000.	1957	197	9.86	2.68	10.34	2.30	99
9180000.	1958	182	11.42	2.67	11.09	1.92	99
9180000.	1959	170	11.75	2.84	12.17	2.74	99
9180000.	1965	222	10.04	2.75	11.24	2.47	98
9180000.	1966	204	12.39	2.80	12.80	2.43	95
9180000.	1967	221	11.67	2.84	12.90	2.59	80
9180000.	1969	265	11.60	2.75	12.31	2.38	93
9180000.	1970	268	10.37	2.81	11.39	2.40	90
9180000.	1971	280	9.56	2.82	11.26	2.08	93
9180000.	1972	248	11.14	2.93	13.09	2.13	95
9180000.	1973	230	11.13	2.64	10.65	2.57	98
9180000.	1974	240	11.51	2.82	12.16	1.98	99
9180000.	1975	270	9.66	2.68	11.49	2.59	90
9180000.	1976	293	11.14	2.93	11.97	1.93	94
9180000.	1977	312	13.61	2.92	12.40	2.09	94
9180000.	1978	291	11.12	2.67	11.98	2.45	99
9180000.	1979	289	11.53	2.58	11.51	2.38	99
9180000.	1980	285	9.70	2.63	12.08	2.90	87
9180000.	1981	301	11.17	2.81	14.13	1.77	92
9180500.	1950	260	10.34	2.75	11.37	1.94	99
9180500.	1951	280	9.74	2.77	11.68	2.04	96

Table 3.--*Harmonic-function coefficients, Colorado River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9180500.	1952	223	10.32	2.72	10.74	1.89	99
9180500.	1953	154	11.75	2.70	12.20	2.06	99
9180500.	1954	256	10.77	1.82	12.51	1.82	99
9180500.	1955	249	11.64	2.68	10.76	1.87	99
9180500.	1956	253	10.37	2.78	11.08	1.96	99
9180500.	1957	245	9.74	2.69	9.89	2.38	99
9180500.	1958	207	10.94	2.70	11.15	2.14	99
9180500.	1959	211	11.33	2.81	11.62	1.81	99
9180500.	1960	208	11.03	2.74	11.63	2.12	99
9180500.	1961	166	11.59	2.78	11.16	2.01	99
9180500.	1962	150	10.38	2.74	11.70	2.19	99
9180500.	1963	139	11.25	2.78	13.02	1.96	99
9180500.	1964	155	11.30	2.67	11.73	2.14	95
9180500.	1965	232	9.49	2.78	10.40	2.31	98
9180500.	1966	250	12.32	2.79	12.60	2.05	92
9180500.	1967	220	10.92	2.73	12.78	2.59	95
9180500.	1968	309	11.13	2.70	11.96	2.48	90
9180500.	1969	298	11.23	2.72	11.76	2.37	90
9180500.	1970	291	9.44	2.77	10.79	2.44	86
9180500.	1971	294	8.60	2.79	10.38	1.88	91
9180500.	1972	281	10.22	2.90	12.16	2.20	89
9180500.	1973	289	10.44	2.68	10.64	2.41	99
9180500.	1974	345	10.15	2.79	11.22	1.84	94
9180500.	1975	342	9.81	2.70	11.14	2.20	91
9180500.	1976	352	10.24	2.89	11.57	1.91	92
9180500.	1977	338	12.60	2.90	11.61	1.82	99
9180500.	1978	355	9.17	2.70	12.17	2.22	89
9180500.	1979	316	11.06	2.62	11.15	2.18	99
9180500.	1980	154	13.25	2.69	11.12	1.56	99
9180500.	1981	350	10.58	2.82	13.61	1.72	94

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description.

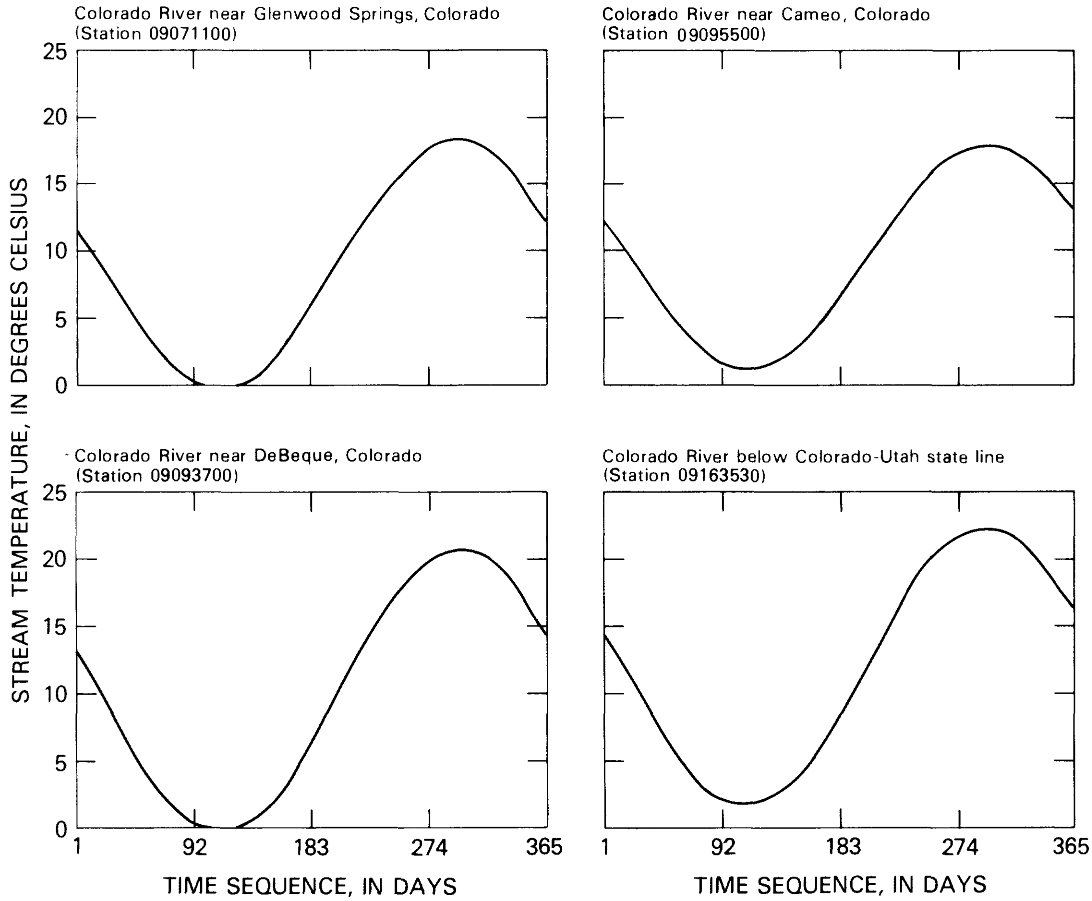


Figure 3.--Stream-reach seasonal water-temperature patterns, Colorado River, 1976 water year.

Table 4.--*Harmonic-function coefficients, San Juan River subbasin*

[NO = number of daily values. SE = standard error or estimate. PVAR = percent variance explained by the harmonic function.]

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9355500.	1955	215	9.29	2.58	11.10	2.69	81
9355500.	1956	324	9.96	2.79	11.08	2.27	90
9355500.	1957	285	7.56	2.65	9.22	2.30	81
9355500.	1958	358	9.72	2.66	9.26	1.76	93
9355500.	1959	365	11.06	2.82	10.55	1.56	95
9355500.	1960	268	11.88	2.64	9.08	2.89	83
9355500.	1961	353	11.13	2.79	11.67	2.09	93
9355500.	1962	303	11.51	2.72	11.36	2.42	89
9355500.	1963	339	7.63	2.66	11.91	2.25	85
9355500.	1964	347	6.19	2.34	10.22	2.01	83
9355500.	1965	316	5.08	2.35	9.86	1.95	75
9355500.	1966	352	5.53	2.24	10.02	2.26	75
9355500.	1967	364	4.49	2.61	9.06	2.84	55
9355500.	1968	359	5.40	2.44	9.26	2.31	73
9355500.	1969	101	4.75	2.21	7.82	1.64	65
9357000.	1959	333	10.21	2.81	14.08	6.23	56
9357000.	1960	324	11.17	2.78	12.49	2.58	89
9357000.	1961	340	11.02	2.83	12.94	2.53	89
9357000.	1962	336	11.27	2.77	12.58	2.64	89
9357000.	1963	333	11.16	2.82	15.22	2.37	90
9364500.	1959	357	9.51	2.82	14.43	5.34	60
9364500.	1960	350	10.26	2.74	12.46	3.92	76
9364500.	1961	363	9.96	2.79	12.80	3.01	84
9364500.	1962	345	10.06	2.73	12.75	3.26	82
9364500.	1963	348	10.54	2.77	13.66	2.48	89
9364500.	1964	346	10.74	2.72	13.37	2.63	89
9364500.	1965	347	7.76	2.76	12.09	2.95	77
9364500.	1966	344	10.64	2.71	13.43	2.60	89
9364500.	1967	350	9.99	2.77	14.46	2.83	86
9364500.	1968	309	7.42	2.54	12.77	3.77	64
9364500.	1969	352	9.32	2.57	11.86	2.77	84
9364500.	1970	355	9.23	2.88	12.51	3.05	82
9364500.	1971	335	9.27	2.80	12.83	3.20	80
9364500.	1972	337	10.10	2.85	13.13	3.20	82
9364500.	1973	331	8.79	2.61	10.08	3.01	80
9364500.	1974	363	11.12	2.73	13.75	3.09	86
9364500.	1975	332	8.36	2.48	10.77	2.99	79
9364500.	1976	361	9.03	2.69	12.56	2.27	88
9364500.	1977	254	10.97	2.95	13.97	3.12	85

Table 4.--*Harmonic function coefficients, San Juan River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9364500.	1978	349	8.68	2.65	11.58	3.35	77
9364500.	1979	277	8.56	2.45	12.53	2.97	68
9364500.	1980	365	10.16	2.65	14.23	2.68	85
9364500.	1981	360	10.38	2.71	12.88	2.68	86
9365000.	1964	351	9.70	2.73	13.59	2.48	88
9365000.	1965	350	7.34	2.69	12.28	2.92	76
9365000.	1966	327	10.23	2.69	14.22	2.02	92
9365000.	1967	349	9.77	2.81	14.20	2.95	84
9365000.	1968	315	7.67	2.60	13.18	3.61	68
9365000.	1969	264	8.24	2.48	13.46	2.46	87
9365000.	1970	354	9.14	2.84	12.54	3.17	80
9365000.	1971	340	8.67	2.83	13.19	3.09	78
9365000.	1972	355	9.03	2.91	13.12	2.99	81
9365000.	1973	352	6.16	2.70	8.70	2.02	82
9365000.	1974	363	9.03	2.82	13.38	2.21	89
9365000.	1975	337	6.83	2.59	9.54	2.03	85
9365000.	1976	364	8.91	2.95	12.04	2.09	90
9365000.	1977	283	9.87	2.93	12.47	2.55	89
9365000.	1978	350	8.08	2.78	11.49	3.08	77
9365000.	1979	278	6.51	2.53	10.90	2.47	66
9365000.	1980	365	8.20	2.72	12.62	1.99	87
9365000.	1981	329	8.33	2.83	12.02	2.21	88
9368000.	1959	337	9.60	2.85	13.95	7.00	48
9368000.	1960	307	10.76	2.76	12.78	2.49	88
9368000.	1961	333	11.55	2.88	14.10	2.75	89
9368000.	1962	357	11.66	2.73	13.13	2.63	90
9368000.	1963	357	12.01	2.79	14.97	2.21	93
9368000.	1964	362	11.21	2.73	13.95	2.30	92
9368000.	1965	364	8.81	2.76	12.91	2.88	82
9368000.	1966	333	10.41	2.75	14.20	2.29	90
9368000.	1967	363	9.19	2.91	14.43	2.78	84
9368000.	1968	338	9.95	3.02	13.60	3.35	80
9368000.	1969	354	8.68	2.73	11.73	2.64	84
9368000.	1970	358	8.36	2.90	12.58	3.15	77
9368000.	1971	360	7.26	2.78	11.76	2.64	78
9368000.	1972	359	8.27	3.01	12.58	3.17	77
9368000.	1973	351	7.87	2.62	9.70	2.41	84
9368000.	1974	358	10.98	2.85	13.97	1.86	94
9368000.	1975	335	8.29	2.63	10.70	1.92	89

Table 4.--*Harmonic function coefficients, San Juan River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9368000.	1976	363	9.55	2.58	12.40	1.55	95
9368000.	1977	306	9.96	2.68	15.03	2.74	84
9368000.	1978	194	13.07	2.99	16.25	2.06	92
9368000.	1979	298	7.37	2.52	9.84	1.93	57
9368000.	1980	307	7.90	2.62	11.51	2.11	85
9368000.	1981	365	8.57	2.82	12.44	1.88	79
9379500.	1945	348	11.30	2.76	12.26	2.31	90
9379500.	1946	320	12.14	2.89	13.17	2.38	88
9379500.	1947	345	10.97	2.37	12.55	2.23	92
9379500.	1948	341	11.38	2.78	12.08	2.12	92
9379500.	1949	352	11.03	2.35	11.96	2.46	83
9379500.	1950	360	11.75	3.05	14.09	2.51	92
9379500.	1951	259	9.79	2.87	13.94	2.63	91
9379500.	1952	277	10.77	2.72	12.58	2.00	81
9379500.	1953	335	10.44	2.31	12.27	2.30	87
9379500.	1954	336	11.11	2.88	12.83	2.16	84
9379500.	1955	340	10.79	2.73	11.72	1.77	98
9379500.	1956	341	10.05	2.65	12.28	2.20	90
9379500.	1957	318	10.12	2.85	12.01	2.66	84
9379500.	1958	360	11.40	2.80	12.34	2.05	93
9379500.	1959	344	10.44	2.67	12.87	2.31	90
9379500.	1960	328	11.07	2.82	12.52	2.07	95
9379500.	1961	345	11.27	2.88	12.10	1.95	96
9379500.	1962	216	11.69	2.89	12.33	2.43	99
9379500.	1963	100	11.37	2.79	15.33	2.28	99
9379500.	1964	124	11.05	2.38	13.50	2.29	91
9379500.	1965	295	9.92	2.82	13.29	2.33	81
9379500.	1966	362	11.68	2.79	14.51	1.81	95
9379500.	1967	364	11.30	2.36	13.87	1.98	94
9379500.	1968	364	11.86	2.88	12.99	2.37	99
9379500.	1969	364	12.00	2.85	13.49	1.96	94
9379500.	1970	341	11.05	2.34	13.34	2.30	92
9379500.	1971	314	10.93	2.94	12.77	2.53	89
9379500.	1972	313	12.49	2.93	14.17	2.29	92
9379500.	1973	293	11.43	2.32	12.22	1.70	97
9379500.	1974	295	12.21	2.74	13.77	1.97	93
9379500.	1975	299	10.43	2.76	12.27	1.88	96
9379500.	1976	294	10.67	3.09	13.17	2.28	92
9379500.	1977	103	11.74	2.94	12.28	2.34	99
9379500.	1979	31	11.96	2.69	11.63	1.27	99
9379500.	1981	238	11.00	2.91	13.92	1.85	88

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description.

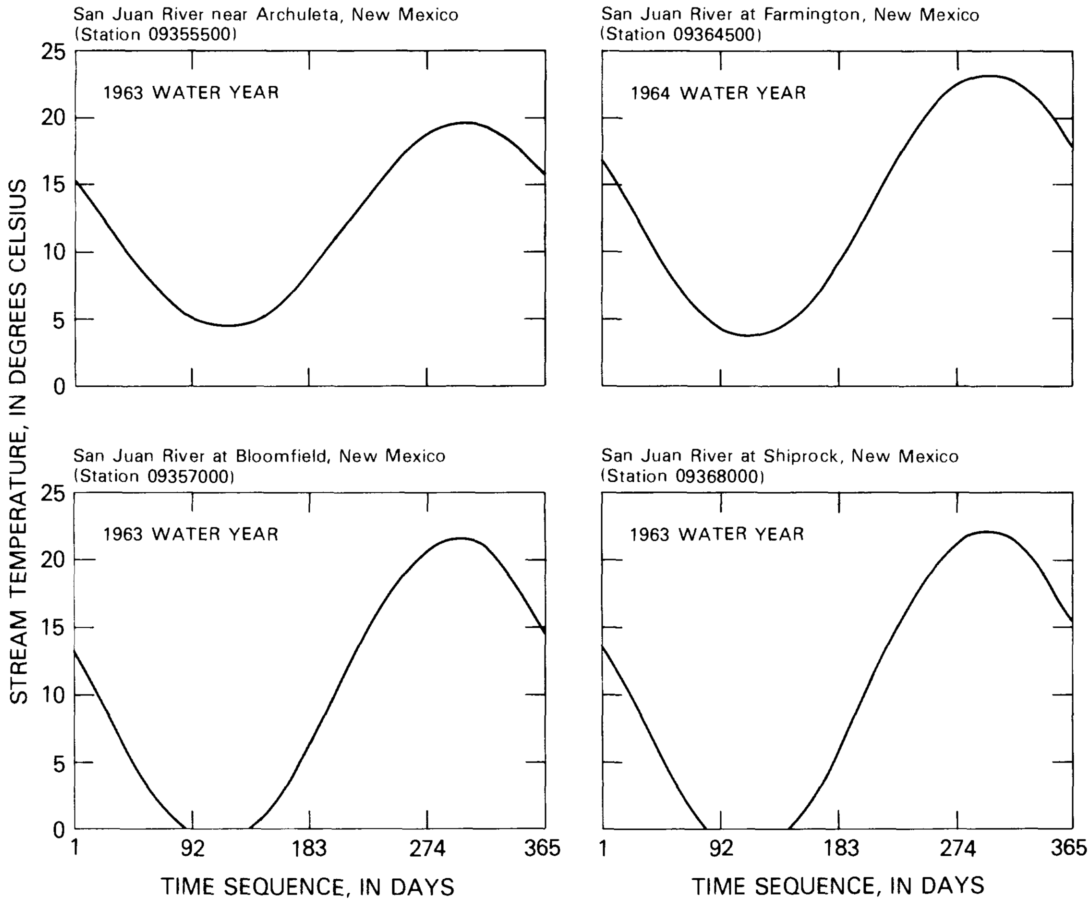


Figure 4.--Stream-reach seasonal water-temperature patterns, San Juan River, 1963 or 1964 water year.

Animas River at Farmington, N. Mex., were quite similar to mean water temperatures at station 09365000 San Juan River at Farmington, N. Mex.; amplitude coefficients were consistently 1 to 2°C greater for the Animas River records.

Green River Subbasin

Daily water-temperature data for 11 sites in the Green River subbasin were analyzed in this study--8 were main-stem sites and 3 were on major tributaries (Duschesne, Price, and San Rafael Rivers in Utah) (see table 10 in the supplemental information section at the end of the report). A total of 226 station years of record was analyzed; harmonic-coefficient results are summarized in table 5.

The Green River subbasin is the largest in the Upper Colorado River Basin system (Iorns and others, 1965). Lowham (1978) developed regional relationships for the harmonic mean and amplitude coefficients and compared estimates from these relationships with observed stream-reach averages for the Green River in Wyoming (see figure 8 of Lowham's 1978 report). Flaming Gorge Reservoir is located between station 09217000 Green River near Green River, Wyo., and station 09234500 Green River near Greendale, Utah. Reservoir operations began in 1963, and the impacts on downstream water temperature are clearly documented by the record at Greendale, Utah, and to a lesser extent further downstream at station 09261000 Green River near Jensen, Utah.

Using harmonic coefficients for the 1976 water year, upstream-downstream changes in the harmonic mean and amplitude coefficients for the six main-stem Green River stations with records for 1976 are summarized from table 5:

Station	Amplitude (°C)	Mean (°C)
09209400 Green River near LaBarge, Wyo----------	10.1	7.0
(Fontenelle Reservoir)		
09211200 Green River near Fontenelle Reservoir, Wyo-------------------	9.2	9.6
09217000 Green River near Green River, Wyo------	9.7	8.3
(Flaming Gorge Reservoir)		
09234500 Green River near Greendale, Utah-------	1.4	6.0
09261000 Green River near Jensen, Utah----------	8.7	9.6
09315000 Green River at Green River, Utah-----	11.7	12.5

Table 5.--*Harmonic-function coefficients, Green River subbasin*

[NO = number of daily values; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function]

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9188500.	1963	313	5.76	2.66	5.62	2.32	74
9188500.	1964	319	5.71	2.72	5.14	1.91	81
9209400.	1964	258	10.73	2.68	7.79	2.58	85
9209400.	1965	249	10.25	2.77	7.30	2.04	88
9209400.	1966	271	11.37	2.74	8.40	2.26	90
9209400.	1967	272	10.95	2.73	7.61	2.30	88
9209400.	1968	281	10.37	2.81	7.56	2.07	90
9209400.	1969	261	10.58	2.76	8.27	2.26	89
9209400.	1970	270	11.18	2.80	7.76	2.47	88
9209400.	1971	240	11.79	2.81	6.47	2.12	88
9209400.	1972	216	11.12	2.81	7.26	1.82	89
9209400.	1973	221	12.49	2.69	6.14	2.26	85
9209400.	1974	257	10.61	2.79	7.57	2.09	88
9209400.	1975	250	10.16	2.64	5.75	1.92	89
9209400.	1976	284	10.13	2.74	7.04	2.15	89
9211200.	1968	350	8.29	2.70	8.06	1.82	90
9211200.	1969	363	8.34	2.56	8.82	1.47	94
9211200.	1970	365	8.01	2.60	9.15	1.61	92
9211200.	1971	365	8.40	2.64	9.22	1.39	94
9211200.	1972	359	8.87	2.63	9.63	1.44	94
9211200.	1973	365	8.09	2.49	8.70	1.42	93
9211200.	1974	365	9.27	2.60	9.34	1.42	95
9211200.	1975	365	8.28	2.47	8.65	1.76	91
9211200.	1976	366	9.25	2.59	9.59	1.73	92
9217000.	1951	147	10.75	2.71	7.10	1.98	61
9217000.	1952	296	11.37	2.80	8.00	2.51	89
9217000.	1953	349	10.89	2.76	9.53	2.36	91
9217000.	1954	355	9.55	2.74	8.92	2.15	90
9217000.	1955	356	10.23	2.77	8.81	2.39	90
9217000.	1956	328	9.40	2.82	8.59	2.15	90
9217000.	1957	279	10.68	2.87	8.39	2.59	87
9217000.	1958	207	12.69	2.78	7.70	1.96	90
9217000.	1959	255	10.48	2.78	8.36	2.47	87
9217000.	1960	198	12.75	2.89	9.16	2.50	88
9217000.	1961	183	13.67	2.83	9.06	1.91	92
9217000.	1962	203	11.63	2.78	7.38	2.22	85
9217000.	1963	290	11.56	2.79	9.15	1.93	93
9217000.	1964	244	12.07	2.66	7.84	2.40	87
9217000.	1965	314	10.15	2.76	7.95	2.10	90

Table 5.--*Harmonic-function coefficients, Green River subbasin*--Continued

			Harmonic coefficient[1]				
Station no.[2]	Year	NO	A	C	M	SE	PVAR
9217000.	1966	294	11.75	2.76	8.90	1.90	93
9217000.	1967	344	10.16	2.75	8.63	2.02	92
9217000.	1968	313	10.07	2.81	8.32	2.18	90
9217000.	1969	246	11.47	2.69	8.79	2.24	87
9217000.	1970	297	10.12	2.81	9.08	2.19	89
9217000.	1971	270	10.54	2.77	8.02	2.67	83
9217000.	1972	234	10.01	2.63	8.57	1.83	89
9217000.	1973	250	10.18	2.79	7.14	2.27	83
9217000.	1974	274	10.59	2.77	7.43	2.65	84
9217000.	1975	283	10.06	2.60	8.08	2.34	87
9217000.	1976	284	9.69	2.73	8.33	2.24	87
9217000.	1977	249	13.05	2.80	8.28	2.36	88
9217000.	1978	252	9.84	2.70	7.60	2.55	79
9217000.	1979	227	12.49	2.64	8.02	2.56	82
9217000.	1980	366	10.17	2.73	8.50	2.08	91
9217000.	1981	365	9.89	2.78	9.52	2.16	90
9234500.	1957	78	12.25	2.71	7.94	1.97	93
9234500.	1958	98	10.97	2.48	9.65	2.48	81
9234500.	1959	40	11.12	2.78	8.54	2.79	76
9234500.	1960	138	11.28	2.76	9.03	2.40	82
9234500.	1961	182	11.48	2.86	8.57	1.78	93
9234500.	1962	187	10.43	2.81	7.79	1.98	91
9234500.	1963	228	2.96	2.09	4.49	1.58	65
9234500.	1964	352	2.75	1.55	6.50	1.67	56
9234500.	1965	327	4.03	1.76	7.58	.93	90
9234500.	1966	356	3.54	.89	6.48	1.23	80
9234500.	1967	359	2.16	1.48	6.04	.60	86
9234500.	1968	344	2.39	1.26	6.44	.80	82
9234500.	1969	338	3.14	1.26	6.56	.91	85
9234500.	1970	274	2.85	1.26	6.43	.82	86
9234500.	1971	251	2.30	1.14	6.01	.88	77
9234500.	1972	272	2.01	1.57	6.31	.52	88
9234500.	1973	364	2.11	.99	5.83	.73	80
9234500.	1974	365	1.80	1.33	6.05	.47	88
9234500.	1975	299	2.07	1.16	5.99	.62	84
9234500.	1976	228	1.74	1.18	5.96	.43	88
9234500.	1978	239	4.35	2.03	7.98	1.87	73
9234500.	1979	236	5.09	2.19	8.71	.80	95
9234500.	1980	243	5.24	2.19	8.33	.69	94

Table 5.--*Harmonic-function coefficients, Green River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficient[1] A	C	M	SE	PVAR
9234500.	1981	239	4.49	2.19	8.33	.78	92
9261000.	1950	360	10.36	2.68	10.74	1.77	94
9261000.	1951	356	9.71	2.72	11.11	1.36	96
9261000.	1952	343	9.47	2.61	10.34	1.43	95
9261000.	1953	314	10.25	2.74	9.55	2.05	92
9261000.	1954	291	11.14	2.86	10.98	2.19	92
9261000.	1955	259	10.70	2.74	9.49	1.66	95
9261000.	1956	258	9.63	2.83	9.36	1.95	91
9261000.	1957	263	10.61	2.91	9.55	1.92	94
9261000.	1958	177	12.08	2.80	10.81	2.20	92
9261000.	1959	167	11.64	2.88	10.84	2.08	93
9261000.	1962	204	12.20	2.75	8.94	2.12	88
9261000.	1963	301	11.18	2.74	11.43	2.15	91
9261000.	1964	223	9.64	2.70	9.55	2.01	86
9261000.	1965	215	9.13	2.69	9.36	1.89	89
9261000.	1966	211	8.66	2.72	10.17	1.74	89
9261000.	1967	213	8.43	2.78	9.96	1.79	87
9261000.	1968	272	8.03	2.85	10.45	1.84	89
9261000.	1969	285	9.00	2.84	10.59	1.27	96
9261000.	1970	264	8.81	2.79	10.53	1.73	92
9261000.	1971	235	8.80	2.88	9.07	1.69	92
9261000.	1972	233	8.94	2.89	10.07	1.84	91
9261000.	1973	218	8.49	2.80	9.51	1.78	90
9261000.	1974	201	8.92	2.83	9.55	1.98	87
9261000.	1975	201	8.25	2.71	9.06	1.75	90
9261000.	1976	135	8.69	2.90	9.56	1.53	92
9261000.	1977	260	8.54	2.80	10.42	2.16	89
9261000.	1978	290	9.72	2.79	11.86	2.09	91
9261000.	1979	253	11.89	2.80	11.29	2.13	92
9261000.	1980	309	9.32	2.66	10.40	2.40	87
9261000.	1981	310	9.94	2.84	12.54	1.76	93
9307000.	1951	156	11.88	2.75	11.62	1.99	94
9307000.	1952	114	16.26	2.60	7.85	2.08	93
9307000.	1954	302	11.84	2.83	12.36	2.12	94
9307000.	1955	63	12.84	2.67	10.72	2.04	88
9307000.	1957	136	12.31	2.80	11.31	2.07	93
9307000.	1958	185	11.71	2.73	11.67	2.63	92
9307000.	1959	205	2.64	2.61	7.21	3.64	13
9307000.	1960	220	12.46	2.79	10.56	2.40	88

Table 5.--*Harmonic-function coefficients, Green River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficient[1] A	C	M	SE	PVAR
9307000.	1961	229	11.37	2.86	11.55	2.24	91
9307000.	1965	189	11.77	2.80	10.72	2.25	83
9307000.	1966	185	12.27	2.80	12.35	1.66	93
9302000.	1951	292	9.12	2.76	8.51	1.71	82
9302000.	1957	321	9.86	2.83	8.61	1.89	85
9302000.	1958	311	10.35	2.81	8.82	1.77	99
9302000.	1959	334	9.95	2.86	8.70	1.65	99
9302000.	1960	257	10.34	2.86	8.62	2.08	99
9302000.	1961	229	11.73	2.89	8.59	1.98	99
9302000.	1962	296	10.35	2.85	7.65	1.98	99
9302000.	1963	361	10.15	2.78	8.76	1.69	95
9302000.	1964	364	10.23	2.72	8.37	1.83	93
9302000.	1965	356	9.39	2.81	7.70	1.93	90
9302000.	1966	359	10.38	2.76	9.28	1.67	95
9302000.	1967	364	9.73	2.75	8.46	1.87	92
9302000.	1968	360	9.41	2.83	8.24	1.80	92
9302000.	1969	357	10.38	2.77	8.59	1.84	92
9302000.	1970	358	10.48	2.84	8.57	1.98	92
9302000.	1971	358	10.28	2.86	8.46	2.01	92
9302000.	1972	352	9.80	2.93	8.63	1.87	92
9302000.	1973	333	9.92	2.71	8.41	2.06	93
9302000.	1974	339	11.40	2.86	10.72	2.54	89
9302000.	1975	346	11.34	2.77	10.11	2.33	88
9302000.	1976	166	11.38	2.92	9.91	3.33	99
9302000.	1977	250	10.69	3.08	12.32	2.14	95
9302000.	1980	153	9.50	2.70	12.89	2.36	99
9314500.	1951	215	11.86	2.83	14.09	2.44	99
9314500.	1952	324	13.78	2.75	11.95	2.50	99
9314500.	1953	342	13.24	2.76	12.97	2.40	93
9314500.	1955	266	10.59	2.60	12.20	3.10	83
9314500.	1956	281	9.80	3.02	11.59	2.73	83
9314500.	1957	206	12.24	2.95	9.41	1.70	95
9314500.	1958	55	12.98	2.58	11.51	2.30	94
9314500.	1959	100	10.15	2.74	11.80	3.70	66
9314500.	1962	198	11.41	2.84	14.03	2.94	87
9314500.	1963	265	10.85	2.90	12.63	3.33	83
9314500.	1965	313	11.81	2.69	13.95	4.16	79
9314500.	1966	248	12.24	2.64	17.57	4.85	70
9314500.	1967	288	10.55	2.75	12.58	3.63	78

Table 5.--*Harmonic-function coefficients, Green River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficient[1] A	C	M	SE	PVAR
9314500.	1968	340	10.62	2.65	10.45	2.77	88
9314500.	1969	326	10.77	2.81	10.34	2.11	92
9314500.	1970	301	8.83	2.82	8.37	2.91	78
9314500.	1971	289	10.87	2.88	9.01	3.14	82
9314500.	1972	308	10.79	2.92	9.98	2.68	87
9314500.	1973	290	11.95	2.81	10.54	2.80	87
9314500.	1974	283	9.22	2.95	9.46	3.23	74
9314500.	1975	277	10.72	2.77	9.96	2.93	84
9314500.	1976	352	10.34	3.06	11.08	2.60	88
9314500.	1978	308	12.84	2.87	13.86	2.70	91
9315000.	1949	137	11.26	2.55	12.83	1.69	79
9315000.	1950	321	11.19	2.74	11.73	1.86	94
9315000.	1951	304	11.50	2.80	12.48	2.06	94
9315000.	1952	288	12.48	2.73	11.49	1.93	95
9315000.	1953	299	11.65	2.73	12.28	2.13	93
9315000.	1954	342	11.79	2.84	13.13	2.29	92
9315000.	1955	277	13.21	2.66	11.53	1.62	96
9315000.	1956	331	11.75	2.79	12.24	1.80	95
9315000.	1957	291	11.30	2.79	11.49	2.44	90
9315000.	1958	298	12.33	2.80	13.75	2.08	94
9315000.	1959	218	10.61	2.78	14.29	1.90	92
9315000.	1960	194	12.94	2.81	13.23	1.99	94
9315000.	1961	84	12.04	2.88	13.85	2.09	93
9315000.	1962	196	12.69	2.80	12.41	2.30	90
9315000.	1963	138	12.17	2.82	14.07	2.38	88
9315000.	1964	214	11.55	2.74	12.16	2.66	85
9315000.	1965	165	12.42	2.77	10.50	2.09	91
9315000.	1966	176	12.13	2.85	13.16	1.76	95
9315000.	1967	274	10.57	2.71	10.96	2.63	87
9315000.	1968	263	10.68	2.82	10.39	1.89	91
9315000.	1969	267	10.27	2.71	10.19	1.41	95
9315000.	1970	277	10.69	2.87	10.53	1.77	94
9315000.	1971	286	10.81	2.87	10.56	1.68	95
9315000.	1972	277	10.80	2.92	12.23	1.95	93
9315000.	1973	257	11.68	2.76	11.12	1.77	95
9315000.	1974	229	11.95	2.88	12.60	3.23	82
9315000.	1975	234	10.97	2.73	11.65	2.06	92
9315000.	1976	265	11.68	2.83	12.49	2.19	92
9315000.	1977	305	13.13	2.83	13.36	1.96	95

Table 5.--*Harmonic-function coefficients, Green River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic Coefficient[1] A	C	M	SE	PVAR
9315000.	1978	285	11.67	2.82	13.34	2.15	93
9315000.	1979	234	12.92	2.77	12.51	2.02	93
9315000.	1980	320	10.00	2.76	12.84	2.42	87
9315000.	1981	309	11.79	2.88	13.05	2.02	94
9328500.	1951	281	12.09	2.88	13.96	3.16	87
9328500.	1952	250	12.47	2.74	12.64	3.23	86
9328500.	1953	250	10.81	2.73	13.61	2.70	86
9328500.	1954	283	13.33	2.94	13.93	2.63	92
9328500.	1955	222	12.89	2.76	12.99	2.81	87
9328500.	1956	218	12.46	3.01	12.95	2.52	93
9328500.	1957	276	11.12	2.92	12.11	3.59	82
9328500.	1958	214	12.90	2.77	12.29	2.87	88
9328500.	1959	262	6.52	2.57	13.01	5.71	35
9328500.	1960	155	12.31	2.80	11.06	3.10	80
9328500.	1961	197	13.77	2.81	9.85	2.92	86
9328500.	1962	207	11.38	2.85	10.74	2.91	84
9328500.	1963	204	11.98	2.93	13.83	2.98	86
9328500.	1964	208	11.94	2.72	11.33	2.85	87
9328500.	1965	198	10.60	2.68	10.99	3.15	82
9328500.	1966	166	12.10	2.83	12.30	2.49	89
9328500.	1967	207	11.17	2.76	11.01	2.76	82
9328500.	1968	234	10.02	2.79	10.81	2.67	82
9328500.	1969	232	11.10	2.92	11.63	2.95	82
9328500.	1970	156	9.94	2.99	12.01	2.98	78
9328500.	1971	98	10.76	2.87	11.27	3.15	83
9328500.	1972	82	12.19	2.95	12.39	3.08	83
9328500.	1973	144	11.86	2.74	11.22	3.07	73
9328500.	1974	212	12.85	2.96	13.39	3.41	82
9328500.	1975	172	11.93	2.78	12.32	2.83	86
9328500.	1976	113	12.81	2.95	13.40	3.09	88
9328500.	1977	57	14.02	3.03	14.41	3.75	84

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description.

Corresponding seasonal patterns at these sites during the 1976 water year are depicted in figure 5. As one proceeds in a downstream direction, the harmonic mean would be expected to increase. Observed anomalies from this expected pattern are caused by Flaming Gorge Reservoir (between station 09217000 Green River near Green River, Wyo., and station 09234500 Green River near Greendale, Utah) and Fontenelle Reservoir (between station 09209400 Green River near LaBarge, Wyo., and station 09211200 Green River near Fontenelle Reservoir, Wyo.). Nonetheless, between the uppermost main-stem site (station 09188500 Green River at Warren Bridge, near Daniel, Wyo.) and the lowermost site (station 09315000 Green River at Green River, Utah), harmonic mean temperatures increase from a range of 5.1 to 5.6°C upstream (partial year results for the 1962 water year in table 5 should be ignored), to 10.2 to 13.8°C downstream; corresponding amplitudes increase from 5.7 to 5.8°C upstream to 10.3 to 13.2°C downstream. Water-temperature characteristics of station 09314500 Price River at Woodside, Utah; station 09302000 Duchesne River near Randlett, Utah; and station 09328500 San Rafael River near Green River, Utah; are similar to those for station 09315000 Green River at Green River, Utah. Harmonic coefficients for three additional smaller tributaries in the Wyoming part of the Green River subbasin have been reported by Lowham (1978, table 4).

Yampa River Subbasin

Fifty-nine years of daily records were available for three sites in the Yampa River subbasin. The two long-term records are for sites located in downstream reaches of the Yampa River and the Little Snake River. For purposes of the time-trend analysis for the Little Snake River, records for station 09259950 Little Snake River above Lily, Colo., and station 09260000 Little Snake River near Lily, Colo., were combined (Wentz and Steele, 1980). No significant trends in these two records were detected, as expected, because of only minor reservoir regulation of streamflows to date of the Yampa River system (Steele and others, 1979; Wentz and Steele, 1980). Recently, monitoring instrumentation has been operating at station 09260025 Yampa River below the Little Snake River, Colo. In evaluating resultant coefficients for the 1979 water year, seasonal water-temperature patterns are intermediate to those for the two upstream measurement sites (table 6 and fig. 6).

For comparative purposes, harmonic coefficients for intermittent water-temperature measurements for the 1975 water year are given (table 6) as reported by Briggs and Ficke (1978); however, the resultant phase-angle coefficient for the Little Snake River near Lily appears somewhat anomalous (table 6). Stream-reach profiles for both the Yampa River and the Little Snake River, using intermittent water-temperature measurements for several main-stem sites not included in this study, showed characteristic increases in a downstream direction of harmonic-mean temperatures, and, to a lesser extent, harmonic amplitudes (Steele and others, 1979, fig. 2).

Colorado River at Lees Ferry, Ariz.

Thirty-two years of daily records were available at station 09380000 Colorado River at Lees Ferry, Ariz. A significant decrease in all three

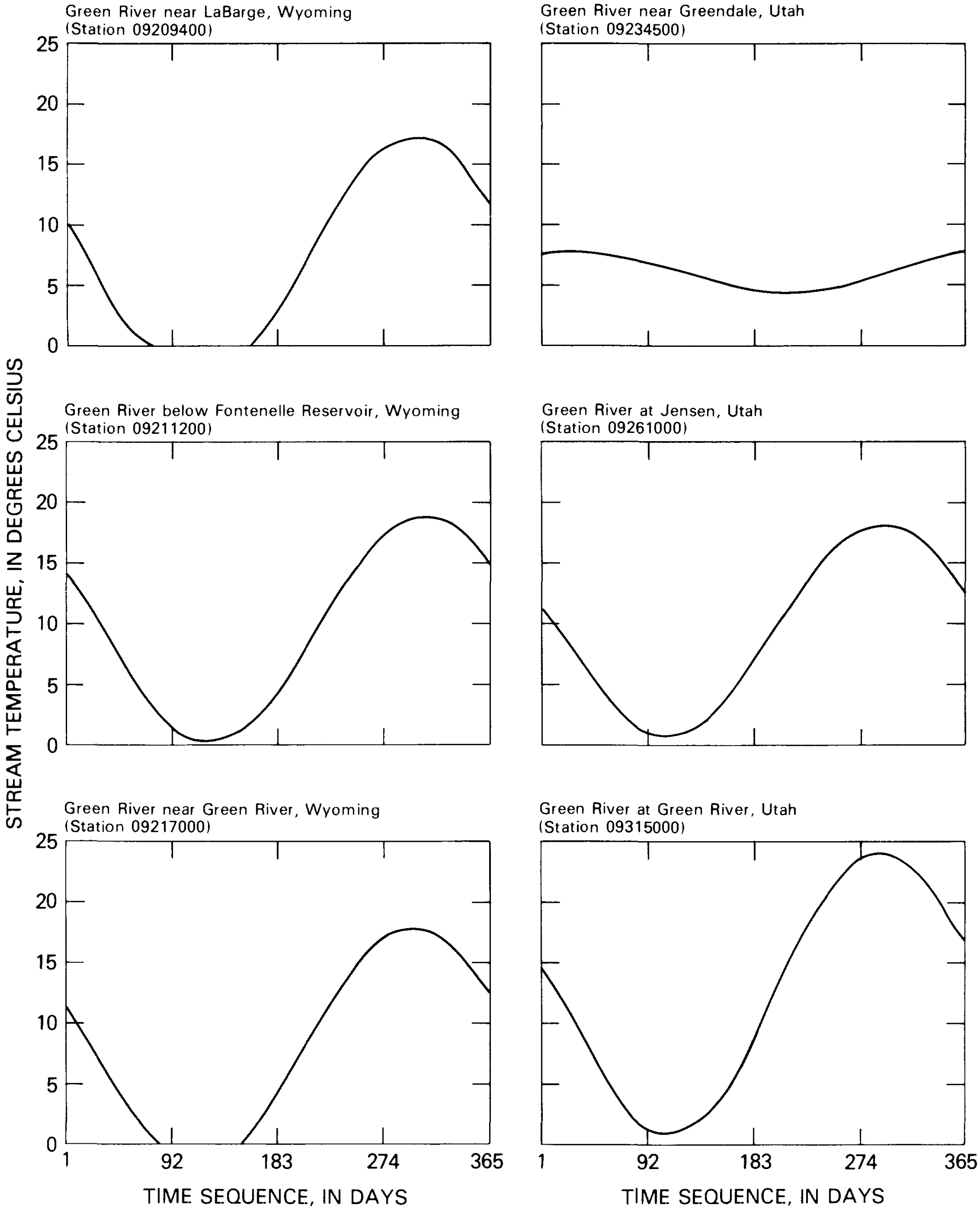


Figure 5.--Stream-reach seasonal water-temperature patterns, Green River, 1976 water year.

Table 6.--*Harmonic-function coefficients, Yampa River subbasin*

[NO = number of daily values; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function]

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9251000.	1951	293	10.52	2.62	10.50	2.20	92
9251000.	1952	340	11.59	2.65	9.74	1.98	94
9251000.	1953	354	12.08	2.55	10.76	2.61	91
9251000.	1954	313	12.85	2.74	10.64	2.00	94
9251000.	1955	361	12.30	2.57	9.91	2.23	93
9251000.	1956	354	11.75	2.67	9.98	2.06	94
9251000.	1957	280	10.60	2.69	9.02	3.01	82
9251000.	1958	287	11.87	2.69	10.26	2.50	89
9251000.	1959	282	9.92	2.71	10.49	2.54	86
9251000.	1960	281	11.19	2.73	9.66	2.87	86
9251000.	1961	238	11.26	2.70	10.45	2.72	87
9251000.	1962	293	11.10	2.71	9.43	2.34	90
9251000.	1963	361	11.00	2.73	10.98	2.38	91
9251000.	1964	357	9.76	2.44	8.86	2.46	88
9251000.	1965	281	9.36	2.45	8.59	2.55	85
9251000.	1966	301	8.26	2.50	9.10	3.54	69
9251000.	1967	338	9.99	2.56	10.03	2.99	84
9251000.	1968	363	8.87	2.55	8.35	2.83	83
9251000.	1969	349	12.00	2.66	10.35	2.89	89
9251000.	1970	364	10.90	2.54	10.11	2.77	88
9251000.	1971	363	11.60	2.43	10.57	2.57	91
9251000.	1972	358	10.75	2.78	9.99	3.35	83
9251000.	1973	304	9.75	2.74	9.40	2.39	88
9251000.	1975	54	11.50	2.84	8.73	1.87	90
9251000.	1976	114	13.40	2.83	8.56	1.58	95
9251000.	1977	177	15.19	2.84	9.55	2.18	91
9251000.	1978	163	6.86	2.29	11.22	2.56	74
9251000.	1979	315	10.50	2.66	8.45	2.19	96
9251000.	1980	235	12.27	2.87	10.50	1.80	99
9251000.	1981	363	10.74	2.86	9.65	1.98	92
9259950.	1951	180	9.34	2.84	9.28	1.96	91
9259950.	1952	128	9.50	2.89	6.52	1.91	82
9259950.	1953	241	10.13	2.96	6.35	2.28	83
9259950.	1954	238	9.32	2.98	7.12	2.12	85
9259950.	1955	234	12.75	2.76	6.55	3.16	79
9259950.	1956	235	14.97	2.83	7.30	3.14	85
9259950.	1957	255	11.10	2.72	10.37	3.41	81
9259950.	1958	269	11.64	2.78	10.32	3.40	79
9259950.	1959	279	12.16	2.84	10.59	3.16	86

Table 6.--*Harmonic-function coefficients, Yampa River subbasin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9259950.	1960	207	13.46	2.80	10.45	3.12	86
9259950.	1961	239	11.38	2.67	10.69	4.19	75
9259950.	1962	175	10.21	2.84	8.96	2.81	79
9259950.	1963	193	11.60	2.95	9.85	3.14	81
9259950.	1964	132	14.50	2.67	9.11	3.55	62
9259950.	1965	190	12.53	2.68	9.00	3.50	71
9259950.	1966	172	12.30	2.82	10.93	2.71	85
9259950.	1967	210	10.64	2.77	10.40	3.29	75
9259950.	1968	176	12.62	2.75	9.23	3.23	77
9259950.	1969	145	12.47	2.82	9.68	3.16	80
9260000.	1975	76	10.91	1.77	11.05	5.10	51
9260000.	1976	160	10.58	2.81	9.18	1.86	89
9260000.	1977	195	8.44	2.80	9.75	2.34	80
9260000.	1978	326	9.10	2.86	9.13	2.33	87
9260000.	1979	182	10.20	2.52	7.61	1.81	83
9260000.	1980	114	9.75	2.90	9.61	1.51	99
9260000.	1981	346	10.61	2.93	9.45	1.85	93
9260025.	1978	272	9.57	2.83	9.42	2.78	86
9260025.	1979	304	10.76	2.71	8.72	1.97	94
9260025.	1980	316	10.70	2.83	8.95	1.97	99

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description

harmonic coefficients and the amplitude plus mean coefficient began around the 1963 water year (table 7). This coincided with the completion and closure of Glen Canyon Dam and Reservoir. For several years (1974, 1977, and 1979 through 1981 water years), the harmonic-function results are not meaningful. Harmonic analyses of data for all these years have less than 50 percent variance explained, which would further confirm that the normal seasonal variability of stream temperatures at this site has been altered in recent years through upstream reservoir development. This change in the pre-reservoir versus post-reservoir downstream water temperature characteristics, depicted in figure 7, is discussed in the next section.

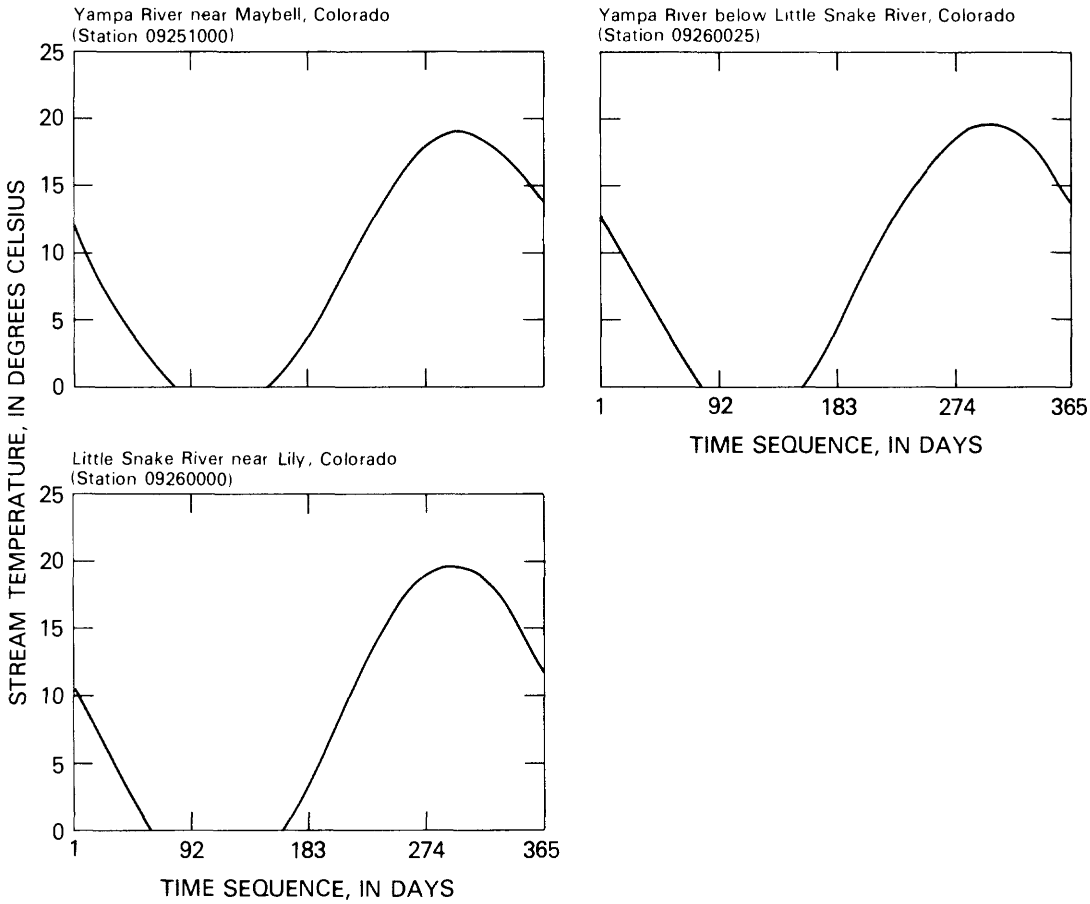


Figure 6.--Seasonal water-temperature patterns, Yampa River subbasin, 1979 water year.

Table 7.--*Harmonic-function coefficients, Colorado River at Lees Ferry, Ariz.*

[NO = number of daily valued; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function]

			Harmonic coefficient[1]				
Station no.[2]	Year	NO	A	C	M	SE	PVAR
9380000.	1950	358	10.91	2.81	13.79	2.07	93
9380000.	1951	354	10.87	2.75	14.19	1.91	94
9380000.	1952	359	11.43	2.74	12.91	1.96	94
9380000.	1953	276	11.21	2.69	14.90	1.89	86
9380000.	1954	319	11.89	2.88	14.84	1.99	93
9380000.	1955	353	11.94	2.69	13.34	1.76	95
9380000.	1956	320	10.48	2.77	14.13	1.67	97
9380000.	1957	323	9.69	2.87	13.38	2.57	86
9380000.	1958	314	10.82	2.77	14.15	3.19	83
9380000.	1959	308	11.67	2.84	14.54	1.90	93
9380000.	1960	278	11.80	2.82	14.29	2.49	90
9380000.	1961	274	11.80	2.86	14.55	1.60	99
9380000.	1962	263	11.58	2.77	13.40	2.09	97
9380000.	1963	245	7.92	2.57	11.65	2.11	87
9380000.	1964	210	5.61	1.83	12.50	2.10	64
9380000.	1965	190	5.83	1.93	14.68	1.40	98
9380000.	1966	217	4.56	1.85	14.49	.94	92
9380000.	1967	331	6.89	2.19	12.70	1.04	94
9380000.	1968	244	7.05	2.32	13.87	1.07	99
9380000.	1969	257	5.14	1.95	12.55	1.22	89
9380000.	1970	299	4.57	2.22	11.50	1.36	80
9380000.	1971	293	3.10	1.89	10.90	1.29	63
9380000.	1972	260	2.02	2.82	10.22	.56	64
9380000.	1973	301	1.66	1.46	8.52	.57	77
9380000.	1974	303	.27	.83	8.45	.18	7
9380000.	1975	278	1.06	2.61	8.66	.46	64
9380000.	1976	355	.90	2.17	9.21	.22	58
9380000.	1977	306	.42	4.10	9.72	.30	8
9380000.	1978	318	1.61	2.59	9.80	.53	79
9380000.	1979	346	.75	.55	9.47	.46	25
9380000.	1980	308	.77	2.05	8.61	.20	29
9380000.	1981	268	.53	2.76	10.07	.28	37

[1]See equation (1), p. 2 of text.
[2]See supplementary information for station description.

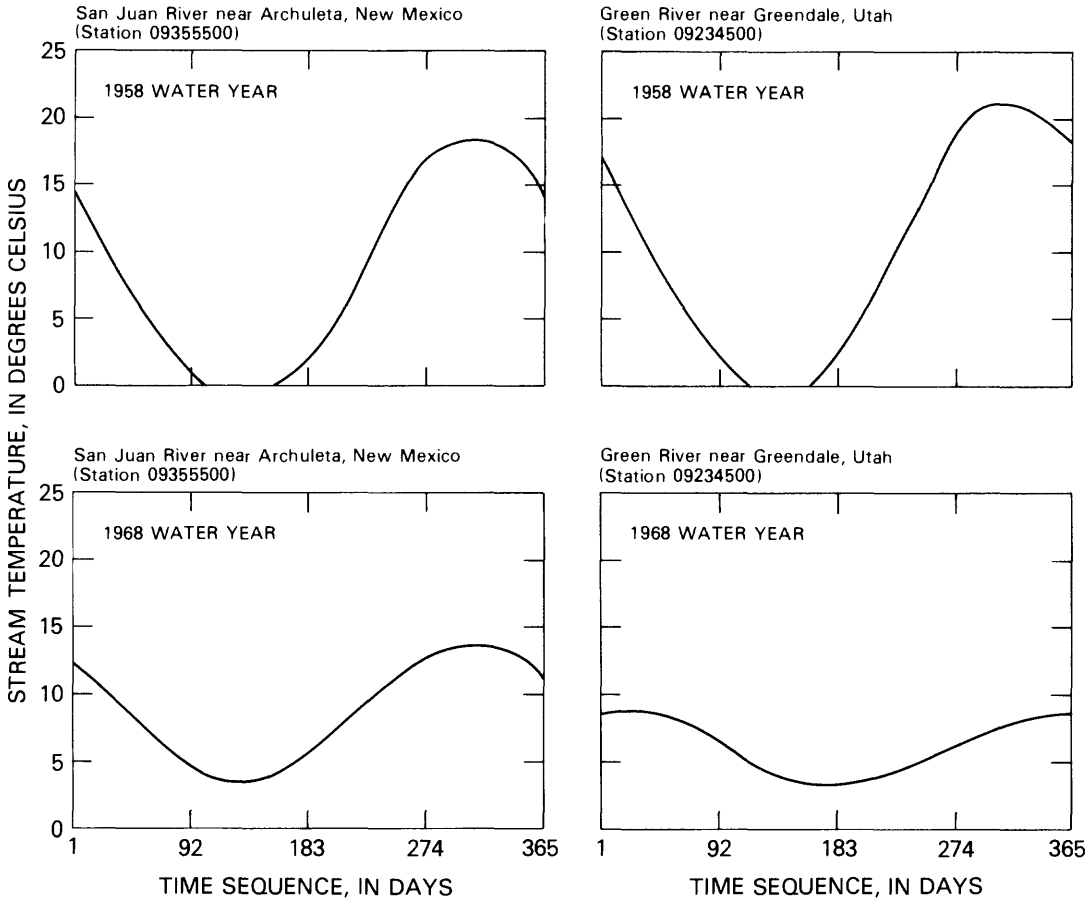


Figure 7.--Changes in seasonal water-temperature patterns, 1958 water year versus 1968 water year.

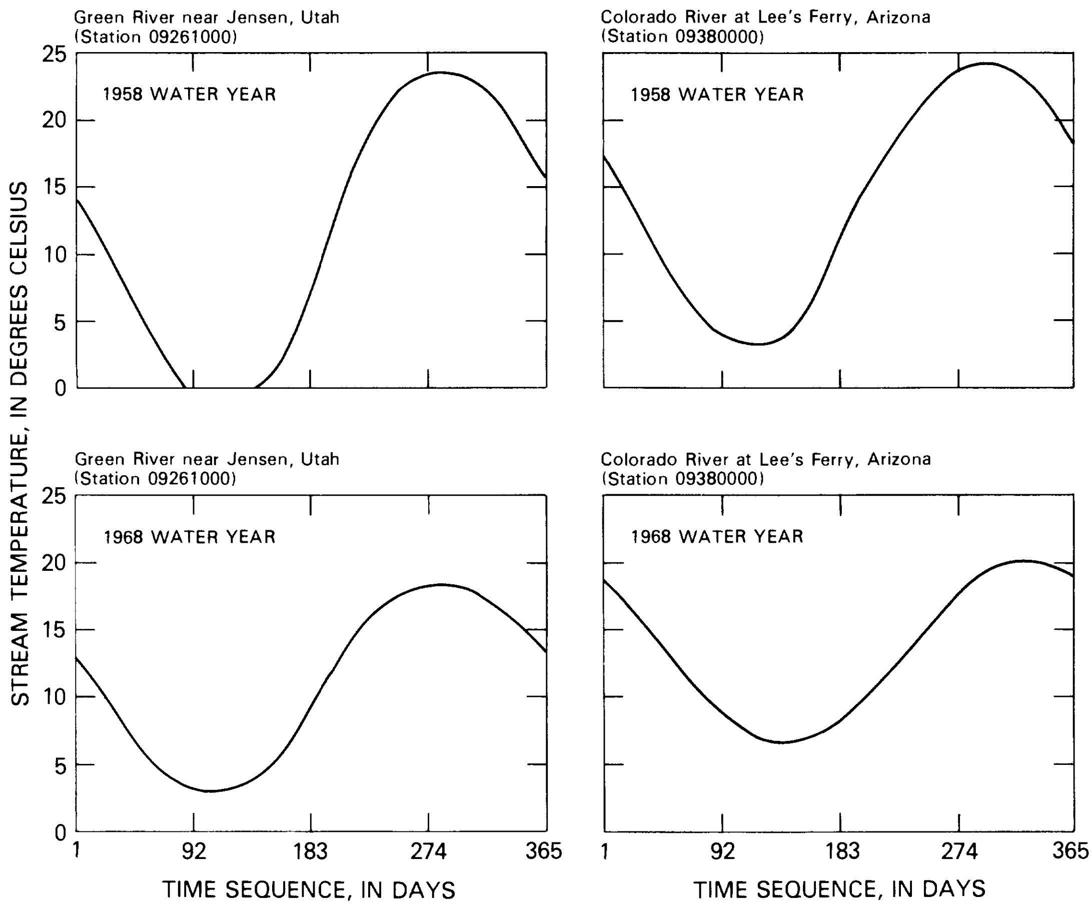


Figure 7.--Changes in seasonal water-temperature patterns, 1958 water year versus 1968 water year--Continued.

Impacts of Reservoirs on Water Temperature

The Kendall's tau test (Conover, 1971) was applied to each annual time series of harmonic coefficients to statistically determine if there were trends in the series. The level of significance was assumed at the 99-percent confidence level, using the same procedures as outlined by Steele and others (1974). Finally, causal effects for observed trends were sought.

Significant trends were found in one or more coefficients for only 6 of the 26 station records on major streams in the Upper Colorado River Basin with 8 or more years of data (table 8). One site was station 09306500 White River near Watson, Utah; the second site was station 09095500 Colorado River near Cameo, Colo. No explanation is provided at this time for the two significant trends in stream-temperature harmonic coefficients. The third and fourth sites were station 09355500 San Juan River near Archuleta, N. Mex., and station 09365000 San Juan River at Farmington, N. Mex. The fifth site was station 09234500 Green River near Greendale, Utah, and the sixth site was station 09380000 Colorado River at Lees Ferry, Ariz. Selected examples of shifts in seasonal patterns are depicted in figure 7.

In the case of the station 09355500 San Juan River near Archuleta record, only the amplitude coefficient showed a significant trend (see table 4); the shift was considered caused by the operating of Navajo Reservoir beginning about 1963. The record at the next measurement site downstream, station 09357000 San Juan River at Bloomfield, did not extend beyond the 1963 water year; the record for the San Juan River at Farmington began in 1964. Hence, no corresponding shift in time would have been expected. Nonetheless, in the latter case, a significant trend in the harmonic mean was observed, even though the reservoir is located upstream from the Bloomfield site (table 8).

For the Green River downstream from Flaming Gorge Reservoir, water is released from depth, so that the time series of amplitude coefficients have changed significantly to smaller values at station 09234500 Green River near Greendale, Utah, measurement site. Coefficient changes are apparent in the annual time series at this site beginning in 1963 (table 5 and fig. 7). Downstream at station 09261000 Green River near Jensen measurement site, some decrease in the harmonic-amplitude coefficient remains, but it was not significant at the 99-percent level of confidence. Some change in its coefficient's time series became more apparent, beginning in the 1964 water year at this site. The selected annual seasonal patterns depicted in figure 7 typify pre- (1957) versus post- (1968) reservoir conditions.

The significant time-series changes in all three harmonic coefficients for the Colorado River at Lees Ferry, as previously discussed, coincide with the construction of Glen Canyon Reservoir upstream from the measurement site.

Table 8.--*Trend-analysis summary, long-term records, Upper Colorado River Basin*

USGS Station no.[1]	Number of years[2]	Level of significance of trend[3] Harmonic coefficient A	C	M	A+M
09306500	26	3-	0	4-	5-
09071100	32	0	2+	4+	3+
09093700	8	0	0	1+	0
09095500	33	2-	0	5-	2-
09152500	31	4-	0	1	3-
09163530	14	0	0	0	0
09180000	26	0	0	0	0
09180500	32	0	0	0	0
09355500	15	5-	4-	1-	5-
09364500	23	0	0	0	0
09365000	18	0	0	5-	2-
09368000	23	4-	1-	2-	3-
09379500	35	1+	0	0	2+
09209400	13	0	0	3-	1-
09211200	9	1+	1-	1+	2+
09217000	31	1-	2-	0	0
09234500	24	5-	3-	1-	4-
09261000	30	3-	0	0	2-
09302000	23	0	0	3+	3+
09307000	11	0	0	0	1-
09314500	23	1-	1+	2-	3-
09315000	33	0	4+	0	0
09328500	27	0	2+	0	0
09251000	30	0	2+	1-	0
09259950*	19	3+	0	3+	3+
09260000*	7	0	3+	1-	0
09380000	32	5-	5-	5-	5-

[1]See supplementary information and text for station descriptions.
[2]See table 1. Stations with fewer than 8 years of record were omitted.
[3]See Conover (1971) and Steele and others (1974);
Levels of significance: 1 = 80 percent
2 = 90 percent
3 = 95 percent
4 = 98 percent
5 = 99 percent
Sign after ranking indicates direction of trend.
*Combined record for purpose of trend analysis.

It was coincidental that the time-series changes in annual water-temperature patterns in several cases cited in the Upper Colorado River Basin occurred around 1963-64. Evaluation of the observed shifts in seasonal water-temperature patterns for the case studies evaluates possible future impacts that may occur in rivers for which reservoirs have been proposed. It should be emphasized that the observed effects below reservoirs can vary with the type of reservoir release and the distance downstream from the impoundment structure.

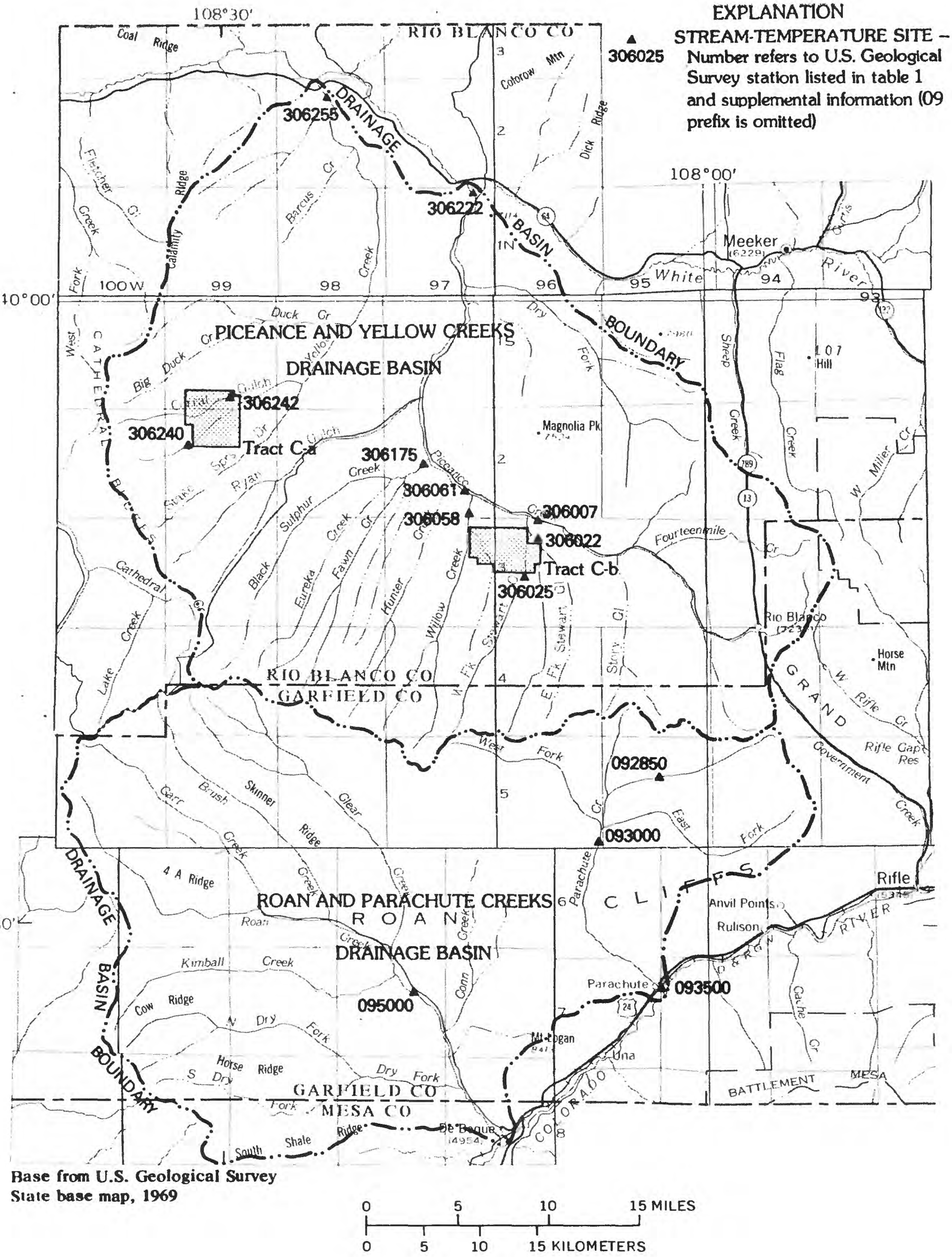
Piceance Basin--A Specific Study Area

Extensive oil-shale development is anticipated in the Piceance basin, with recently projected production levels as great as 1.7 million barrels per day (Colorado Department of Natural Resources, 1979). Among environmental concerns are the changes in quality and flow conditions in streams draining areas impacted by the development. As part of an extensive analysis of ambient conditions, a total of 83 daily water-temperature records at 14 sites in the basin (see supplemental information section at the end of the report) have been collected during the 1975-81 water-year period. These records were analyzed using the previously described harmonic-analysis approach; resultant coefficients depicting annual seasonal patterns are summarized in table 9.

Stream drainage areas for the measurement sites in this special study area were smaller than those main-stem and tributary sites analyzed previously. Site locations are given in figure 8; drainage areas range from 22.3 to 1,632 square kilometers.

In general, standard errors of estimate were small (less than 2°C), and percent annual variability explained by the harmonic function was large (greater than 80 percent) (table 9). Given that a maximum of 7 years of record was available at a given site, no formal analysis of possible trends was attempted.

As examples of regional water-temperature patterns, 1979 harmonic-function results are depicted in figure 9 for selected sites in the Piceance basin. Amplitude coefficients for the Parachute Creek and Roan Creek sites were small, considering the lower elevations of the measurement sites compared with the Piceance Creek and Yellow Creek sites. For the main-stem Piceance Creek sites (stations 09306007 Piceance Creek below Rio Blanco, Colo.; 09306061 Piceance Creek above Hunter Creek, near Rio Blanco, Colo.; and 09306222 Piceance Creek at White River, Colo.), an increasing stream-reach trend of harmonic-mean temperatures in a downstream direction was apparent (table 9 and fig. 9).



Base from U.S. Geological Survey
State base map, 1969

Table 9.--*Harmonic-function coefficients, Piceance basin*

[NO = number of daily values; SE = standard error of estimate; PVAR = percent variance explained by the harmonic function.]

			Harmonic coefficients[1]				
Station no.[2]	Year	NO	A	C	M	SE	PVAR
9092850.	1977	285	8.07	2.66	5.77	1.35	94
9092850.	1978	229	7.18	2.73	6.85	1.32	74
9092850.	1979	293	7.70	2.70	5.74	1.46	99
9092850.	1980	268	7.79	2.74	6.54	1.43	88
9092850.	1981	316	7.79	2.79	6.51	1.52	89
9093000.	1975	166	5.68	2.49	7.11	1.22	81
9093000.	1976	360	6.30	2.77	7.72	1.68	87
9093000.	1977	185	8.39	2.88	6.44	1.44	90
9093000.	1978	282	4.67	3.07	7.88	1.52	82
9093000.	1979	352	4.41	2.76	6.35	1.30	85
9093000.	1980	366	3.26	2.72	6.82	.95	81
9093500.	1975	243	6.76	2.38	11.31	1.91	87
9093500.	1976	324	7.17	2.79	11.34	1.64	89
9093500.	1977	266	9.64	2.81	10.95	1.54	95
9093500.	1978	214	6.98	2.81	10.38	2.03	87
9093500.	1979	229	5.94	2.67	9.20	1.73	83
9093500.	1980	303	6.34	2.53	9.58	1.60	76
9095000.	1975	231	6.16	2.58	9.60	1.58	87
9095000.	1976	341	7.57	2.92	9.73	1.33	94
9095000.	1977	176	10.06	2.97	11.82	1.37	96
9095000.	1978	349	6.54	2.78	9.72	1.48	90
9095000.	1979	362	6.62	2.74	8.51	1.42	91
9095000.	1980	312	6.76	2.81	9.65	1.63	99
9306007.	1975	159	7.21	2.89	7.79	1.56	92
9306007.	1976	255	7.62	2.86	8.42	1.38	93
9306007.	1977	307	9.35	2.86	8.20	1.42	95
9306007.	1978	296	6.66	2.80	8.15	1.39	92
9306007.	1979	285	6.66	2.89	8.00	1.27	92
9306007.	1980	241	6.55	2.83	7.69	1.38	90
9306007.	1981	349	7.52	2.90	9.19	1.38	92
9306022.	1975	122	3.72	3.13	7.33	1.09	85
9306022.	1976	306	3.00	3.01	7.87	.69	90
9306022.	1977	253	3.72	2.91	8.11	.81	91
9306022.	1978	255	3.21	3.04	8.21	.94	82
9306022.	1979	250	3.57	3.13	7.93	.91	99
9306022.	1980	307	3.17	2.96	7.90	.76	87
9306022.	1981	259	2.83	2.96	8.40	.72	99

Table 9.--*Harmonic-function coefficients, Piceance basin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9306025.	1975	124	11.32	2.84	7.23	2.24	60
9306025.	1976	38	11.07	3.22	9.03	2.83	86
9306058.	1975	161	5.91	2.94	7.66	1.98	79
9306058.	1976	143	4.53	2.55	9.00	2.17	63
9306058.	1977	182	7.12	2.93	6.87	1.33	90
9306058.	1978	181	6.45	3.09	8.41	1.62	89
9306058.	1979	193	7.04	2.92	6.88	1.43	88
9306058.	1980	266	6.51	2.95	7.76	1.27	89
9306058.	1981	302	7.01	2.94	8.60	1.50	87
9306061.	1975	125	5.62	2.53	8.46	2.03	79
9306061.	1976	280	6.53	2.82	8.38	1.31	91
9306061.	1977	146	8.42	2.88	8.25	1.10	94
9306061.	1978	333	6.56	2.81	8.89	1.53	90
9306061.	1979	222	5.98	2.78	8.78	1.53	85
9306061.	1980	295	6.51	2.86	8.33	1.27	92
9306061.	1981	330	6.80	2.85	9.19	1.38	92
9306175.	1975	190	4.61	2.33	10.00	1.45	79
9306175.	1976	184	5.45	2.90	9.53	.97	87
9306175.	1977	353	6.46	2.87	8.24	1.33	92
9306175.	1978	361	5.25	2.94	9.12	1.34	88
9306175.	1979	352	5.61	2.91	8.89	1.52	87
9306175.	1980	325	5.82	2.90	7.95	1.20	85
9306175.	1981	339	5.92	2.92	8.24	1.18	95
9306222.	1976	237	9.78	2.95	9.17	1.85	91
9306222.	1977	168	10.73	2.87	8.60	2.44	73
9306222.	1978	349	9.58	2.91	9.94	1.92	92
9306222.	1979	309	9.51	2.89	9.32	1.85	92
9306222.	1980	313	9.58	2.91	9.12	1.53	99
9306222.	1981	352	9.69	2.90	10.21	1.64	93
9306235.	1977	90	9.13	2.80	5.60	2.27	83
9306235.	1978	139	8.09	2.84	7.41	1.31	90
9306235.	1979	272	6.76	2.88	7.26	1.40	91
9306242.	1975	223	2.29	2.33	9.84	1.32	63
9306242.	1976	234	3.25	2.74	9.14	1.65	53
9306242.	1977	292	3.00	2.78	8.93	1.45	69
9306242.	1978	335	5.29	2.85	10.49	1.76	81
9306242.	1979	356	5.81	3.16	12.82	1.84	83

Table 9.--*Harmonic-function coefficients, Piceance basin*--Continued

Station no.[2]	Year	NO	Harmonic coefficients[1] A	C	M	SE	PVAR
9306242.	1980	340	3.57	2.82	9.30	1.32	68
9306242.	1981	357	2.52	2.87	9.64	.62	88
9306255.	1975	183	8.60	2.74	9.15	2.64	77
9306255.	1976	182	9.98	2.99	8.80	2.20	88
9306255.	1977	308	10.33	2.92	8.66	1.74	94
9306255.	1978	304	10.13	2.90	10.40	2.05	92
9306255.	1979	248	10.85	2.90	8.92	1.70	93
9306255.	1980	291	9.61	2.96	8.96	1.56	87
9306255.	1981	340	10.26	2.95	10.11	1.83	92

[1]See equation (1), p. 2 of text.
[2]See supplemental information for station description.

Goosenecks of the San Juan River, Upper Colorado River Basin, looking southeast near Mexican Hat, Utah.

Canyon de Chelly and Chinle Creek, Upper Colorado River Basin, looking east near Chinle, Arizona.

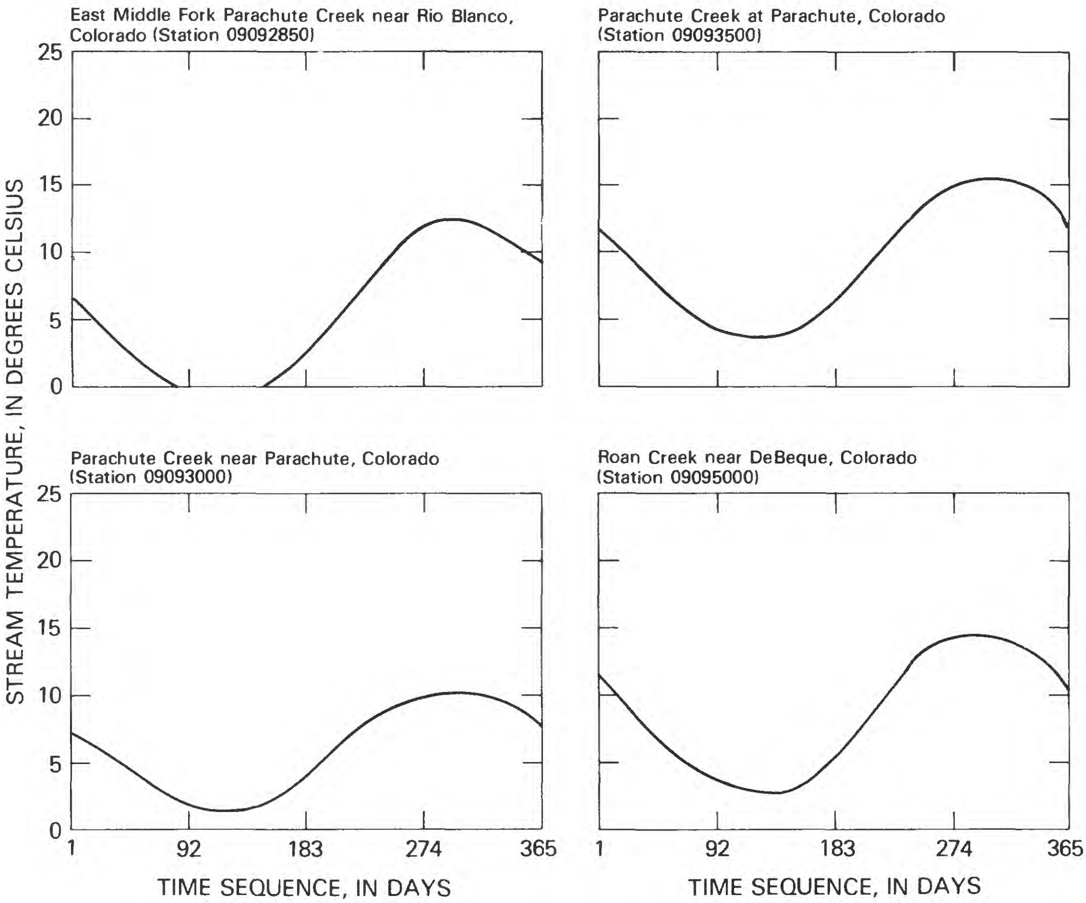


Figure 9.--Seasonal water-temperature patterns at selected sites, Piceance basin, 1979 water year.

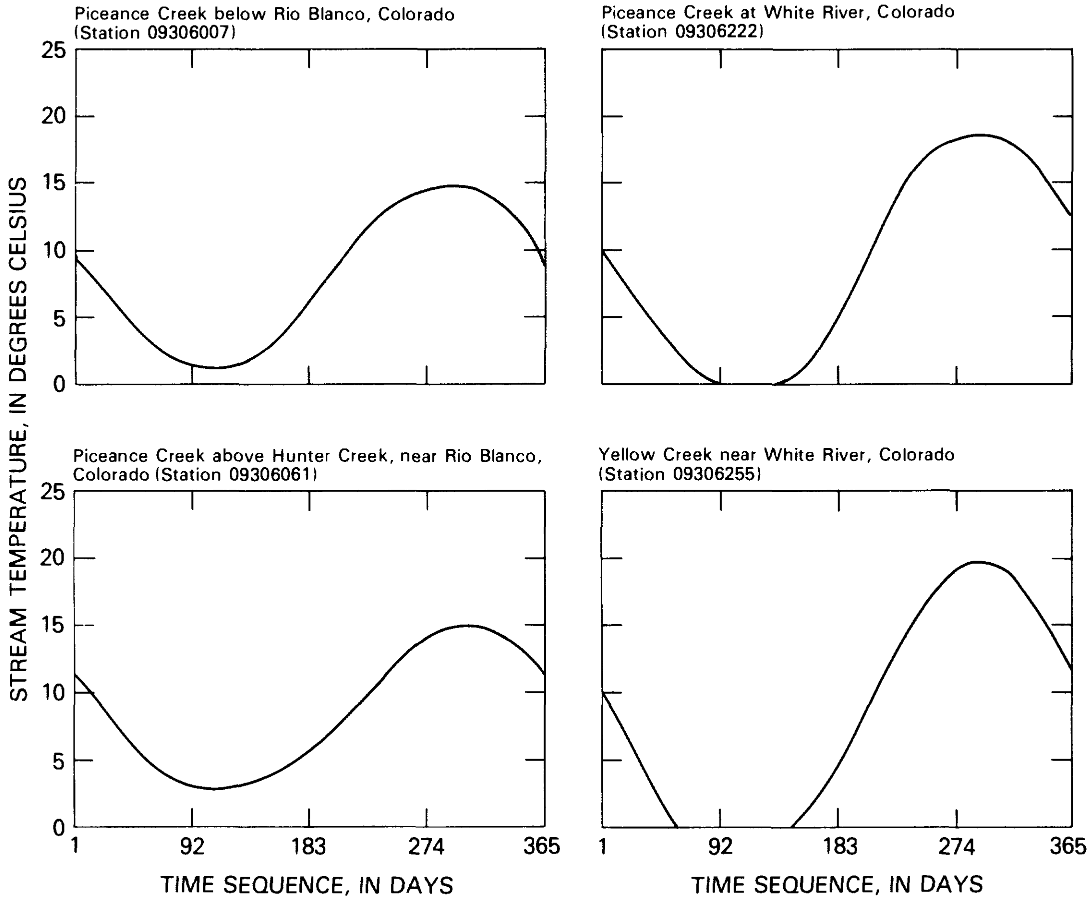


Figure 9.--Seasonal water-temperature patterns at selected sites, Piceance basin, 1979 water year--Continued.

SUMMARY

Simple-harmonic functions were used to characterize annual-seasonal patterns of water temperature at numerous measurement sites on main-stem streams and major tributaries in the Upper Colorado River Basin and on smaller streams in the Piceance basin. Daily water-temperature records were evaluated using this technique. A total of 668 station years of daily record was available at 36 sites in the Upper Colorado River Basin; 83 station years of daily record was available at 14 sites in the Piceance basin. Most records contain missing days or gaps in measurements; this technique helps to overcome these data deficiencies and provides a set of coefficients that could be evaluated both areally and temporally.

Comparison of observed discrete water-temperature measurements with a harmonic function, whose coefficients were determined directly from these data or by some indirect means, results in a time-series trace of harmonic residuals (that is, differences between observed and estimated values). Through analysis of these residual values, possible causes can be sought for prolonged periods of positive or negative residuals that may reflect deviations from a standardized seasonal pattern.

Unless short-term monitoring of water temperature is required by legislative mandate or some current purpose, little justification exists for perpetuating a daily-measurement frequency. Related previous studies (Gilroy and Steele, 1972; Steele, 1978; Wentz and Steele, 1980) have shown that minimal information on annual variability is lost by reducing measurement frequency to an approximate monthly pattern. For example, in cases where the measurement site coincides with a streamflow-gaging station, measurements then could be made by field personnel servicing the stage recorders on an intermittent schedule.

Admittedly, water-temperature measurements are relatively inexpensive in terms of time, instruments, and manpower, relative to most other water-quality variables. However, when data processing, publication, data file-storage, and quality-control factors are considered, costs begin to add up. A need to identify specific information needs and desired accuracies of statistical measurements of water temperature is inherent in any review to justify continuance of daily measurements.

In this study, possible benefits of generating long-term water-temperature records have been demonstrated in several cases, where upstream surface-water impoundments were placed "on-line" within the available period of historical record. In these instances, annual seasonal patterns frequently changed, and the resultant annual series of harmonic coefficients were evaluated statistically to assess the observed changes. From these documented case studies, one could anticipate what changes would occur for certain forms of releases for proposed reservoirs. Impacts on fish and aquatic life could be assessed beforehand, which might affect future design criteria for reservoir-release structures. This impact-evaluation feature of the proposed data-analysis procedure is felt to have general applicability.

In the Piceance basin, water-temperature records were of relatively short duration (2 to 7 years). However, a stronger case should be made to justify continuation of daily measurements of this variable. Otherwise, discrete intermittent measurements taken in conjunction with collecting water-quality samples or servicing stage recorders may be adequate for the intended uses of the information.

In summary, harmonic analysis has been a useful technique for evaluating historical water-temperature records. Use of harmonic functions for estimation purposes provides several cost-saving features and standard comparison capabilities for a more efficient network design and operation.

SELECTED REFERENCES

Briggs, J. C., and Ficke, J. F., 1978, Quality of rivers of the United States, 1975 water year--Based on the National Stream Quality Accounting Network (NASQAN): U.S. Geological Survey Open-File Report 78-200, May, 474 p.

Clement, R. W., 1978, Temperature in streams of New Mexico for the period October 1964 to September 1969: U.S. Geological Survey Water-Resources Investigations 78-140, 35 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-299 360.

Colorado Department of Natural Resources, 1979, Upper Colorado River Basin 13(a) assessment - The availability of water for oil shale and coal gasification development in the Upper Colorado River Basin: Summary report submitted to U.S. Water Resources Council, October, IV.

Collings, M. R., 1969, Temperature analysis of a stream: U.S. Geological Survey Professional Paper 650-B, p. B174-B179.

Conover, W. J., 1971, Practical nonparametric statistics: New York, John Wiley, 462 p.

Gilroy, E. J., and Steele, T. D., 1972, An analysis of sampling frequency alternatives for fitting a daily stream temperature model: Tucson, Ariz., International Symposium on Uncertainties in Hydrologic and Water Resource Systems, Proceedings, v. 2, p. 594-608.

Hawkinson, R. O., Ficke, J. F., and Saindon, L. G., 1977, Quality of rivers in the United States, 1974 water year--Based on the National Stream Accounting Network (NASQAN): U.S. Geological Survey Open-File Report 77-151, 199 p.

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

Hutchinson, N. E., compiler, 1975, WATSTORE user's guide: U.S. Geological Survey Open-File Report 75-426, v. 1, August, chap. 4, sec. B.

Iorns, W. V., Hembree, C. H., and Oakland, G. L., 1965, Water resources of the Upper Colorado River Basin--Technical report: U.S. Geological Survey Professional Paper 441, 370 p.

Lowham, H. W., 1978, An analysis of stream temperatures, Green River basin, Wyoming: U.S. Geological Survey Water-Resources Investigations 78-13, 41 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-284 062.

Shampine, W. J., 1977, Indiana stream-temperature characteristics: U.S. Geological Survey Water-Resources Investigations 77-6, 61 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-265 346.

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

Steele, T. D., 1974, Harmonic analysis of stream temperatures: Reston, VA, U.S. Geological Survey Computer Contribution, 246 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-239 016/AS.

Steele, T. D., 1978, A simple-harmonic model for depicting the annual cycle of seasonal temperatures of streams: U.S. Geological Survey Open-File Report 78-155, 36 p.

Steele, T. D., 1983, A regional analysis of water quality in major streams of the United States: Symposium on Dissolved Loads of Rivers and Water Quality/Quantity Relationships, Proceedings: Hamburg, West Germany, International Association of Hydrological Sciences, Publication No. 141, p. 131-143.

Steele, T. D., Bauer, D. P., Wentz, D. A., and Warner, J. W., 1979, The Yampa River basin, Colorado and Wyoming--A preview to expanded coal-resource development and its impacts on regional water resources: U.S. Geological Survey Water-Resources Investigations 78-126, 142 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-300 815.

Steele, T. D., Gilroy, E. J., and Hawkinson, R. O., 1974, An assessment of areal and temporal variations in streamflow quality using selected data from the National Stream Quality Accounting Network: U.S. Geological Survey Open-File Report 74-217, 210 p.

Ward, J. C., 1963, Annual variation of stream water temperature: American Society of Civil Engineers, Proceedings, Journal of the Sanitary Engineering Division, v. 89, no. SA6, December, p. 1-16.

Wentz, D. A., and Steele, T. D., 1980, An analysis of stream quality in the Yampa River basin, Colorado and Wyoming: U.S. Geological Survey Water Resources Investigations 80-8, 157 p.; available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, as PB-81 108 904.

SUPPLEMENTAL INFORMATION

Table 10.--*Water-temperature measurement-site descriptions*

[mi^2, square mile; km^2, square kilometer]

A. Mainstream and major tributary sites, Upper Colorado River Basin (total of 36 stations).

USGS Station no.	Station description	Drainage area mi^2	(km^2)
09304200	White River above Coal Creek, near Meeker, Colo.	660	(1,710)
09304600	White River at Meeker, Colo---------------------	808	(2,090)
09304800	White River below Meeker, Colo------------------	1,040	(2,690)
09306395	White River near Colorado-Utah State line-------	3,680	(9,530)
09306500	White River near Watson, Utah-------------------	4,020	(10,400)
09306900	White River at mouth, near Ouray, Utah----------	5,120	(13,300)
09071100	Colorado River near Glenwood Springs, Colo------	n.a.	--
09072500	Colorado River at Glenwood Springs, Colo--------	4,558	(11,800)
09085000	Roaring Fork River at Glenwood Springs, Colo----	1,451	(3,760)
09093700	Colorado River near De Beque, Colo--------------	7,370	(19,100)
09095500	Colorado River near Cameo, Colo-----------------	8,050	(20,800)
09152500	Gunnison River near Grand Junction, Colo--------	7,928	(20,500)
09163530	Colorado River below Colorado-Utah State line---	18,034	(46,700)
09180000	Delores River near Cisco, Utah------------------	4,580	(11,900)
09180500	Colorado River near Cisco, Utah-----------------	24,100	(62,400)
09355500	San Juan River near Archuleta, N. Mex-----------	3,260	(8,440)
09357000	San Juan River at Bloomfield, N. Mex------------	5,410	(14,000)
09364500	Animas River at Farmington, N. Mex--------------	1,360	(3,520)
09365000	San Juan River at Farmington, N. Mex------------	7,240	(18,800)
09368000	San Juan River at Shiprock, N. Mex--------------	12,900	(33,400)
08379500	San Juan River near Bluff, Utah-----------------	23,000	(59,600)
09188500	Green River at Warren Bridge, near Daniel, Wyo--	468	(1,210)
09209400	Green River near La Barge, Wyo------------------	3,190	(10,100)
09211200	Green River below Fontenelle Reservoir, Wyo-----	4,280	(11,100)
09217000	Green River near Green River, Wyo---------------	10,000	(25,900)
09234500	Green River near Greendale, Utah----------------	15,100	(39,100)
09261000	Green River near Jensen, Utah-------------------	25,400	(65,800)
09302000	Duchesne River near Randlett, Utah--------------	3,920	(10,200)
09307000	Green River near Ouray, Utah--------------------	35,500	(91,900)
09314500	Price River near Woodside, Utah-----------------	1,500	(3,880)
09315000	Green River at Green River, Utah----------------	40,600	(105,200)
09328500	San Rafael River near Green River, Utah---------	1,670	(4,330)
09251000	Yampa River near Maybell, Colo------------------	3,410	(8,830)
09259950*	Little Snake River above Lily, Colo-------------	n.a.	--
09260000*	Little Snake River near Lily, Colo--------------	3,730	(9,660)
09260025	Yampa River below Little Snake River, Colo------	8,080E	(20,900)
09380000	Colorado River at Lees Ferry, Ariz--------------	107,900	(279,500)

*Treated as identical station.

Table 10.--*Water-temperature measurement-site descriptions*--Continued

B. Measurement sites, Piceance basin (total of 14 stations)

1. Parachute Creek-Roan Creek Basins (4 stations)

USGS Station no.	Station description	Drainage area mi^2	(km^2)
09092850	East Middle Fork Parachute Creek near Rio Blanco, Colo-------------------	22.1	(57.2)
09093000	Parachute Creek near Parachute, Colo-----	141	(365)
09093500	Parachute Creek at Parachute, Colo-------	198	(513)
09095000	Roan Creek near De Beque, Colo-----------	321	(831)

2. Piceance Creek-Yellow Creek Basins (10 stations)

USGS Station no.	Station description	Drainage area mi^2	(km^2)
09306007	Piceance Creek below Rio Blanco, Colo----	177	(458)
09306022	Stewart Gulch above West Fork, near Rio Blanco, Colo-----------------------	43.4	(112)
09306025	West Fork Stewart Gulch, near Rio Blanco, Colo-----------------------	14.2	(36.8)
09306058	Willow Creek near Rio Blanco, Colo-------	48.7	(126)
09306061	Piceance Creek above Hunter Creek, near Rio Blanco, Colo-----------------------	309	(800)
09306175	Black Sulphur Creek near Rio Blanco, Colo-----------------------	103	(267)
09306222	Piceance Creek at White River, Colo------	630	(1,632)
09306235	Corral Gulch below Water Gulch, near Rangely, Colo---------------------	8.61	(22.3)
09306242	Corral Gulch near Rangely, Colo----------	31.6	(81.8)
09306255	Yellow Creek near White River, Colo------	262	(679)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1985—578-336/25160 REGION NO. 8