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TEMPERATURE IN STREAMS OF NEW MEXICO FOR THE PERIOD OCTOBER 1964 TO SEPTEMBER 1969

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Prepared in cooperation with the office of the New Mexico State Engineer and the Interstate Stream Commission

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No.

4. Title and Subtitle
Temperature in streams of New Mexico for the period October 1964 to September 1969

5. Report Date
November 1978

6.

7. Author(s)
Ralph W. Clement

8. Performing Organization Rept. No. USGS/WRI-78-140

9. Performing Organization Name and Address
U.S. Geological Survey, Water Resources Division
P. O. Box 26659
Albuquerque, New Mexico 87125

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U.S. Geological Survey, Water Resources Division
P. O. Box 26659
Albuquerque, New Mexico 87125

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes

16. Abstracts
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17. Key Words and Document Analysis. 17a. Descriptors

*Streams, *Water temperature, Water properties, Regression analysis, Correlation analysis, Variability

17b. Identifiers/Open-Ended Terms

New Mexico

17c. COSATI Field/Group

18. Availability Statement
No restriction on distribution

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
30

22. Price

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS - Concluded

TABLES

INCH-POUND UNIT TO METRIC UNIT CONVERSION FACTORS

In this report figures for measurements except water temperature are given in inch-pound units only. Water temperatures are expressed in degrees Celsius. The following table contains factors for converting to metric units.

Multiply inch-pound units	By	To obtain metric units
°F (Fahrenheit)	(1/)	°C (Celsius)
in (inch)	2.54	cm (centimeter)
ft (foot)	0.3048	m (meter)
mi (mile)	1.609	km (kilometer)
mi^2 ($mile^2$)	2.590	km^2 ($kilometer^2$)

(1/) Temp °C = (Temp. °F - 32)/1.8

TEMPERATURE IN STREAMS OF NEW MEXICO FOR THE PERIOD
OCTOBER 1964 TO SEPTEMBER 1969

By Ralph W. Clement

ABSTRACT

Harmonic equations were developed to describe stream temperatures at 144 sites using periodically observed water temperatures collected from October 1964 through September 1969. The harmonic equations explained at least 80 percent of the variability at 70 of the sites. Standard errors of estimate ranged from 1.3 degrees Celcius to 5.4 degrees Celcius and averaged 3.1 degrees Celcius. Stream-temperature characteristics are defined in terms of the mean, amplitude, and phase coefficients of the harmonic equations. The characteristics vary widely throughout the State, hence are described areally by regionalized regression equations. Regional equations developed to describe the mean temperature characteristic accounted for at least 84 percent of the variability and had standard errors of estimate less than 13 percent. Only one equation was adequate for describing the amplitude. That equation was for streams having drainage areas less than 2,500 square miles and in the northwestern part of the state. No equation was developed for the phase coefficient. Stream-temperature characteristic profiles are used to describe the trends of the three characteristics along major streams.

INTRODUCTION

Water-temperature data have been used in numerous studies to establish thermal-pollution standards, to select sites for recreation facilities and fish hatcheries, to investigate the effects of various thermal environments on aquatic life, to gain a greater understanding of water-temperature variations, and to establish priorities for future studies.

The U.S. Geological Survey has collected stream-temperature data in New Mexico for more than 50 years, although those data collected prior to about 1946 are rather sparse. Not until recently, however, has there been sufficient interest to analyze the accumulated records. In 1972, the U.S. Geological Survey, in cooperation with the offices of the New Mexico State Engineer and the Interstate Stream Commission, initiated this study of water temperatures of streams in New Mexico.

Purpose of study

The purpose of this study is to investigate and describe water temperatures and their variability in the streams of the State. Specific objectives of the investigation were to (1) define and determine water-temperature characteristics on streams where data were available; and (2) areally describe stream-temperature characteristics.

AVAILABLE DATA

The water temperature data available for this investigation consisted of records from two thermographs, records of daily temperature observations at regular stations, and numerous periodic measurements of water temperature made at various regular and partial record stations. The two thermograph records collected in New Mexico--Rio Grande at Otowi Bridge near San Ildefonso (station 08313000) and Pecos River near Artesia (station 08396500) began in October 1948 and April 1949, respectively. The temperature data collected at the Otowi station consisted of a simultaneous analog record of air and water temperatures. The Artesia record consisted of water temperatures only, recorded on a continuous strip chart. Channel conditions and placement of the temperature sensor cause this record to be susceptible to the effects of silting and direct solar radiation on the sensor. The data were considered unreliable for the purpose of this study.

Records of daily water temperatures collected at 28 quality of water monitoring sites, operated in conjunction with regular streamflow gaging stations are filed on magnetic tape. This Daily Values File also contains a record of maximum and minimum daily water temperatures as recorded by the thermograph located on the Rio Grande at Otowi Bridge (station 08313000).

Records of periodic measurements of water temperature from October 1964 through September 1969 were available from the District's data file. The frequency of measurement ranged from once a week to 8 or 10 times a year and the accuracy was limited by the observer's ability to read the thermometer, normally ±0.5°C.

Only those records of periodic water-temperature measurements which extended over a minimum period of two years and had a minimum of 20 observations where used in the analysis. The data file contained 144 station records which met these criteria. The location of these stations is shown in figure 1.

PREVIOUS STUDIES

Previous reports recognize that stream temperature follows a seasonal (cyclic) pattern that can be described using a harmonic equation with an annual periodicity. Investigators generally agree with Collins (1925) that variations in water temperatures are directly related to the daily and seasonal changes in air temperatures.

Ward (1963) described seasonal variation by deriving a sine curve (simple harmonic function) using 365 daily-mean water temperatures for each of 38 stations in Arkansas equipped with thermographs.

Thomann (1967) and Kothandaraman (1971) used a Fourier series carrying the harmonic to the 10th order. However, both concluded that any harmonic past the first did not substantially improve the equation.

Moore (1967) succeeded in correlating periodic water-temperature measurements with nearby thermograph records. Using the date and time of day, he then synthesized monthly mean temperature records of ungaged sites. Brown (1969) was able to predict daily water-temperature fluctuations by measuring thermal radiation, evaporation, and several other physical parameters.

Collings (1969), using thermograph records of the Chehalis River near Grand Mound, Washington, derived harmonic equations to describe the probable occurrence of maximum and minimum monthly temperatures for each of 9 years of record and for the entire period of record.

Moore (1968) described water temperatures on the Columbia River downstream from Bonneville Dam by constructing profiles of monthly mean, maximum, and minimum temperatures for each month during the period August 1941 through July 1942.

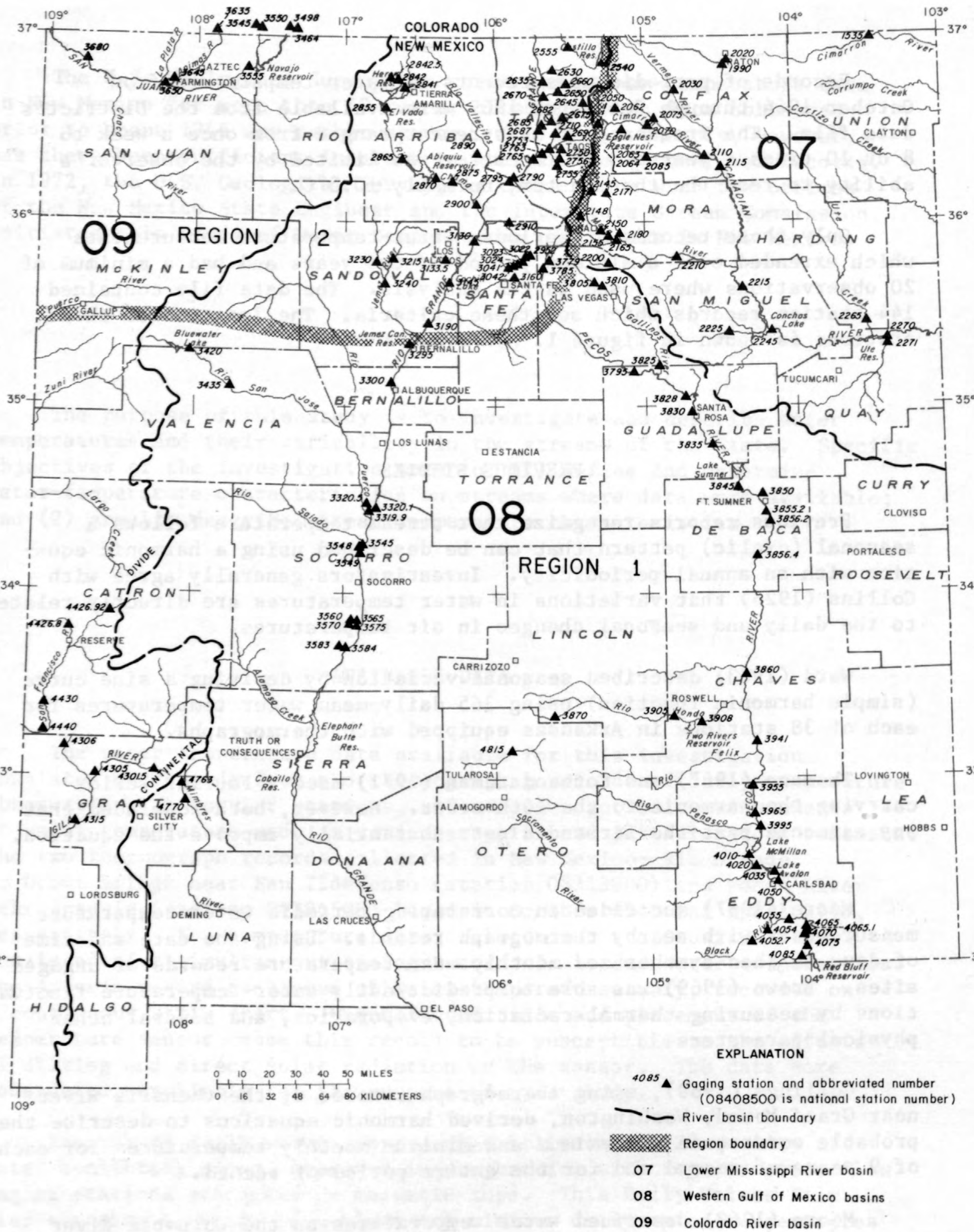

Figure 1.--Location of stream-gaging stations and river-basin and regional boundaries.

Gilroy and Steele (1972) investigated the variation in coefficients of the harmonic equation resulting from the fit of daily and less-than-daily observations of water temperature to a regression model. Equations were developed using daily stream-temperature observations at three separate locations. Subsequent equations were developed using only those observations made at selected uniform sampling intervals. The resulting coefficients for each record were then tested and the variations found to be relatively small. The results indicate that less-than-daily sampling frequencies yield estimates of annual stream temperatures that are comparable to those obtained from daily sampling.

Steele, Gilroy, and Hawkinson (1974) using daily stream-temperature data from 88 stations located throughout the United States and Puerto Rico, including four in New Mexico, developed harmonic equations to depict seasonal stream-temperature variation at each site. The resulting equation coefficients were used to assess time trends in the data at each site and to describe the areal variation in stream temperatures between sites.

Numerous other studies of stream temperatures have been conducted in recent years including those in Georgia (Dyar and Stokes, 1973), in central New England (Tasker and Burns, 1974), and in Kentucky (Zogorski and Kiesler, 1976).

Steele (1974) has developed a computer program with numerous input, output, and computational options for analyzing stream-temperature data.

TECHNIQUES OF THE INVESTIGATION

General use of regression models

Linear regression models were used to conduct the numerical analyses in this study. Deriving the least-square equation to fit certain data, the regression describes a single dependent variable in terms of one or more independent variables. The resulting equation takes the following generalized form:

$$Y = a + b_1 X_1 + b_2 X_2 \ldots\ldots + b_n X_n \qquad (1)$$

where Y is the dependent variable, a is the regression constant, and $b_1, b_2 \ldots b_n$ are the regression coefficients of the independent variables $X_1, X_2 \ldots X_n$, respectively. Riggs (1968) further explains the use of the regression model.

Harmonic equations and temperature characteristics

Stream temperatures at a specific location can be described by the simple harmonic equation for those periods when water temperatures are above freezing (0°C). The harmonic equation is:

$$T = \overline{T} + A\,[\sin (K + P)] \qquad (2)$$

where T, in degrees Celcius, is the estimated stream temperature at time of year K; $\overline{T}$, in degrees Celcius, is the mean of the harmonic and assumed to be the mean-annual stream temperature characteristic; A, in degrees Celcius, is the amplitude characteristic of the harmonic and is equal to the range in stream temperature above and below the mean, $\overline{T}$, when $\overline{T}$ is greater than 0°C; and P, in radians, is the phase shift characteristic in the equation. The time variable, K, in radians, is equal to the number of days since January 1 multiplied by the conversion factor, k, where:

$$k = 2\pi/366 = 0.0172 \text{ radians/day}$$

Equation 2 is described graphically in figure 2. Because of the occurrence of the phase shift, P, in the sine function equation 2 cannot be conveniently analyzed to determine the variables $\overline{T}$, A, and P. However, the equation can be rewritten in an alternate form

$$T = \overline{T} + b_1 \sin K + b_2 \cos K \qquad (3)$$

where

$$A = \sqrt{b_1^{\,2} + b_2^{\,2}} \qquad (4)$$

and

$$P = \tan^{-1} b_1/b_2 \qquad (5)$$

Ward (1963) and Thomann (1967) further describe the derivation of the equation. In its alternate form (equation 3) the harmonic equation can then be analyzed using regression techniques. Using the general regression equation (1) the stream temperature, T, observed at time K is used as the dependent variable, Y, and sin K and cos K are used as the independent variables, X_1 and X_2, respectively. Given multiple sets of values of T, sin K and cos K the regression can then solve for the constant, $\overline{T}$, and coefficients, b_1 and b_2. Subsequently, the amplitude coefficient, A, and phase coefficient, P, can be calculated using equations 4 and 5, respectively.

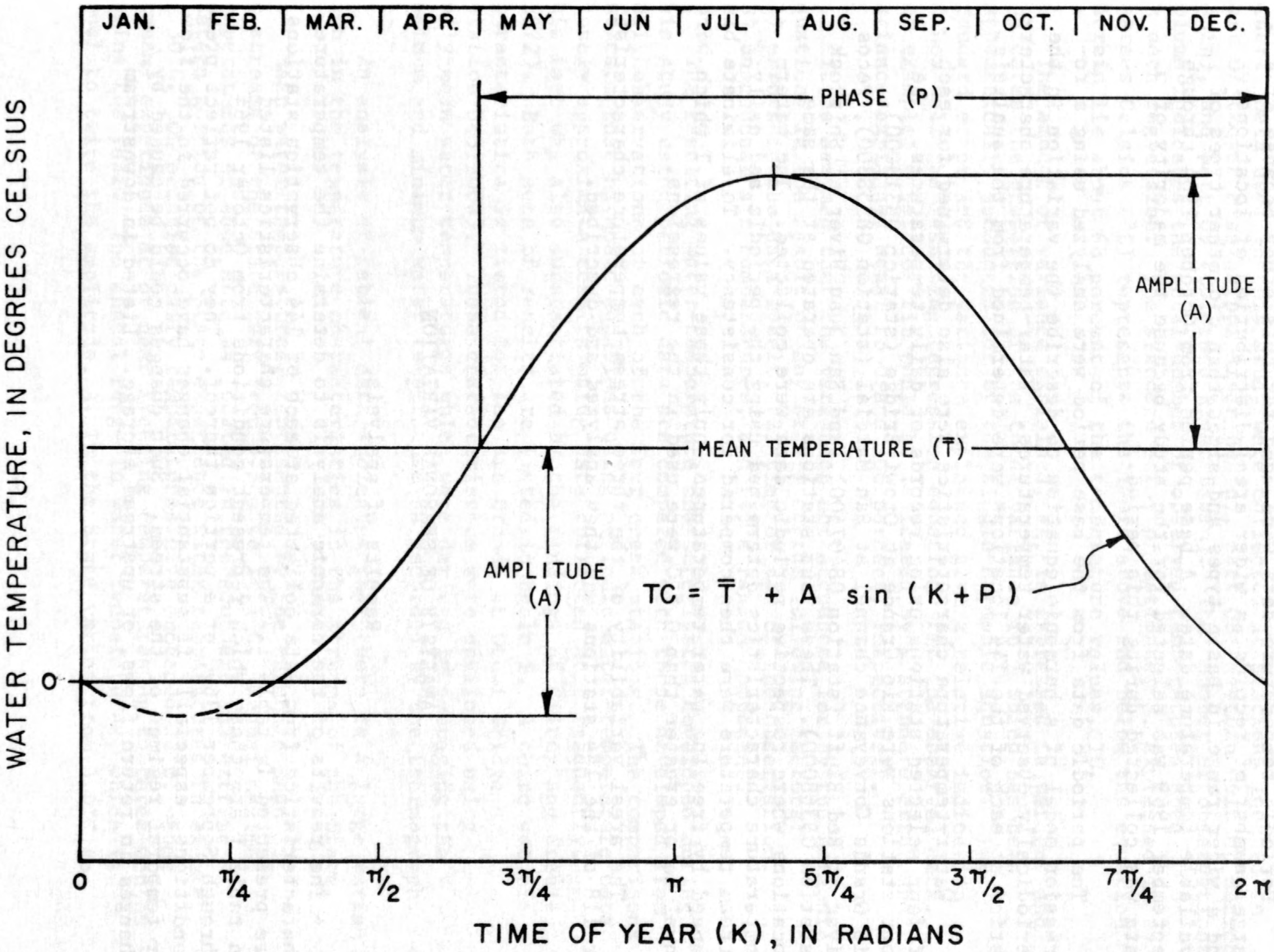

Figure 2.--Typical model for describing annual variation in observed water temperature.

General approach

Periodic temperature data were used for this study because of a larger number of records, a wider areal distribution of locations, and a wider range in basin types and sizes than did other types of available temperature data. A base period from October 1964 through September 1969 was selected for the study because the majority of data was collected during this period.

The periodic data from the base period were analyzed using a regression model of a harmonic equation to describe the variation in the periodically observed water temperatures. Water-temperature characteristics at each of the 144 locations were determined from the analysis.

Water-temperature characteristics were also determined for each of four selected stations using records of daily temperatures. The four stations were Rio Grande at Otowi Bridge (station 08313000), Rio Grande Conveyance channel at San Marcial (station 08358300), Pecos River at Red Bluff (station 08407500), and San Juan River at Shiprock (station 09368000). These four stations are operated at the same locations where respective periodic data were collected. The water-temperature characteristics determined using the periodic and daily stream temperature were then compared for consistancy. To eliminate bias caused by freezing water temperatures, only those values of T which were equal to or greater than 0.5°C were used in the regressions.

The areal variability of the three stream-temperature characteristics at 118 of the 144 stations was then analyzed and described.

ANALYSIS OF SEASONAL VARIATION

Results of analysis

The results of the harmonic analysis to determine the temperature characteristics from data collected at each of 144 observation stations are presented in table 1. The temperature characteristics listed in table 1 are those which represent conditions from October 1964 through September 1969, or a portion thereof. They do not reflect present conditions, especially if substantial changes have occurred in the flow or temporal regimen of the stream. Such changes could be caused by changes in return flows, or upstream storage. Listed in downstream order are the number and name of those stations for which harmonic equations were developed. All surface-water sites have been assigned unique eight-digit station numbers. The first two digits indicate the "part" and the remaining six digits indicate the station location in downstream order. Data used in this study were collected at stations located in part 07 (Lower Mississippi River Basin), part 08 (Western Gulf of Mexico Basin), and part 09 (Colorado River Basin). The "number of observations" column indicates the total number of observed temperatures used in each regression. The standard error of estimate, S, expressed in degrees Celsius (°C) represents the limit above and below the equation wherein lie about 68 percent of the temperature values, TC.

The amount of variance explained, VE, is expressed in percent and indicates the proportion of the total variance in T which has been mathematically accounted for by the single-harmonic equation. The standard error and the variance explained give a relative indication of how well the resulting regression equations fit the observed data. For example, a perfect fit would be indicated by a standard error and variance explained equal to 0 and 100 percent, respectively.

It is assumed that the variation not accounted for by the harmonic equations is the result of any or all of the following factors: (1) errors in the data itself, (2) time of day of the observation, (3) unseasonal air temperatures, and (4) a random component.

The resulting water-temperature characteristics developed during this study using periodic data are compared with those developed from daily observations at each of the four check stations. The comparisons indicate that harmonic equations using periodic water-temperature data closely approximate results using data collected more frequently. This fact was also substantiated by the findings of Gilroy and Steele (1972). Both sets of results are listed in table 1. A third set of characteristics is listed for the Rio Grande at Otowi Bridge (station 08313000). These characteristics were developed using daily-mean water temperatures which were derived by averaging the maximum and minimum water temperature as recorded by the thermograph.

An analysis of table 1 data indicates that there is a large variation in the temperature characteristics in the streams of the State.

Mean water temperatures, represented by the harmonic mean, $\overline{T}$, in streams of the State vary from 4.3°C to 21.1°C. Annual maximum temperatures of some streams located in the southern and extreme eastern portion of the State experience water temperatures in excess of 30°C. On occasion daily temperatures have exceeded 34°C. Some streams experience at or near freezing temperatures up to three months during the year. The annual range in water temperatures, which is equal to twice the amplitude, A, in the State varies from 3.6°C to

23.6°C. Analysis of the phase coefficients, P, indicates that annual maximum stream temperatures in natural streams generally occur during the month of July. Maximum stream temperatures immediately downstream from large storage reservoirs occur later than those experienced in natural streams, normally during August. Prime examples of the effects of upstream storage are reflected in all three temperature characteristics at Pecos River below Alamagordo Dam (station 08384500) and San Juan River near Archuleta (station 09355500) which is located below Navajo Dam. In both cases there was substantial storage during the period of record used for the analysis, thus causing smaller amplitude characteristics, A; lower mean temperatures, $\overline{T}$; and higher phase coefficients, P. The effects of storage were not as pronounced at other stations located downstream from reservoirs due primarily to the fact that at many times flows were being routed through empty or near empty reservoirs.

At locations where stream temperatures are affected by significant spring or ground-water inflow annual maximums usually occur in June. The identification of streams whose water temperatures are affected by spring-flow or ground-water contributions is not as simple as identification of those affected by reservoir storage. However, known locations where stream temperatures are affected by ground-water discharges include: Red River at mouth near Questa (station 08267000), Rio San Jose near Grants (station 08343500), Black River at Harkey Crossing (station 08405400), Mimbres River near Mimbres (station 08477000), and Tularosa River above Aragon (station 09442692). The primary effect of spring or ground-water flow on stream temperatures is to dampen the amplitude characteristic, A, reflecting the relatively constant temperature of the ground-water discharge. The magnitude of this effect depends on the proximity of the point of discharge to the point of measurement; the effect is lessened by greater distances which allow ambient air temperature and solar radiation to influence the stream temperatures.

A typical example of the effects of large industrial return flows is reflected in the mean water temperature, $\overline{T}$, for the Pecos River at Carlsbad (station 08405000). This station is located about one-half mile downstream from the point of discharge of cooling water from a steam generator plant. The effect in this case is an increased mean water temperature, $\overline{T}$

Twenty-one stations experience freezing stream temperatures during winter months. This is indicated by harmonic equations whose amplitude, A, is greater than its respective mean, $\overline{T}$. All of the 21 stations are located in the State's northern mountains.

Table 1.--Station temperature characteristics

STATION NUMBER: 8-DIGIT STATION IDENTIFIER. SEE TEXT FOR EXPLANATION. ASTERISK(*) INDICATES STATION DATA WERE USED IN REGIONAL ANALYSIS.
STATION NAME: ABBREVIATIONS USED IN STATION NAMES-AB, ABOVE; BL, BELOW; C, CREEK; CA, CANAL; CH, CHANNEL; CON, CONVEYANCE; EF, EAST FORK; MF, MIDDLE FORK; NF, NORTH FORK; SF, SOUTH FORK; NR, NEAR; R, RIVER; RES, RESERVOIR TR, TRIBUTARY
TYPE OF RECORD: P, PERIODIC OBSERVATIONS; DAO, DAILY OBSERVATIONS; DRX, DAILY RECORDED MAXIMUM; DRN, DAILY RECORDED MINIMUM; DCM, DAILY COMPUTED MEAN
NUMBER OF OBSERVATIONS: NUMBER OF OBSERVED, RECORDED OR COMPUTED TEMPERATURES WHICH WERE USED AND WERE GREATER THAN 0.5 DEGREES CELSIUS
CHARACTERISTICS: TEMPERATURE CHARACTERISTICS AS DERIVED FROM THE HARMONIC EQUATIONS- $\overline{T}$, IN DEGREES CELSIUS, MEAN TEMPERATURE; A, IN DEGREES CELSIUS, AMPLITUDE; P, IN RADIANS, PHASE
EQUATION STATISTICS: MEASURES OF RELIABILITY OF THE HARMONIC EQUATIONS-S, IN DEGREES CELSIUS, STANDARD ERROR OF ESTIMATE; VE, IN PERCENT, THE AMOUNT OF VARIABILITY EXPLAINED

STATION NUMBER	STATION NAME	TYPE OF RECORD	NUMBER OF OBSER-VATIONS	CHARACTERISTICS $\overline{T}$ (°C)	A (°C)	P (RAD)	EQUATION STATISTICS S (°C)	VE (%)
	ARKANSAS RIVER BASIN							
*07153500	DRY CIMARRON R NR GUY NM	P	71	16.3	11.3	4.45	4.9	71
*07199000	CANADIAN R NR HEBRON NM	P	64	11.5	9.7	4.52	4.1	72
*07202000	CHICORICA C NR HEBRON NM	P	45	9.5	8.8	4.32	4.6	60
*07203000	VERMEJO R NR DAWSON NM	P	77	12.9	9.8	4.46	3.4	79
*07205000	SIXMILE C NR EAGLE NEST NM	P	48	8.1	9.6	4.44	3.8	64
*07206200	MCEVOY C NR EAGLE NEST NM	P	35	7.0	4.7	4.24	1.7	81
*07206300	TOLBY C NR EAGLE NEST NM	P	23	6.2	5.2	4.53	3.2	46
*07206400	CLEAR C NR UTE PARK NM	P	33	5.3	5.9	4.23	2.1	73
*07207000	CIMARRON R NR CIMARRON NM	P	61	9.6	6.7	4.41	3.1	68
*07207500	PONIL C NR CIMARRON NM	P	54	10.9	10.5	4.44	4.5	71
*07208500	RAYADO C AT SAUBLE RANCH NR CIMARRON NM	P	76	9.9	8.2	4.43	3.0	78
*07211000	CIMARRON R AT SPRINGER NM	P	57	13.7	9.8	4.50	4.7	66
*07211500	CANADIAN R AT TAYLOR SPRING NM	P	33	15.4	9.7	4.63	5.4	56
*07214500	MORA R NR HOLMAN NM	P	59	10.0	7.8	4.39	3.2	71
*07214800	RIO LA CASA NR CLEVELAND NM	P	66	8.2	6.5	4.38	2.2	78
07215000	LA CUEVA CA AT LA CUEVA NM	P	74	10.1	7.4	4.31	3.3	70
*07215500	MORA R AT LA CUEVA NM	P	62	10.5	6.3	4.50	3.8	57
*07216500	MORA R NR GOLONDRINAS NM	P	58	10.3	7.4	4.61	3.8	62
*07217100	COYOTE C AB GUADALUPITA NM	P	74	9.5	7.7	4.49	2.8	77
*07218000	COYOTE C NR GOLONDRINAS NM	P	64	12.4	7.8	4.43	3.4	70
*07220000	SAPELLO R AT SAPELLO NM	P	79	10.1	8.1	4.37	4.1	66
*07221000	MORA R AT SHOEMAKER NM	P	77	10.5	9.7	4.42	2.4	89

Table 1.--Station temperature characteristics - Continued

STATION NUMBER	STATION NAME	TYPE OF RECORD	NUMBER OF OBSER-VATIONS	CHARACTERISTICS $\overline{T}$ (°C)	A (°C)	P (RAD)	EQUATION STATISTICS S (°C)	VE (%)
	ARKANSAS RIVER BASIN - CONTINUED							
*07221500	CANADIAN R NR SANCHEZ NM	P	83	15.5	10.7	4.48	3.5	82
*07222500	CONCHAS R AT VARDIADERO NM	P	74	16.8	9.9	4.48	4.4	72
07224500	CANADIAN R BL CONCHAS DAM NM	P	57	13.3	7.6	4.14	2.4	84
*07226500	UTE C NR LOGAN NM	P	43	15.6	11.5	4.40	2.6	89
07227000	CANADIAN R AT LOGAN NM	P	89	19.7	10.5	4.54	3.6	81
*07227100	REVUELTO C NR LOGAN NM	P	114	17.7	10.2	4.50	4.0	74
	RIO GRANDE BASIN							
08254000	COSTILLA C BL COSTILLA DAM NM	P	47	6.4	7.3	4.09	3.2	50
*08255500	COSTILLA C NR COSTILLA NM	P	88	7.3	7.3	4.28	3.0	68
*08263000	LATIR C NR CERRO NM	P	77	5.3	6.0	4.37	2.5	69
*08263500	RIO GRANDE NR CERRO NM	P	29	9.3	8.9	4.37	2.5	86
*08264500	RED R BL ZWERGLE DAMSITE NR RED RIVER NM	P	63	5.5	5.8	4.26	2.3	71
*08265000	RED R NR QUESTA NM	P	64	7.9	7.3	4.30	2.9	70
*08266000	CABRESTO C NR QUESTA NM	P	65	7.1	6.8	4.33	2.5	73
08267000	RED R AT MOUTH NR QUESTA NM	P	58	9.6	5.3	4.26	2.6	67
*08267500	RIO HONDO NR VALDEZ NM	P	67	5.5	6.0	4.25	2.1	77
*08268200	RIO HONDO AT DAMSITE AT VALDEZ NM	P	23	6.5	6.6	4.08	2.6	72
*08268500	ARROYO HONDO AT ARROYO HONDO NM	P	76	9.3	7.6	4.25	3.2	74
*08268700	RIO GRANDE NR ARROYO HONDO NM	P	73	9.3	7.8	4.25	3.0	76
*08269000	RIO PUEBLO DE TAOS NR TAOS NM	P	60	6.5	7.0	4.34	2.5	77
*08271000	RIO LUCERO NR ARROYO SECO NM	P	73	5.1	5.7	4.28	2.2	71
*08275000	RIO FERNANDO DE TAOS NR TAOS NM	P	86	7.8	7.4	4.30	3.2	69
*08275300	RIO PUEBLO DE TAOS NR RANCHITO NM	P	71	9.9	8.8	4.32	3.4	75
*08275500	RIO GRANDE DEL RANCHO NR TALPA NM	P	86	8.0	8.1	4.25	3.3	70
*08275600	RIO CHIQUITO NR TALPA NM	P	69	7.3	8.2	4.32	3.2	71
*08276300	RIO PUEBLO DE TAOS BL LOS CORDOVAS NM	P	96	9.7	8.9	4.23	3.1	78
*08276500	RIO GRANDE BL TAOS JUNCTION BRIDGE NR TAOS NM	P	57	10.2	8.6	4.32	3.3	76
*08279000	EMBUDO C AT DIXON NM	P	70	10.9	7.4	4.32	3.5	65
*08279500	RIO GRANDE AT EMBUDO NM	P	72	10.2	7.7	4.34	2.7	79
*08284100	RIO CHAMA NR LA PUENTE NM	P	76	8.3	8.0	4.09	3.0	72
*08284200	WILLOW C AB HERON RES NR LOS OJOS NM	P	83	8.1	9.1	4.28	3.7	70
*08284250	WILLOW C AT STEEL BRIDGE NR LOS OJOS NM	P	75	9.4	9.7	4.25	3.9	71
08285500	RIO CHAMA BL EL VADO DAM NM	P	35	9.7	8.6	4.14	2.2	88
*08286500	RIO CHAMA AB ABIQUIU RES NM	P	85	10.2	9.6	4.23	3.4	77
08287000	RIO CHAMA BL ABIQUIU DAM NM	P	65	10.1	7.8	4.27	2.8	82

Table 1.--Station temperature characteristics - Continued

STATION NUMBER	STATION NAME	TYPE OF RECORD	NUMBER OF OBSER-VATIONS	CHARACTERISTICS T̄ (°C)	A (°C)	P (RAD)	EQUATION STATISTICS S (°C)	VE (%)
	RIO GRANDE BASIN - CONTINUED							
*08287500	RIO CHAMA NR ABIQUIU NM	P	83	10.7	8.9	4.18	3.4	76
*08289000	RIO OJO CALIENTE AT LA MADERA NM	P	109	11.3	9.2	4.19	3.2	80
*08290000	RIO CHAMA NR CHAMITA NM	P	132	11.6	9.0	4.21	3.8	69
*08291000	SANTA CRUZ R AT CUNDIYO NM	P	84	8.6	7.0	4.39	4.3	52
*08295200	RIO EN MEDIO NR SANTA FE NM	P	39	5.0	5.0	4.24	2.8	56
*08302200	NF TESUQUE C NR SANTA FE NM	P	26	4.5	6.0	4.03	2.8	63
*08302300	MF TESUQUE C NR SANTA FE NM	P	22	5.3	3.4	3.87	3.0	35
*08302400	SF TESUQUE C NR SANTA FE NM	P	30	4.6	5.1	4.31	2.7	58
*08304100	LITTLE TESUQUE C NR SANTA FE NM	P	23	4.3	5.0	4.16	2.2	70
*08304200	LITTLE TESUQUE C TR 4 NR SANTA FE NM	P	26	5.9	7.0	4.26	3.3	65
*08313000	RIO GRANDE AT OTOWI BRIDGE NR SAN ILDEFONSO PUEBLO NM	P	151	10.9	8.8	4.28	2.7	83
---DO---	----------DO--	DAO	1764	14.2	10.2	4.38	2.1	91
---DO---	----------DO--	DRX	1762	14.3	10.2	4.38	2.1	92
---DO---	----------DO--	DRN	1646	10.2	9.1	4.33	2.2	93
---DO---	----------DO--	DCM	1764	12.1	9.7	4.36	2.1	92
*08313350	RITO DE LOS FRIJOLES IN BANDELIER NATIONAL MONUMENT NM	P	105	8.7	7.6	4.25	2.5	80
*08314500	RIO GRANDE AT COCHITI NM	P	113	12.5	10.6	4.32	2.9	85
08316000	SANTA FE R NR SANTA FE NM	P	39	9.2	6.7	4.24	2.1	85
*08319000	RIO GRANDE AT SAN FELIPE NM	P	89	12.7	10.8	4.28	2.5	88
*08321500	JEMEZ R BL EF NR JEMEZ SPRINGS NM	P	89	9.1	9.2	4.32	2.8	83
*08323000	RIO GUADALUPE AT BOX CANYON NR JEMEZ NM	P	78	9.9	10.3	4.28	3.2	81
*08324000	JEMEZ R NR JEMEZ NM	P	93	12.1	9.8	4.29	3.3	81
*08329500	RIO GRANDE NR BERNALILLO NM	P	162	13.8	10.5	4.39	3.5	81
*08330000	RIO GRANDE AT ALBUQUERQUE NM	P	250	13.0	9.9	4.38	3.1	83
*08331990	RIO GRANDE CON CH NR BERNARDO NM	P	231	14.0	10.7	4.42	3.0	87
*08332010	RIO GRANDE FLWY NR BERNARDO NM	P	74	15.1	9.2	4.44	3.2	77
08332050	BERNARDO INTERIOR DRAIN NR BERNARDO NM	P	111	16.8	6.3	4.54	2.9	69
*08342000	BLUEWATER C NR BLUEWATER NM	P	43	11.3	9.0	4.56	3.1	78
08343500	RIO SAN JOSE NR GRANTS NM	P	52	13.8	4.1	4.43	3.5	44
08354500	SOCORRO MAIN CA N AT SAN ACACIA NM	P	155	15.3	8.6	4.46	2.9	68
*08354800	RIO GRANDE CON CH AT SAN ACACIA NM	P	183	14.5	10.5	4.40	2.8	87
*08354900	RIO GRANDE FLWY NR SAN ACACIA NM	P	221	16.5	8.1	4.35	3.7	68
08356000	SOCORRO MAIN CA S NR SAN ANTONIO NM	P	89	14.0	9.7	4.36	2.9	75
08356500	SAN ANTONIO RIVSD DRAIN NR SAN ANTONIO NM	P	128	16.7	7.1	4.47	2.6	77
08357000	ELMENDORF INTERIOR DRAIN NR SAN ANTONIO NM	P	109	16.4	9.1	4.45	2.7	83
08357500	SAN ANTONIO RIVSD DRAIN NR SAN MARCIAL NM	P	135	15.1	9.0	4.39	2.4	87
*08358300	RIO GRANDE CON CH AT SAN MARCIAL NM	P	256	14.0	9.6	4.45	2.5	88

Table 1.--Station temperature characteristics - Continued

STATION NUMBER	STATION NAME	TYPE OF RECORD	NUMBER OF OBSER-VATIONS	CHARACTERISTICS T (°C)	A (°C)	P (RAD)	EQUATION STATISTICS S (°C)	VE (%)
	RIO GRANDE BASIN - CONTINUED							
08358300	RIO GRANDE CON CH AT SAN MARCIAL NM	DAO	1671	13.5	9.4	4.44	2.4	87
*08358400	RIO GRANDE FLWY AT SAN MARCIAL NM	P	97	15.1	9.0	4.32	2.8	68
*08377900	RIO MORA NR TERRERO NM	P	72	5.7	7.0	4.29	2.9	67
*08378500	PECOS RIVER NR PECOS NM	P	71	6.6	6.9	4.30	2.4	78
*08379500	PECOS RIVER NR ANTON CHICO NM	P	97	16.4	9.2	4.43	3.4	77
*08380500	GALLINAS C NR MONTEZUMA NM	P	59	9.9	7.6	4.57	3.6	64
*08381000	GALLINAS C AT MONTEZUMA NM	P	38	12.7	7.7	4.53	3.5	73
*08382500	GALLINAS R NR COLONIAS NM	P	26	13.6	10.1	4.21	3.8	49
*08382800	PECOS R AB LOS ESTEROS DAMSITE NR SANTA ROSA NM	P	59	16.4	9.0	4.54	3.7	73
*08383000	PECOS R AT SANTA ROSA NM	P	127	15.2	7.9	4.46	4.1	65
*08383500	PECOS R NR PUERTO DE LUNA NM	P	126	15.8	9.7	4.38	3.6	78
08384500	PECOS R BL ALAMAGORDO DAM NM	P	96	15.2	9.2	4.19	2.4	88
08385000	FORT SUMNER MAIN CA NR FORT SUMNER NM	P	74	16.1	9.9	4.29	3.3	76
*08385520	PECOS R BL FORT SUMNER NM	P	88	17.5	10.8	4.40	4.7	73
*08385620	PECOS R BL YESO ARROYO NR FORT SUMNER NM	P	64	18.0	11.8	4.36	3.9	82
*08385640	PECOS R AB HUGGINS C NR ROSWELL NM	P	70	16.7	11.1	4.41	4.1	78
*08386000	PECOS R NR ACME NM	P	192	16.3	10.2	4.39	3.7	79
*08387000	RIO RUIDOSO AT HOLLYWOOD NM	P	101	12.2	7.0	4.43	3.0	74
*08390500	RIO HONDO AT DIAMOND A RANCH NR ROSWELL NM	P	59	15.6	7.4	4.40	3.8	47
08390800	RIO HONDO BL DIAMOND A DAM NR ROSWELL NM	P	51	15.9	7.1	4.28	3.3	54
08394100	PECOS R NR HAGERMAN NM	P	45	18.2	10.2	4.45	3.3	84
*08395500	PECOS R NR LAKE ARTHUR NM	P	170	16.1	10.5	4.42	2.6	88
*08396500	PECOS R NR ARTESIA NM	P	228	16.7	10.3	4.38	3.2	83
*08399500	PECOS R (KAISER CH) NR LAKEWOOD NM	P	135	17.4	10.3	4.43	3.2	83
08401000	PECOS R BL MCMILLAN DAM NM	P	46	18.0	7.6	4.30	2.3	73
*08402000	PECOS R AT DAMSITE 3 NR CARLSBAD NM	P	102	17.3	8.5	4.43	2.3	86
08403500	CARLSBAD MAIN CA AT HEAD NR CARLSBAD NM	P	55	17.4	9.0	4.39	2.7	71
08405000	PECOS R AT CARLSBAD NM	P	123	21.1	8.6	4.45	3.0	79
*08405270	BLACK R BL MAYES RANCH NR WHITE CITY NM	P	28	18.6	4.1	4.30	1.7	74
08405400	BLACK R AT HARKEY CROSSING NR MALAGA NM	P	30	19.4	1.8	4.52	1.3	50
*08405500	BLACK R AB MALAGA NM	P	76	17.3	9.3	4.44	3.5	78
*08406500	PECOS R NR MALAGA NM	P	102	18.4	9.3	4.46	2.7	85
*08406510	PECOS R AT FISHING ROCK CROSSING NR MALAGA NM	P	55	18.1	9.5	4.46	3.4	79
*08407000	PECOS R AT PIERCE CANYON CROSSING NR MALAGA NM	P	130	19.9	9.8	4.52	2.5	88
*08407500	PECOS R AT RED BLUFF NM	P	111	19.3	10.2	4.53	3.2	83
---DO---	-----------DO-----------	DAO	1781	20.0	10.7	4.48	2.3	90
*08408500	DELAWARE R NR RED BLUFF NM	P	94	16.9	9.9	4.52	3.1	82

Table 1.--Station temperature characteristics - Concluded

STATION NUMBER	STATION NAME	TYPE OF RECORD	NUMBER OF OBSER-VATIONS	CHARACTERISTICS $\bar{T}$ (°C)	A (°C)	P (RAD)	EQUATION STATISTICS S (°C)	VE (%)
	MIMBRES RIVER BASIN							
*08476300	MIMBRES R AT MCKNIGT DAMSITE NR MIMBRES NM	P	24	15.7	7.3	4.31	3.6	65
08477000	MIMBRES R NR MIMBRES NM	P	63	16.0	3.5	4.11	2.7	48
	TULAROSA VALLEY							
*08481500	RIO TULAROSA NR BENT NM	P	82	14.1	8.3	4.61	2.5	85
	SAN JUAN RIVER BASIN							
*09346400	SAN JUAN R NR CARRACAS CO	P	84	7.9	7.6	4.16	2.8	71
*09349800	PIEDRA R NR ARBOLES CO	P	91	8.9	7.0	4.14	2.9	71
*09354500	LOS PINOS R AT LA BOCA CO	P	94	9.5	7.9	4.37	2.3	78
*09355000	SPRING C AT LA BOCA CO	P	79	8.3	7.8	4.39	2.4	76
09355500	SAN JUAN R NR ARCULETA NM	P	155	8.3	3.8	3.86	2.3	59
*09363500	ANIMAS R NR CEDAR HILL NM	P	115	9.0	6.9	4.20	2.8	70
*09364500	ANIMAS R AT FARMINGTON NM	P	134	10.4	7.9	4.26	2.5	80
*09365000	SAN JUAN R AT FARMINGTON NM	P	154	10.5	8.1	4.23	2.9	78
*09368000	SAN JUAN R AT SHIPROCK NM	P	181	11.0	8.5	4.31	2.8	81
---DO---	----------DO-------------	DAO	1752	13.4	9.3	4.40	2.8	83
	GILA RIVER BASIN							
09430150	SAPELLO C BL LK ROBERTS NR SILVER CITY NM	P	66	15.5	9.2	4.42	1.8	92
*09430500	GILA R NR GILA NM	P	118	13.9	8.0	4.39	2.5	84
*09430600	MOGOLLON C NR CLIFF NM	P	43	12.5	9.4	4.41	2.9	85
*09431500	GILA R NR REDROCK NM	P	98	14.0	9.1	4.38	2.4	87
*09442680	SAN FRANCISCO R NR RESERVE NM	P	69	13.9	9.5	4.35	3.3	80
09442692	TULAROSA R AB ARAGON NM	P	40	16.2	6.4	4.65	2.6	76
*09443000	SAN FRANCISCO R NR ALMA NM	P	78	16.0	9.9	4.54	3.9	77
*09444000	SAN FRANCISCO R NR GLENWOOD NM	P	122	15.9	7.2	4.35	3.7	65

AREAL DESCRIPTION OF TEMPERATURE CHARACTERISTICS

One of the purposes of this investigation was to describe the stream temperatures areally within the State. To accomplish this, variations in stream-temperature characteristics were evaluated in terms of selected basin and meteorological parameters. Trends in the temperature characteristics on major streams were also described graphically using stream-temperature profiles. The respective temperature characteristic was plotted against the distance (river mile) of the observation site above the stream's mouth.

Regional regression

The model used to determine the regional descriptive equations was a multiple-regression function which described each of the coefficients of the harmonic equation, as dependent variables, in terms of various basin and meteorological characteristics, the independent variables (similar to equation 1). Initially, the multiple-regression technique computes the coefficients of an equation which relates the dependent variable to all of the independent variables. Coefficients for each of the independent variables are then evaluated based on their significance to the overall equation. The least significant independent variable is deleted and a new equation computed relating the dependent variable to the remaining independent variables. The process is repeated until only those independent variables which are significant at the 95 percent level remain in the equation.

Independent variables selected for this analysis and used in the regression were:

LA = Latitude minus 30°.

LO = Longitude minus 100°.

DA = Drainage area, in square miles.

TA_7= Mean July air temperature at the nearest meteorological station, in degrees Fahrenheit.

DF = Difference between mean July and mean January air temperatures at nearest meterological station, in degrees Fahrenheit.

RO = Runoff, mean annual yield, in inches.

A list of those independent variables which were significant at the 95 percent level or higher in describing temperature characteristics in the regional regressions is contained in table 2.

Table 2.--Independent variables for stations used in regional regression analysis

STATION NUMBER: 8-DIGIT STATION IDENTIFIER. SEE TEXT FOR EXPLANATION.
REGION: REGION IN WHICH STATION IS LOCATED. SEE TEXT FOR EXPLANATION.
INDEPENDENT VARIABLES: HYDROLOGIC AND PHYSICAL BASIN CHARACTERISTICS USED AS INDEPENDENT VARIABLES IN THE REGIONAL REGRESSION-LA, IN DEGREES, LATITUDE OF STATION; LO, IN DEGREES, LONGITUDE OF STATION; DA, IN SQUARE MILES, DRAINAGE AREA; TA-7, IN DEGREES FAHRENHEIT, MEAN JULY AIR TEMPERATURE; DF, IN DEGREES FAHRENHEIT, DIFFERENCE BETWEEN MEAN JULY AND MEAN JANUARY AIR TEMPERATURES; RO, IN INCHES, MEAN ANNUAL RUNOFF.

STATION NUMBER	REGION	INDEPENDENT VARIABLES					
		LA	LO	DA	TA-7	DF	RO
07153500	1	36.99	103.42	545.00	72.2	41.5	.28
07199000	1	36.92	104.46	229.00	64.7	38.3	.49
07202000	1	36.78	104.40	381.00	64.7	38.3	.45
07203000	1	36.68	104.79	301.00	65.3	35.2	.87
07205000	1	36.53	105.27	10.50	61.0	42.1	3.44
07206200	1	36.55	105.23	1.95	61.0	42.1	1.45
07206300	1	36.53	105.23	8.50	61.0	42.1	2.90
07206400	1	36.53	105.18	7.44	61.0	42.1	4.13
07207000	1	36.52	104.98	294.00	70.3	38.1	.95
07207500	1	36.57	104.95	171.00	70.3	38.1	.98
07208500	1	36.37	104.97	65.00	70.3	38.1	3.03
07211000	1	36.36	104.60	1032.00	71.5	41.5	.25
07211500	1	36.30	104.49	2850.00	71.5	41.5	.48
07214500	1	36.11	105.38	57.00	65.6	37.6	3.31
07214800	1	35.97	105.39	23.00	61.3	32.1	8.50
07215500	1	35.94	105.25	173.00	61.3	32.1	2.23
07216500	1	35.90	105.16	267.00	61.3	32.1	1.78
07217100	1	36.16	105.23	71.00	65.6	37.6	1.91
07218000	1	35.92	105.16	215.00	61.3	32.1	.74
07220000	1	35.77	105.25	132.00	68.7	38.0	2.32
07221000	1	35.80	104.78	1104.00	68.7	38.0	.73
07221500	1	35.65	104.38	6015.00	78.3	41.7	.49
07222500	1	35.40	104.44	523.00	79.2	44.3	.44
07226500	1	35.44	103.53	2060.00	79.8	44.8	.18
07227100	1	35.34	103.39	786.00	79.8	44.8	.97
08255500	2	36.97	105.51	195.00	66.8	44.9	2.98
08263000	2	36.83	105.55	10.50	66.8	44.9	7.81
08263500	2	36.74	105.68	5500.00	66.8	44.9	.90
08264500	2	36.67	105.38	25.70	58.1	38.7	9.98
08265000	2	36.70	105.57	113.00	66.8	44.9	6.49
08266000	2	36.73	105.55	36.70	66.8	44.9	3.55
08267500	2	36.54	105.56	36.20	68.6	44.1	13.24
08268200	2	36.54	105.60	40.30	68.5	44.1	10.11
08268500	2	36.53	105.69	65.60	68.6	44.1	5.75
08268700	2	36.53	105.71	5820.00	68.5	44.1	1.31
08269000	2	36.44	105.50	66.60	68.6	44.1	6.01
08271000	2	36.51	105.53	16.60	68.6	44.1	18.56
08275000	2	36.37	105.55	71.70	68.6	44.1	1.26
08275300	2	36.39	105.62	199.00	68.6	44.1	1.95
08275500	2	36.30	105.58	83.00	68.6	44.1	3.29
08275600	2	36.38	105.58	37.00	68.6	44.1	3.09
08276300	2	36.37	105.67	380.00	68.6	44.1	1.79
08276500	2	36.32	105.75	6790.00	68.5	44.1	1.46
08279000	2	36.21	105.91	305.00	72.4	43.2	3.50
08279500	2	36.21	105.96	7460.00	68.5	44.1	1.86
08284100	2	36.66	106.63	480.00	64.0	40.9	8.88
08284200	2	36.74	106.63	112.00	64.0	40.9	1.27
08284250	2	36.29	106.79	130.00	64.0	40.9	1.26
08286500	2	36.32	106.60	1500.00	67.0	45.4	3.24
08289000	2	36.35	106.04	419.00	72.4	43.2	2.23
08290000	2	36.07	106.11	3144.00	74.0	47.2	2.34
08291000	2	35.96	105.90	86.00	72.4	43.2	4.56
08295200	2	35.79	105.80	.63	70.5	40.6	17.19
08302200	2	35.77	105.81	1.60	70.5	40.6	12.73
08302300	2	35.77	105.81	.43	70.5	40.6	9.47
08302400	2	35.76	105.81	.47	70.5	40.6	7.22
08304100	2	35.74	105.64	.64	70.5	40.6	3.63
08304200	2	35.74	105.83	.69	70.5	40.6	2.16
08313000	2	35.87	106.14	11360.00	74.0	47.2	1.83
08313350	2	35.78	106.28	17.50	67.9	39.3	.92
08314500	2	35.63	106.32	11660.00	78.5	44.0	1.52
08319000	2	35.44	106.44	13160.00	78.5	44.0	1.43

Table 2.--Independent variables for stations used in regional regression analysis - Concluded

STATION NUMBER	REGION	INDEPENDENT VARIABLES LA	LO	DA	TA-7	DF	RO
08321500	2	35.83	106.65	173.00	71.0	38.1	2.06
08323000	2	35.73	106.76	235.00	71.0	38.1	1.88
08324000	2	35.66	106.74	470.00	71.0	38.1	1.89
08329500	1	35.28	106.60	14360.00	78.5	44.0	1.01
08330000	1	35.09	106.68	14460.00	78.5	44.0	1.00
08331990	1	34.41	106.80	16290.00	75.1	42.2	.41
08332010	1	34.42	106.80	16290.00	75.1	42.2	.20
08342000	1	35.29	108.03	209.00	71.2	42.9	.60
08354800	1	34.25	106.90	23830.00	75.1	42.2	.29
08354900	1	34.26	106.89	23830.00	75.1	42.2	.16
08358300	2	33.69	106.99	24760.00	80.3	38.7	.28
08358400	2	33.68	106.99	24760.00	80.3	38.7	.10
08377900	2	35.77	105.66	53.20	61.3	32.1	7.14
08378500	2	35.71	105.68	189.00	70.5	40.6	7.05
08379500	1	35.18	105.11	1050.00	76.7	41.1	1.73
08380500	1	35.65	105.32	84.00	68.3	38.3	3.17
08381000	1	35.65	105.28	87.00	69.1	38.3	2.98
08382500	1	35.18	104.90	610.00	76.7	41.1	.36
08382800	1	35.04	104.68	2430.00	77.1	42.6	.51
08383000	1	34.94	104.70	2650.00	76.7	41.1	.72
08383500	1	34.73	104.52	3970.00	76.7	41.1	.74
08385520	1	34.35	104.17	5600.00	78.2	40.8	.07
08385620	1	34.23	104.23	7000.00	78.2	40.8	.05
08385640	1	33.92	104.28	7800.00	80.3	43.3	.03
08386000	1	33.54	104.38	11380.00	80.3	43.3	.24
08387000	1	33.33	105.61	120.00	63.3	32.7	1.33
08390500	1	33.35	104.85	947.00	78.6	40.7	.34
08395500	1	32.99	104.32	14760.00	80.0	39.2	.24
08396500	1	32.84	104.32	15300.00	80.0	39.2	.32
08399500	1	32.69	104.30	16700.00	80.0	39.2	.12
08402000	1	32.51	104.33	17980.00	80.0	39.6	.13
08405270	1	32.06	104.48	116.00	78.9	33.3	.18
08405500	1	32.23	104.15	343.00	81.5	39.8	.59
08406500	1	32.21	104.02	19100.00	80.0	39.6	.19
08406510	1	32.23	104.00	19200.00	80.0	39.6	.17
08407000	1	32.19	103.98	19260.00	80.0	39.6	.12
08407500	1	32.08	104.04	19540.00	80.0	39.6	.14
08408500	1	32.02	104.05	689.00	81.5	39.8	.29
08476300	1	32.93	108.02	97.30	70.2	35.6	.72
08481500	1	33.13	105.90	120.00	78.8	33.6	1.07
09346400	1	37.01	107.31	1230.00	66.0	41.1	6.97
09349800	2	37.09	107.40	629.00	66.0	41.1	7.08
09354500	2	37.01	107.60	510.00	74.0	46.4	5.11
09355000	2	37.01	107.60	58.00	74.0	46.4	6.72
09363500	2	37.04	107.87	1090.00	73.8	44.8	11.10
09364500	2	36.72	108.20	1360.00	76.5	45.3	9.24
09365000	2	36.72	108.23	7240.00	76.5	45.3	4.57
09368000	2	36.80	108.73	12900.00	74.2	43.7	2.35
09430500	2	33.06	108.54	1864.00	76.9	40.8	.93
09430600	1	33.16	108.65	69.00	76.9	40.8	1.97
09431500	1	32.72	108.68	2829.00	79.6	40.3	.93
09442680	1	33.74	108.77	350.00	72.3	40.7	.88
09443000	1	33.67	108.91	1546.00	76.7	37.8	.55
09444000	1	33.25	108.88	1653.00	76.7	37.8	.54

Temperature characteristics for all 144 stations were not used in the regional analysis. Deleted from the analysis were water-temperature characteristics for 28 stations influenced by upstream storage, significant spring or return flows, or were located on diversion canals. Temperature characteristics for the 116 stations used in the areal analysis are noted by an asterisk (*) in table 1.

Independent variables were initially selected using the assumption that they would relate to the variation in water temperature. Many independent variables were interrelated, which can have adverse effects in a multiple-regression analysis (Benson, 1965; Riggs, 1968). Only those independent variables which had a correlation coefficient of less than 0.6 when related to other independent variables were used in this analysis.

Riggs (1968) and Steele and Jennings (1972) showed that logarithmic transformation of hydrologic data frequently results in linear relations between dependent and independent variables. For this study base, ten transformations of both dependent and independent variables were used to compute the descriptive equations. The regression equation 1, when transformed, takes the form:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 \ldots + b_n \log X_n \qquad (6)$$

or

$$Y = a X_1^{b_1} X_2^{b_2} \ldots X_n^{b_n} \qquad (7)$$

After the initial regressions were derived which describe the harmonic mean temperature characteristic, $\overline{T}$, residuals were computed by subtracting the observed value of $\overline{T}$ from the computed value of $\overline{T}$ using the derived regional regression equation. The residuals for stations located below large drainages, generally greater than 2,500 square miles, indicated a large negative trend (computed values were considerably larger than observed values). Hence, two equations were developed--one for stations having drainage areas greater than 2,500 square miles (36 stations) and the other for stations with drainage areas less than 2,500 square miles. A residual analysis indicated that little bias remained for those stations located below large drainages and that the equation adequately described the mean temperature, $\overline{T}$, at those stations. Residuals computed for stations located on streams with drainage areas of less than 2,500 square miles indicated areal bias.

By plotting residuals according to station location on a State map it was noted that the residuals for stations in the north-central and northwest parts of the State were consistently negative. Based on these plots, the State was divided into two separate regions (fig. 1). New regression equations were determined using data from only those stations located within each respective region and having drainage areas less than 2,500 square miles. Region 2 contained 52 stations and included that part of the State generally west of the ridge line of the Sangre de Cristo Mountains and north of Interstate Highway 40. Region 1 encompassed the remainder of the State and consisted of 64 stations.

Definition of the computed regional mean temperature characteristic, $\overline{T}$, was generally improved for those stations in region 2 but remained basically the same or slightly poorer in region 1. Residuals computed from observed and computed mean temperature characteristics indicated considerably less bias and the regional equations were considered adequate for describing the mean temperature characteristics in the respective regions.

Three equations were derived to describe the mean temperature characteristic, $\overline{T}$; one for stations located below drainages larger than 2,500 square miles and two regional equations for stations located on streams with smaller drainages. Each step in arriving at the three equations--termed regionalization--generally resulted in better definition of the mean temperature characteristic. Regression equations had smaller standard errors of estimate and explained a greater amount of the variability in the dependent variable. Regionalized equations had average standard errors of less than 13.2 percent and explained at least 84 percent of the variability in the characteristic. The equation for drainages larger than 2,500 square miles had a standard error of estimate of 8.5 percent and explained 86 percent of the variability in $\overline{T}$.

Regionalization was used to better describe the amplitude characteristic, A, with the same basic results. Again, the bias indicated at stations located below large drainages was reduced by using one equation and areal bias was reduced by using two regional equations. The resulting equations described up to 79 percent of the variability in the amplitude characteristic.

Attempts to describe the variability of the phase charcteristic, P resulted in two equations. One equation describes P for those stations located below drainages greater than 2,500 square miles and one for all other stations. Although the standard errors of estimate are less than 3 percent, the equations explained less than 50 percent of the variability.

The results of the regional regression analysis to describe all temperature characteristics are presented in table 3. The table lists the simplest, usable equation to describe each temperature characteristic for each region. Also listed are the standard error of estimate, S, and the amount of variability explained, VE, for each equation.

Generally, the equations describing the mean temperature characteristic, $\overline{T}$, are adequate as indicated by relatively small standard errors of estimate and relatively large amounts of the explained variability. Although the equations which attempted to describe the amplitude, A, and phase, P, characteristics resulted in relatively small standard errors of estimate, the amount of the variability explained was rather small, which leaves considerable question as to their usefulness. Only the equation, which describes the amplitude characteristic, A, for stations located on drainages less than 2,500 square miles in region 2, can be considered adequate.

Stream-temperature characteristic profiles

In order to describe the trend in the three stream-temperature characteristics, as the flow progresses downstream, temperature characteristic profiles were constructed for the Canadian River, Rio Grande, Rio Chama, Pecos River, and the San Juan River (figs. 3-7). This was done only for five major streams which had at least four observation sites where stream-temperature charactertistics had been defined. Each of the characteristics were plotted against river mile, miles above the mouth, for each of the respective streams. The results show how the stream-temperature characteristics are affected by various physiographic and artificial influences such as reservoirs or return flows.

Dashed lines between points indicate the trend of the respective characteristic as they change between observation sites. Slopes of these lines were arbitrarily broken at specific locations to indicate estimated changes affected by reservoir storage. The breaks are located at the approximate point where the normal pool elevation of the reservoir intersects the water surface of the inflowing stream and at the respective dam.

Because the dashed lines represents only the trend in the respective characteristic they should not be used to interpolate values of characteristics between observation sites.

Table 3.--Regression equations describing temperature characteristics

Temperature characteristics	Region	Area Size (mi^2)	Regression equation	Percent S	Percent VE
$\bar{T}$	1	<2,500	$\bar{T} = 0.0502\ DA^{0.0463}\ TA_7^{1.93}\ DF^{-0.810}\ RO^{-0.645}$	12.6	84.0
	2	<2,500	$\bar{T} = 0.0263\ DA^{0.0895}\ TA_7^{1.30}\ RO^{-0.135}$	10.6	86.9
	1 and 2	>2,500	$\bar{T} = 0.00471\ LO^{-0.234}\ TA_7^{1.93}\ RO^{-0.074}$	8.5	86.2
A	1	<2,500	$A = 4.40\ LA^{0.161}\ DA^{0.0660}$	15.5	45.5
	2	<2,500	$A = 0.0182\ DA^{0.377}\ RO^{1.82}$	10.2	79.3
	1 and 2	>2,500	$A = 0.0206\ LA^{0.166}\ TA_7^{1.35}\ RO^{-0.0449}$	9.0	41.2
P	1 and 2	<2,500	$P = 2.36\ LO^{0.0231}\ DF^{0.0946}\ RO^{0.0105}$	2.9	33.9
	1 and 2	>2,500	$P = 1.47\ LO^{0.0330}\ DF^{0.213}$	2.3	49.5

All independent variables are those described in table 2 and are significant at the 95 percent level.

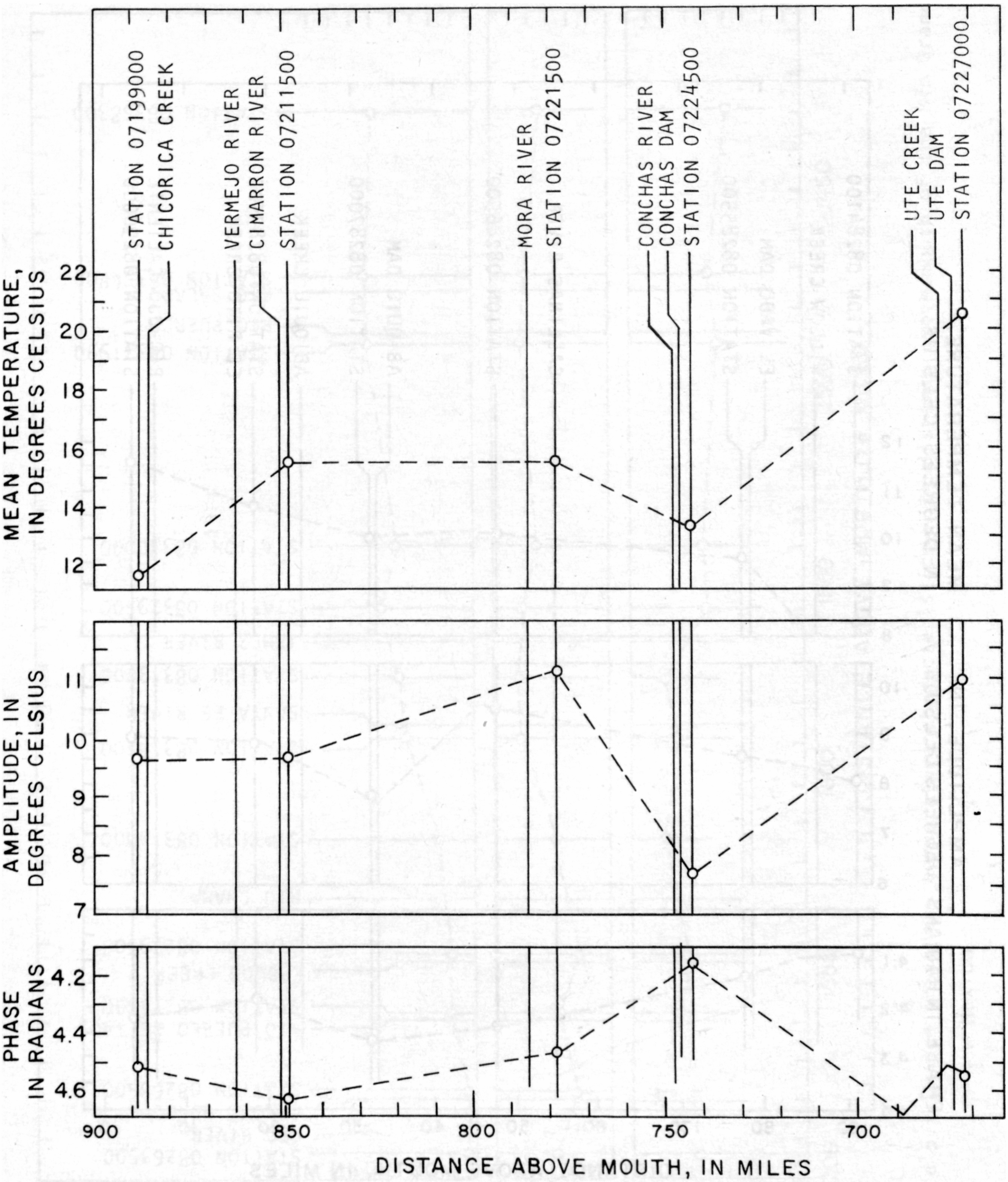

Figure 3.--Change in stream temperature characteristics with distance above mouth of the Canadian River, New Mexico.

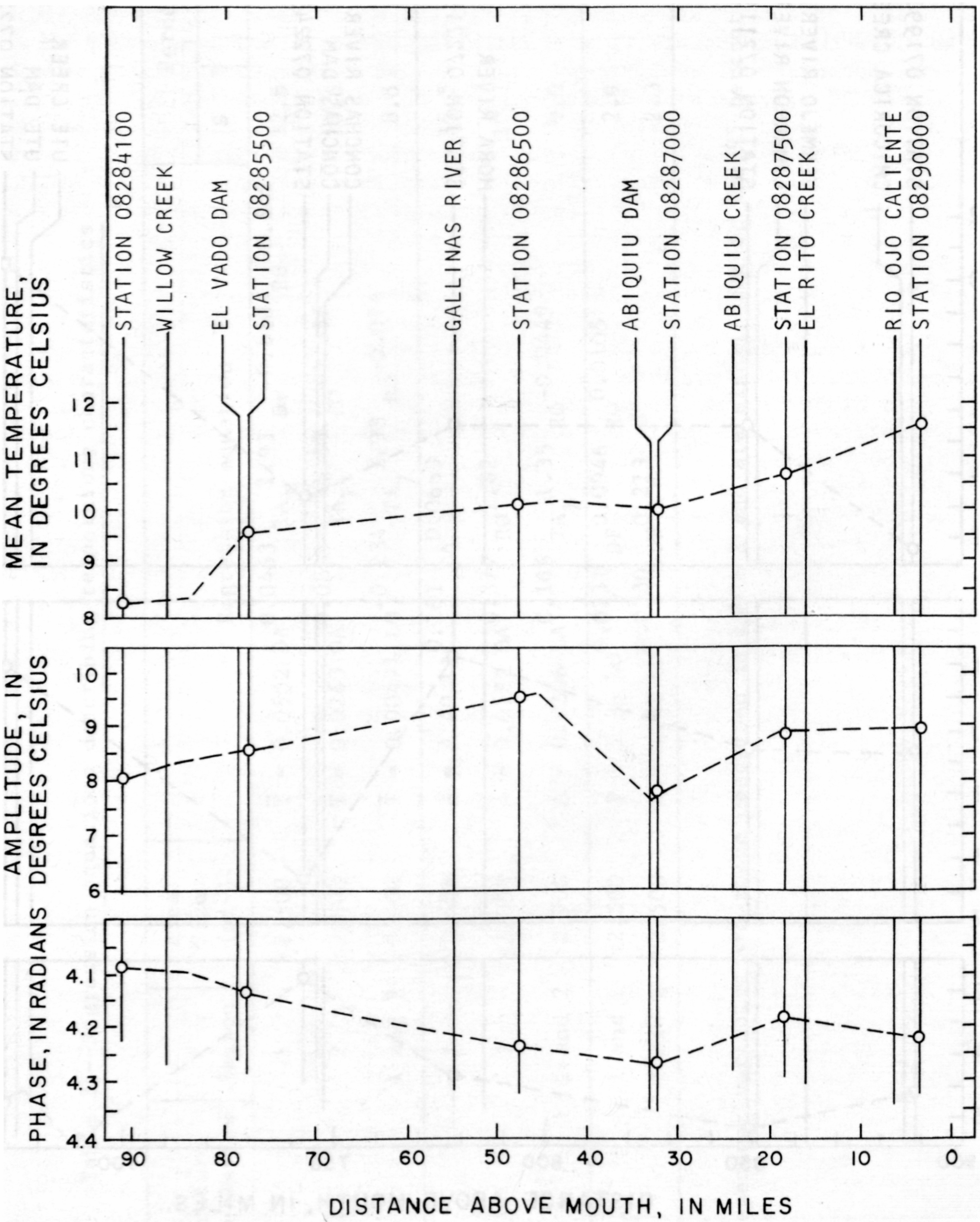

Figure 4.--Change in stream temperature characteristics with distance above mouth of Rio Chama, New Mexico.

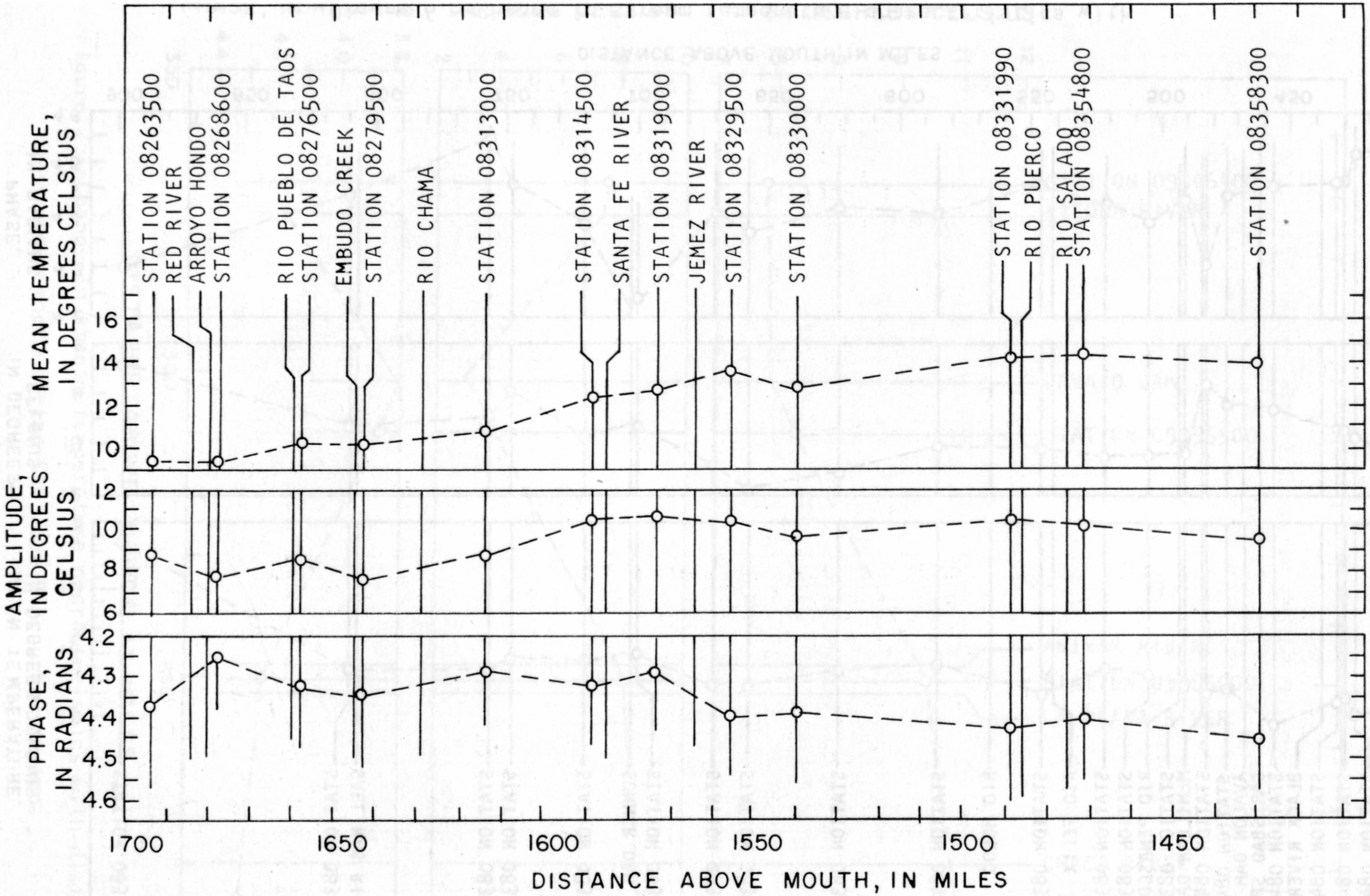

Figure 5.--Change in stream temperature characteristics with distance above mouth of the Rio Grande, New Mexico.

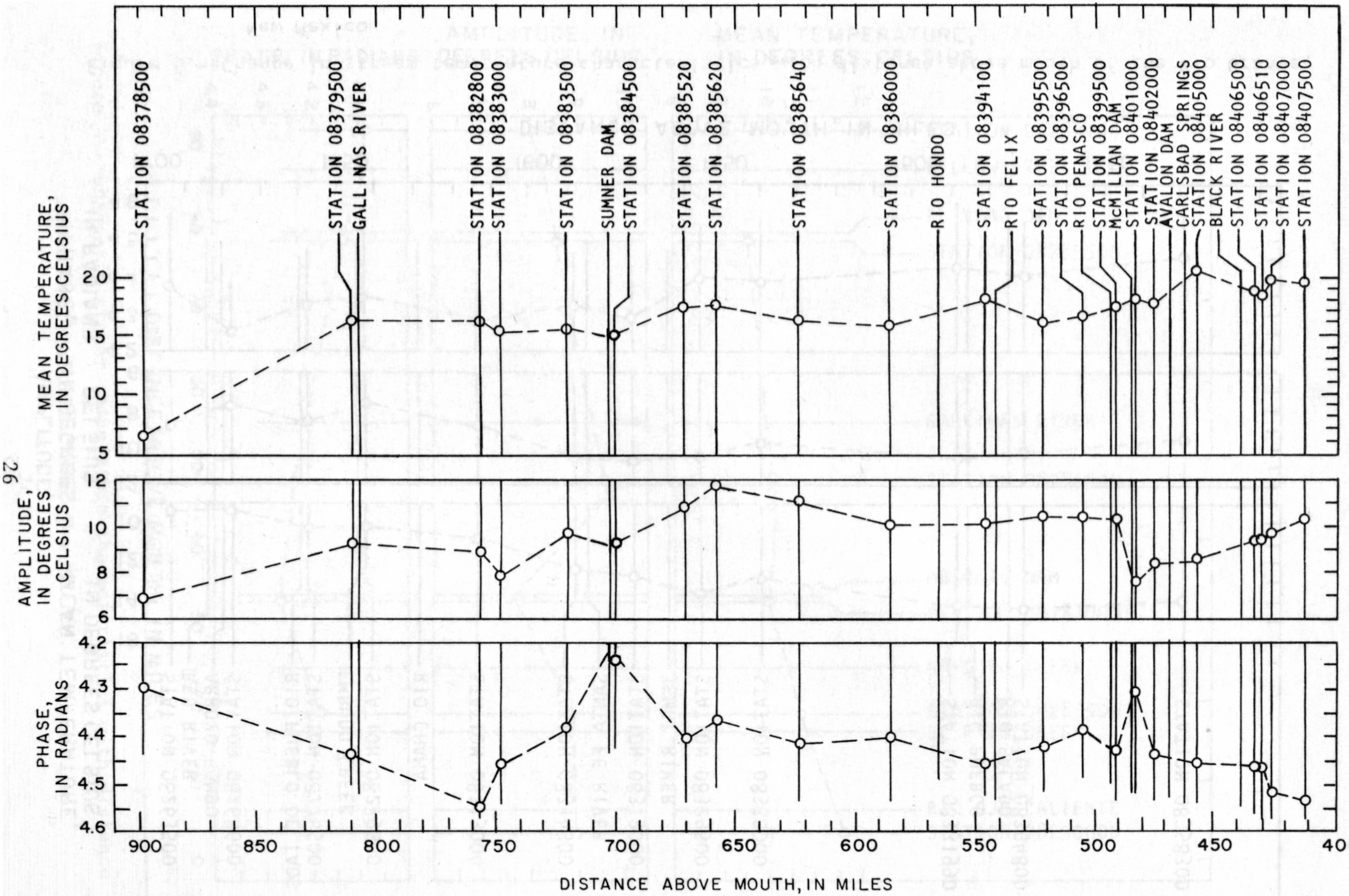

Figure 6.--Change in stream temperature characteristics with distance above mouth of the Pecos River, New Mexico.

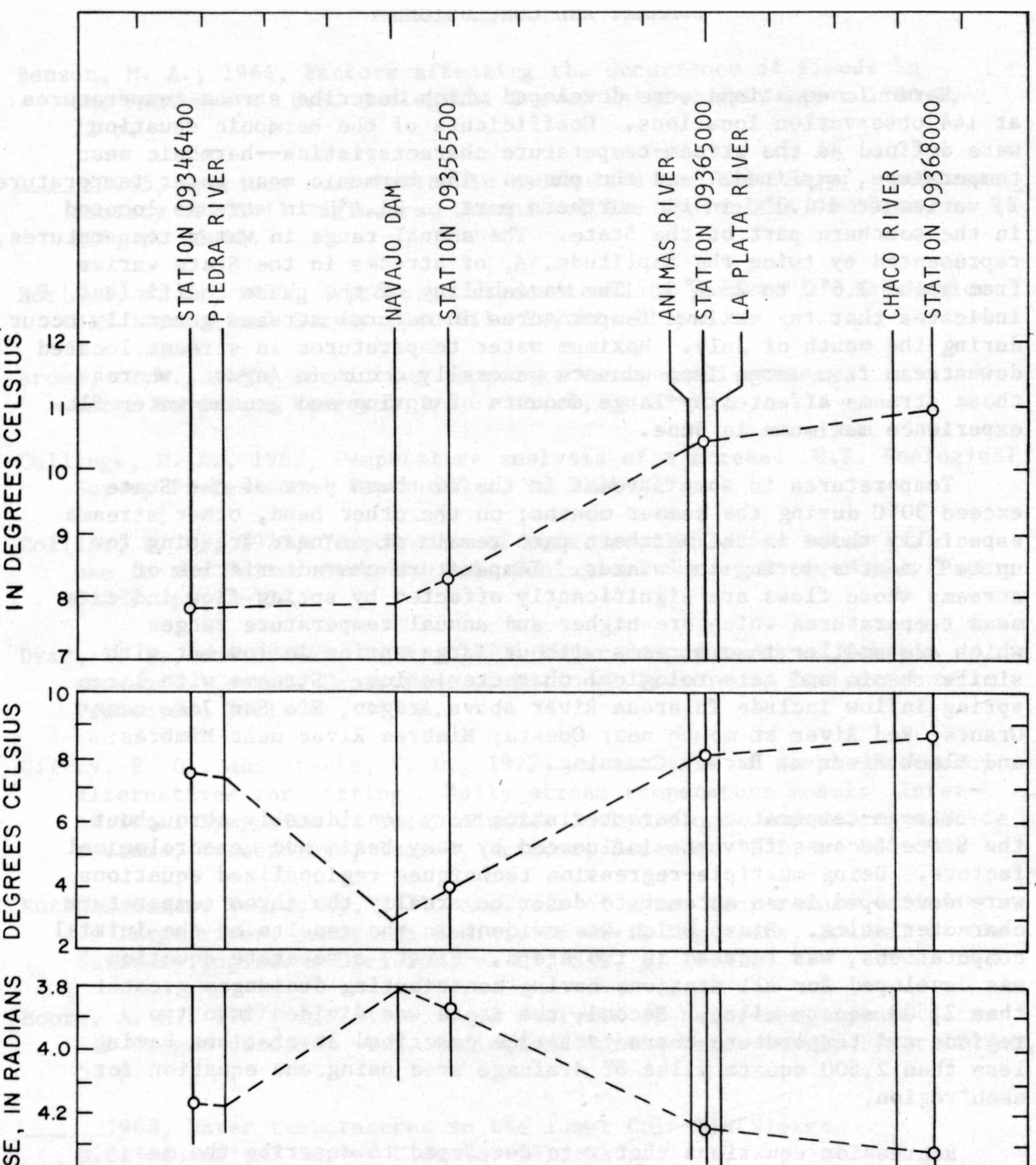

Figure 7.--Change in stream temperature characteristics with distance above mouth of the San Juan River, New Mexico.

SUMMARY AND CONCLUSIONS

Harmonic equations were developed which describe stream temperatures at 144 observation locations. Coefficients of the harmonic equation were defined as the stream-temperature characteristics--harmonic mean temperature, amplitude, and the phase. The harmonic mean water temperature, $\overline{T}$, varies from 4.3°C in the northern part to 21.1°C in streams located in the southern part of the State. The annual range in water temperatures, represented by twice the amplitude, A, of streams in the State varies from about 3.6°C to 23.6°C. The variability of the phase coefficient, P, indicates that the maximum temperatures in natural streams generally occur during the month of July. Maximum water temperatures in streams located downstream from large impoundments generally occur in August, whereas those streams affected by large amounts of spring and ground-water flow experience maximums in June.

Temperatures in some streams in the southern part of the State exceed 30°C during the summer months; on the other hand, other streams especially those in the northern part remain at or near freezing for up to 3 months during the winter. Temperature characteristics of streams whose flows are significantly affected by spring flow indicate mean temperatures which are higher and annual temperature ranges which are smaller than streams without large spring inflow but with similar basin and meteorological characteristics. Streams with large spring inflow include Tularosa River above Aragon; Rio San Jose near Grants; Red River at mouth near Questa; Mimbres River near Mimbres; and Black River at Harkey Crossing.

Stream-temperature characteristics vary considerably throughout the State because they are influenced by many basin and meteorological factors. Using multiple-regression techniques regionalized equations were developed in an attempt to describe areally the three temperature characteristics. Bias, which was evident in the results of the initial computations, was reduced in two steps. First, a separate equation was developed for all stations having contributing drainages greater than 2,500 square miles. Second, the State was divided into two regions and temperature characteristics described at stations having less than 2,500 square miles of drainage area using one equation for each region.

Regression equations that were developed to describe the mean temperature characteristic, $\overline{T}$, accounted for at least 84 percent of the variability with standard errors of estimate less than 12.8 percent. Only one equation is considered adequate for describing the amplitude, A. That equation is for streams located in region 2 which have contributing drainages less than 2,500 square miles. No equation was developed which describes the variability in the phase characteristic, P.

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