Generalization of Stream-Temperature Data in Washington

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2029–B

Prepared in cooperation with the State of Washington Department of Ecology

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By M. R. COLLINGS

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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By M. R. Collings

ABSTRACT

The effect of water temperature on the ecosystem of streams necessitates an analysis of various physical characteristics that influence stream temperatures. This study was conducted to determine (1) the effective relations that define site-to-site variation in stream temperatures, (2) equations and methods to estimate stream temperatures at sites where little or no data are now available, and (3) a procedure to evaluate the effect of water impoundment on natural stream temperatures.

Statistical multiple-regression analyses were used to develop equations for relations between stream temperatures and topographic and climatic characteristics of the drainage basins.

Multiple-regression techniques, generally, produced more accurate equations for estimating temperatures of streams in western Washington than for those in eastern Washington. A standard error of estimate was used to show how precisely stream temperatures may be defined by air-temperature and topographic drainage-basin characteristics. Of 24 original parameters tested, 15 were found effective to determine the equations of one or more of the 15 stream-temperature characteristics.

Effects of holding reservoirs on downstream water temperatures may be evaluated by the use of harmonic curves of probable maximum and minimum stream temperatures. By examples, it was shown that (1) below a hydroelectric-power dam winter-minimum river temperatures were raised and occur 9 days later than they would under natural conditions; and (2) below a flood-control dam, which also augments natural flows during low-flow periods, summer-minimum river temperatures were raised and occur 4 days earlier than they would under natural conditions.

INTRODUCTION

IMPORTANCE OF STREAM TEMPERATURES

In the field of water-quality control, temperature is recognized as one of the most important physical characteristics of water. Water temperatures have a direct influence on fish and other aquatic life, chemical and biological reactions, water treatment, toxicity of contaminants, taste, odor and general quality of domestic water, and industrial and agricultural water uses.

Increases in water temperatures affect fish by increasing their metabolic rates and oxygen requirements, increasing their sensitivity to toxic materials, and reducing swimming speeds (Burrows, 1963, p. 29–35).

The effects that temperatures have on concentrations of dissolved oxygen and rates of biochemical oxygen demand and on aquatic life are well documented (Wurtz and Renn, 1965) and must be considered in any program of water-quality control.

For domestic water treated before consumption, the flocculation and sedimentation rates increase with temperature increase, and the effects of chlorine on bacteria are greater at higher water temperatures (McKinney, 1962). Water is usually considered satisfactory for drinking when it is at or below 10°C (Celsius) or 50°F, but when it is at temperatures above 18.5°C (65°F), noticeable tastes and odors may occur. However, pathogens survive longer at lower temperatures (Everts, 1963).

Agriculturists prefer water above 15.5°C (60°F) for irrigation; return irrigation flows usually increase temperatures in receiving streams.

Thermal stratification in water impoundments on streams will modify the natural water temperature and oxygen concentration in the waters downstream from the impoundments. In turn, this affects the aquatic life, as does heat in water used for industrial- and powerplant-cooling purposes (Arnold, 1962).

More knowledge of the effect of water uses and watershed activity is needed to establish reasonable objectives and practical procedures to adjust and control water temperatures.

PREVIOUS TEMPERATURE STUDIES

Results of regional stream-temperature investigations generally have been presented in one of the following ways: (1) basic data listing maximum and minimum daily recorded temperatures, daily observed temperatures, and (or) irregularly measured temperatures (U.S. Geol. Survey, 1947–67; Aagaard, 1969; Moore, 1964); (2) basic-data listing, supplemented by results from regression relations among thermograph data, daily observations, and (or) irregular observations of stream temperatures and, in some cases, air temperatures—these regression relations were used to fill gaps in the record (Moore, 1969; Nece, 1968); and (3) by energy-budget equations and model-study results (Delay and others, 1964).

Moore (1969) published downstream water-temperature profiles of selected reaches of rivers in the Columbia River basin, to show the effects of dams and tributary inflow on the temperature of water in the main stem of the Columbia River.

Collings and Higgins (1972) presented stream-temperature data for the State of Washington in maps of the amplitudes, maximums, minimums, and medians of stream temperature.

PURPOSE AND SCOPE

Objectives of this study were to: (1) statistically describe and define the relation between natural stream temperatures and the topographic and climatic drainage-basin characteristics that are most effective in explaining the site-to-site variations in those stream temperatures, (2) present a procedure to estimate water temperatures at sites where little or no stream-temperature data are now available, and (3) use selected examples to show how the effect of water impoundment on natural stream temperatures may be evaluated.

Stream-temperature data were investigated for more than 400 sites; about 300 of these were west of the Cascade Range. Temperature data for the main stem of the Columbia River were omitted from this report because the river has unique or anomalous stream temperatures compared to those of most other rivers in the State and because a complex individual stream-temperature study of the Columbia River is beyond the scope of this report.

ACKNOWLEDGMENTS

This study was authorized by a cooperative agreement between the State of Washington Department of Ecology and the U.S. Geological Survey. The constructive criticism and suggestions by colleagues D. R. Dawdy and J. E. Cummans of the Geological Survey were of great benefit in preparation of the final report.

DATA USED IN THIS ANALYSIS

STREAM-TEMPERATURE DATA

Measurements of stream temperatures made at irregular intervals are the most basic method of collecting these data. Measurements are made at a site on a stream by the use of a thermometer or other type of noncontinuous recording device, usually at the time streamflow measurements are obtained by personnel of the Geological Survey. These temperature data are generally collected from 6 to 15 times a year.

More complete data can be obtained by hiring an observer to measure water temperatures at a preestablished frequency. Observation frequency may be hourly, bihourly, twice daily, daily, weekly, monthly, or at some other set time interval.

A third type of temperature-data collection is the placement of a maximum-minimum self-registering thermometer in the stream and the recording of the highest and lowest stream temperatures for the period between visits to that site.

A thermograph is the most complete and adequate type of water-temperature data-collection device. This instrument continuously records the temperature of the water at a selected site. Maximum, minimum, and mean daily temperatures are readily obtained from a thermograph record.

The analyses of stream temperatures in Washington were made from data from the 307 temperature-collecting sites shown in figure 1. Data which were only seasonal, or had fewer than eight temporally well-spaced observations a year, were not used in the analysis. Unnatural data, such as data collected downstream from a point of thermal discharge or below an impoundment which may contain thermally stratified water, were not used for the regression analyses. Anomalous data, from naturally occurring thermal springs which would not be characteristic of most stream temperatures of a basin, were not included; nor were data not representative of that basin or stream because of the sampling location on the stream or in the channel cross section. However, some controlled and unnatural stream-temperature data were used in this report in other analyses and evaluations.

For a determination of the characteristics of the cyclic nature of Washington stream temperatures, to index the temperature differences from site to site, the basic data for each site were fitted to a harmonic curve (Collings, 1969) of the form

$$T=M+A[\sin(0.0172d+C)]$$

where T is stream temperature, in degrees Celsius (°C), on day d, with d varied from 1 to 366 (January first as day 1); M is the mean annual water temperature, in °C; A is the annual amplitude of the stream-temperature curve, in °C; and C is the phase coefficient of the cycle, in radians (fig. 2).

At stream sites where thermograph records are available, the maximum, mean, and minimum daily stream temperatures for each year were fitted to the harmonic curve. In addition, when the record covered a sufficient period of years, monthly frequency distributions were determined. The monthly temperature frequency curves were assumed, for operational purposes, to be normally distributed. Harmonic curves, which define the 95-percent probability of occurrence of maximum and minimum temperatures (table 1)—equaling or less than maximum temperature and exceeding or equaling minimum temperature—were derived from data obtained from the frequency distributions (Collings, 1969, p. B178).

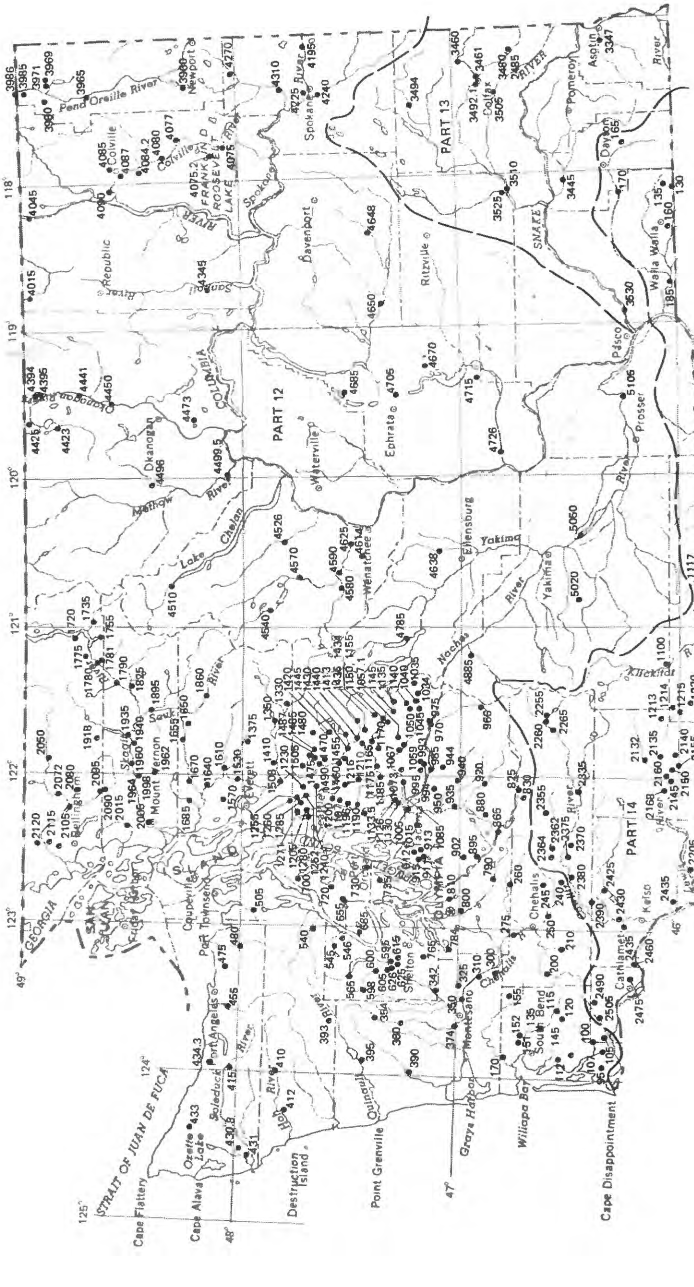

Figure 1.—Map of Washington showing sites of stream-temperature data collection by the U.S. Geological Survey for analysis in this study. Numbers are permanently assigned in U.S. Geological Survey numbering system and are shown in tables 7–10, with numbers prefixed by part number.

Figure 3 shows an example of fitted maximum, mean, and minimum probable stream temperatures. Also, from the frequency dis-

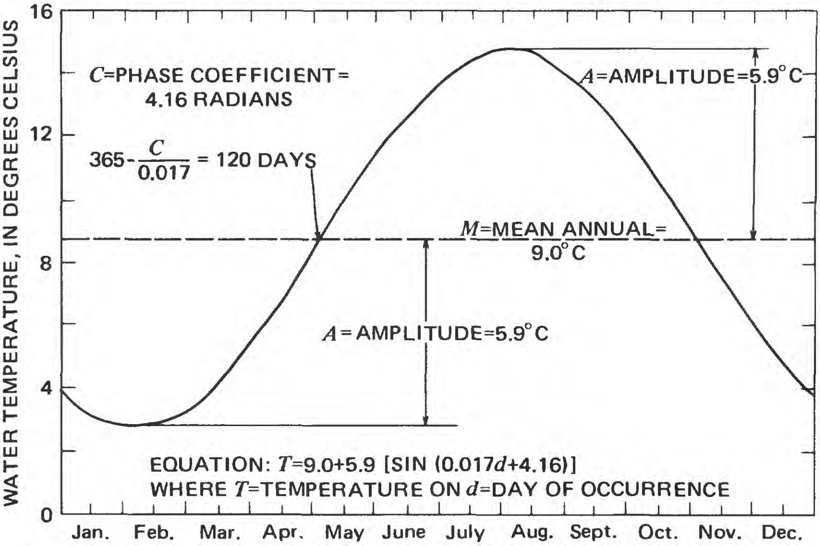

FIGURE 2.—Typical harmonic-fitted temperature graph showing mean stream-temperature curve, for station 12–0830, Mineral Creek near Mineral.

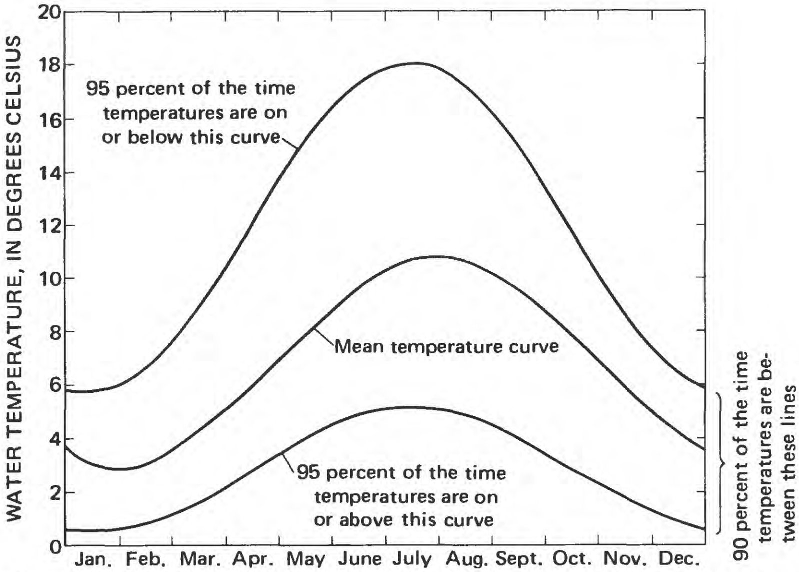

FIGURE 3.—Typical harmonic-fitted temperature graph, computed from thermograph records, showing the 90-percent confidence interval about the maximum and minimum stream temperatures, for station 12–0825, Nisqually River near National.

tributions, the standard deviations (*SD*) of the mean monthly temperatures for each month of the year were calculated for use in the regression analysis.

The values of *M*, *A*, and *C* for each stream-temperature data-collection site and of *M*, *A*, *C*, and *SD* for each long-term thermograph station, are listed in table 7.

TOPOGRAPHIC DATA

Topographic characteristics of the basins, as used in this analysis (tables 9 and 10, end of report), are defined by Benson (1962) and Collings (1971) except for definition of stream orientation which, measured in degrees from true north, is the average direction of flow of the main stem above the site of the water-temperature observation.

TABLE 1.—*Stream-temperature characteristics for probability curves, from thermograph sites in western Washington*

[Equation: $T=M+A\ [\sin\ (bx+C)]$. Characteristics of the mean temperature curves are listed in tables 7 and 8, along with the station name]

Station number (fig. 1)	95 percent probable maximum temperature (equal to or less than)			95 percent probable minimum temperature (equal to or greater than)			Beginning of record (year)
	Amplitude (°C)	Phase coefficient (radians)	Mean annual (°C)	Amplitude (°C)	Phase coefficient (radians)	Mean annual (°C)	
12–0115	6.4	4.47	14.7	6.0	4.32	6.0	1952
0275	9.2	4.37	16.3	7.0	4.28	7.5	56
0600	6.4	4.39	12.2	4.0	4.08	4.5	56
0615	5.6	4.45	12.7	3.0	4.05	5.5	57
0825	6.2	4.46	11.8	2.3	4.43	2.8	53
0830	8.4	4.28	13.2	5.0	4.23	5.0	52
1130 (see table 5)							
1175	5.7	4.43	11.8	3.9	4.18	6.3	54
1350	7.5	4.24	12.7	4.1	4.15	4.3	59
1640	8.0	4.37	13.4	5.3	4.27	4.8	53
1655	5.9	4.18	10.5	3.3	4.31	4.5	52
1685	9.8	4.32	14.3	5.4	4.17	5.0	54
1790	3.6	4.00	9.2	3.4	3.93	5.2	53
1825	4.6	4.35	9.8	3.2	4.20	3.5	53
2005	5.2	4.20	11.1	3.6	4.14	6.4	63
14–1100	5.3	4.22	8.6	3.7	4.26	2.9	51
1130	6.6	4.42	12.7	5.2	4.39	4.5	51
2205	6.5	3.62	12.1	2.9	3.84	5.9	51
2225	8.4	4.30	14.4	5.2	4.19	4.7	51
2235	6.4	4.34	12.8	4.3	4.26	5.2	55
2325	5.1	4.22	10.6	4.1	4.23	3.8	53
2335 (see table 3)							
2355	8.6	4.29	13.3	4.4	4.11	3.7	52
2380 (see table 3)							
2425	7.5	4.31	13.6	4.2	4.21	4.6	51
2430 (see table 3)							
2450	9.6	4.40	16.3	6.2	4.37	5.3	51
2460	6.2	4.37	13.8	3.9	4.27	4.5	52
2475	8.1	4.37	15.2	5.4	4.29	5.4	52
2505	6.4	4.39	14.2	4.6	4.06	5.6	52

CLIMATIC DATA

Normal air-temperature data from 79 climatic stations in Washington (U.S. Environmental Science Services Administration, 1967) were used to determine the cyclic characteristics of the normal air temperatures by means of fitting the data from each site to a harmonic curve. These characteristics of air temperatures (tables 9 and 10) were plotted on State maps, and lines were drawn of equal annual air-temperature amplitude (isallotherms; fig. 4), mean annual air temperature (isotherms; fig. 5), and the phase coefficient of the air temperature. The air-temperature amplitudes and mean annual air temperatures used in the regression analyses were obtained from these maps. The phase coefficient of air temperature was found to be not a significant factor for an estimate of stream temperatures, and therefore was omitted as a variable from tables 9 and 10.

The mean monthly air temperatures for western Washington only were plotted on State maps, and isotherms were drawn. Figures 6 and 7 show the mean monthly isotherms for January and February, and August and October, respectively. The mean monthly air temperatures at each stream-temperature thermograph station were determined from these mean monthly isotherm maps. January (T_1), February (T_2), August (T_8), and October (T_{10}) were the only months in which air temperatures improved the regression analysis of monthly standard deviations of stream temperatures, and therefore are the only months for which data are listed in table 8.

ANALYTICAL PROCEDURES

MULTIPLE-REGRESSION ANALYSIS

A statistical multiple-regression analysis was used to develop separately, for each stream-temperature characteristic, the relation between that characteristic (dependent variable) and the topographic and climatic-basin characteristics (independent variables). With the multiple-regresison techniques an equation is computed which defines relations between a dependent variable and the independent variables. Also provided is a measure of the usefulness of each independent variable to define the dependent variable and a measure of the accuracy of the resultant equation (standard error of estimate).

The standard error of estimate is a measure of how well an equation defines a dependent variable. The standard error encompasses about two-thirds of the dependent-variable site values used to determine the equation; doubling the standard error of estimate will encompass about 95 percent of the dependent-variable site values.

The usefulness of each independent variable is determined by the (1) intercorrelation coefficients—in this report if the intercorrelation coefficient between independent variables was greater than 0.5 (1.0 being perfect), one of the independent variables was omitted and the regression analysis recomputed; (2) statistical significance of the independent variable in relation to the dependent variable—all variables were tested at the 95-percent probability-of-effectiveness level; (3) variance-covariance coefficients, which allow computation of simple regressions and standard errors of estimate between any two independent variables or between a dependent and any one independent variable; and (4) amount by which the standard error of estimate was reduced when an independent variable was added to the regression equation.

Multiple-regression models are based on the linearity of the relation between the dependent variable and independent variables. In many hydrologic studies (Benson, 1962; Thomas and Benson, 1969; and Collings, 1971), findings showed that generally the variables were logarithmically linear. To satisfy the requisite of linearity, all data were transformed into logarithms (logs) and the calculations for the regression analysis were performed. In addition to the transformed model, analysis was performed on untransformed or natural data. The standard error of estimate, tests of significance, correlation coefficients, and variance-covariance relations were used as guides; thus, the multiple-regression analysis was performed several times with various combinations of transformed and untransformed variables until the most effective semilog regression equation was determined for each of the stream-temperature characteristics.

Standard deviations of monthly mean stream temperatures for long-term thermograph stations were also subjected to multiple-regression analysis (table 2). This allows the determination of the standard deviation of the mean monthly stream temperatures at any site on any stream in western Washington; thus, confidence-interval curves can be determined for the mean stream-temperature harmonic.

RESIDUALS AND SUBDIVISION OF THE STATE

After a determination was made of the most effective transformed and untransformed independent variables related to each stream-temperature characteristic, the regression analysis of all data in the State was performed and the residual for each site was calculated. A residual, in essence, is the difference between the value of the dependent variable computed from the regression equation and the original data value of that variable. (Where the logarithms of the data are used, the residual is the logarithm of the ratio of these values.)

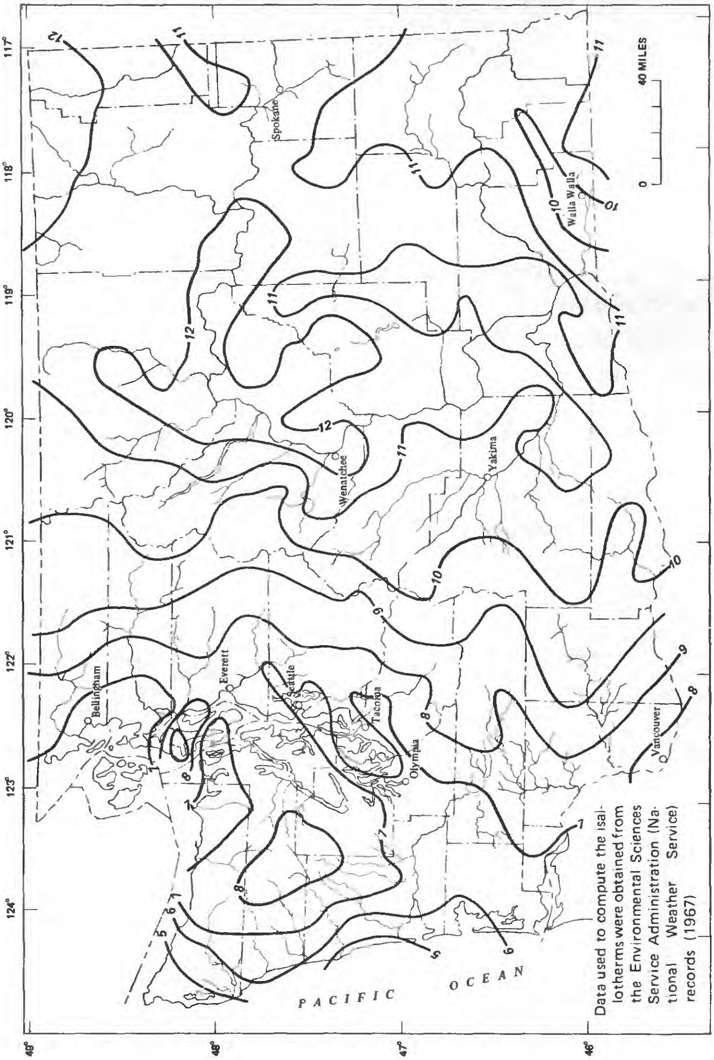

FIGURE 4.—Isallotherms showing annual air-temperature amplitude, in degrees Celsius.

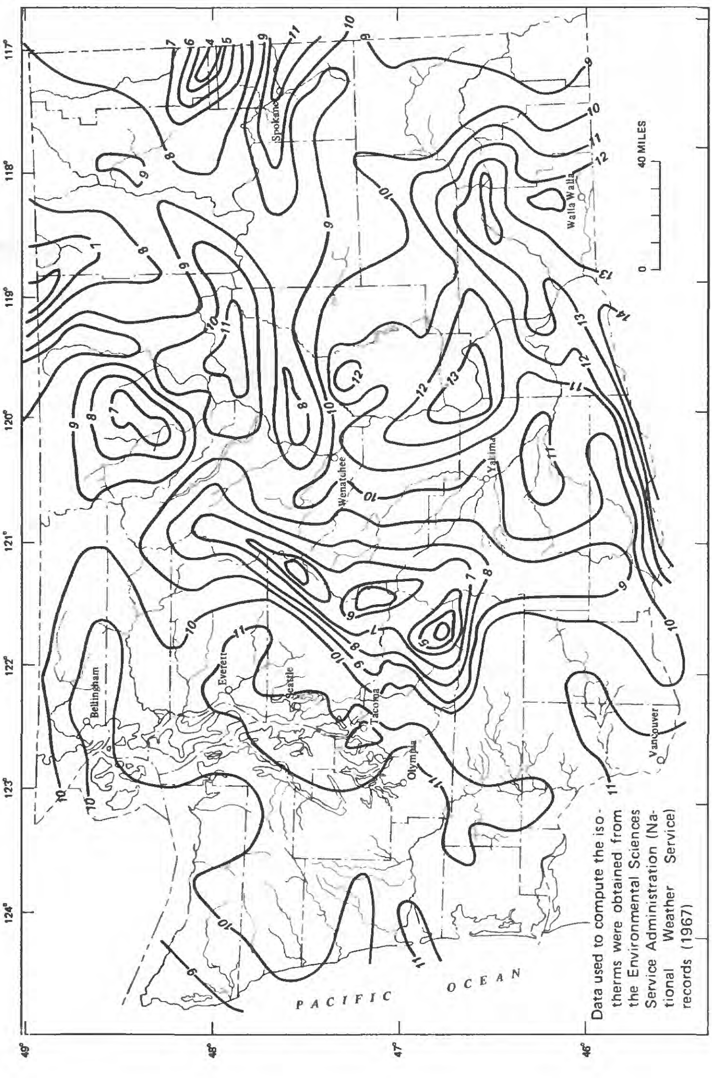

FIGURE 5.—Isotherms showing mean annual air temperature, in degrees Celsius.

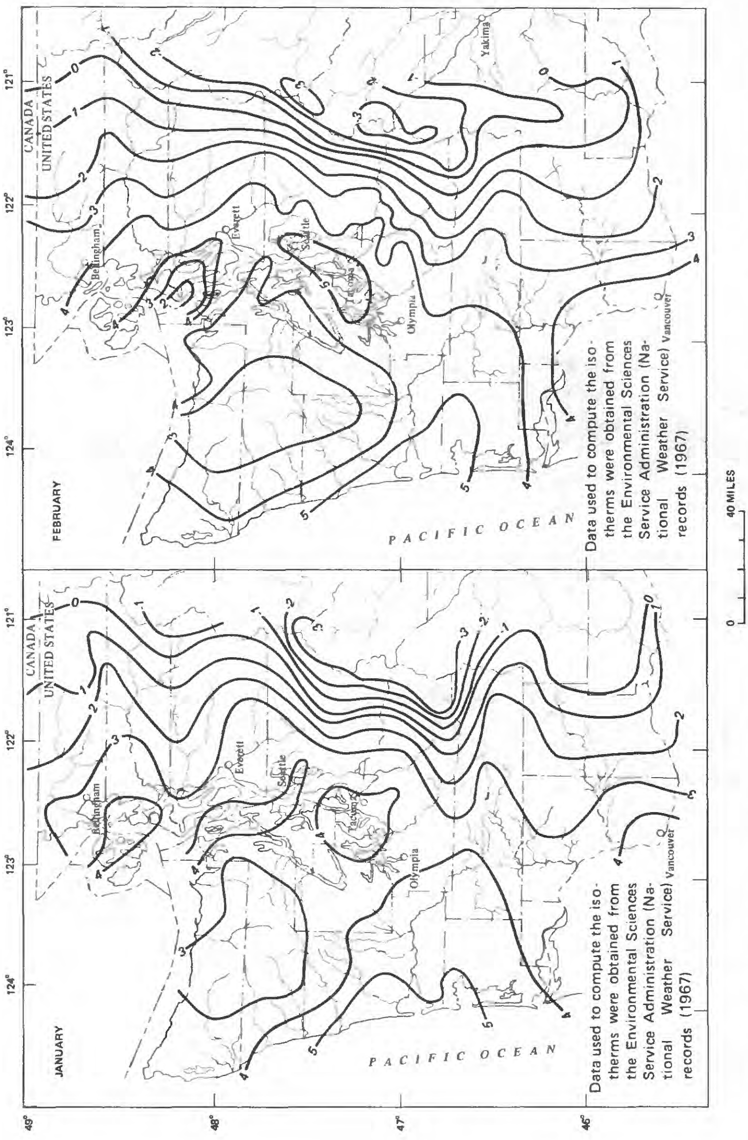

FIGURE 6.—Isotherms showing mean monthly air temperatures, in degrees Celsius, in January and February in western Washington.

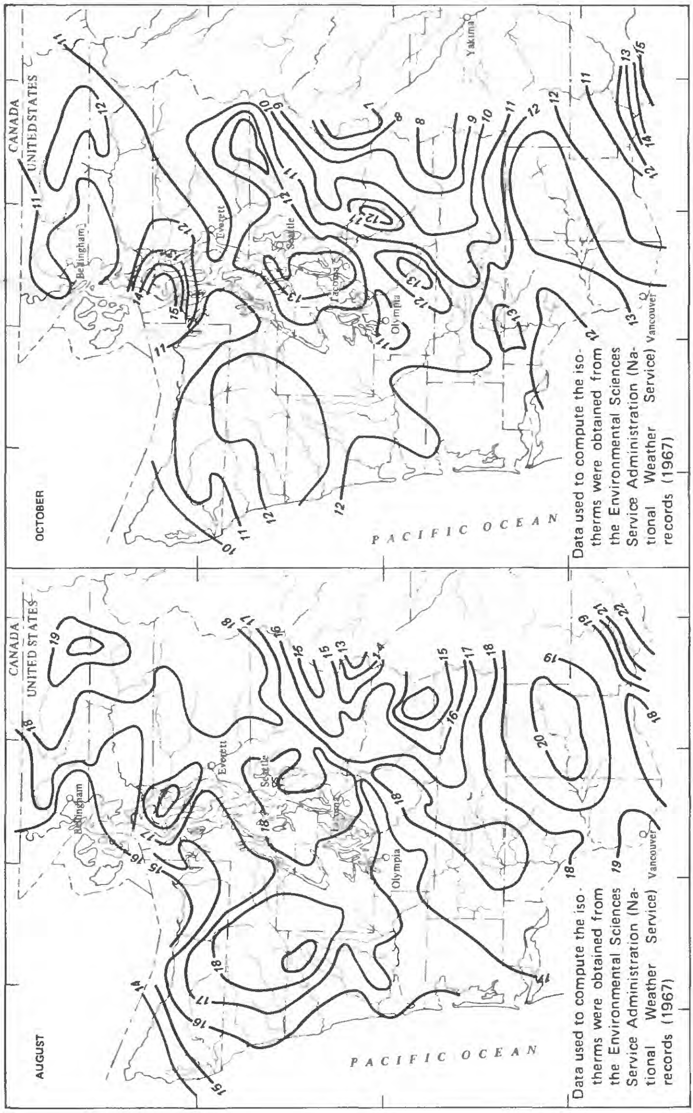

FIGURE 7.—Isotherms showing mean monthly air temperatures, in degrees Celsius, in August and October in western Washington.

The residuals from the statewide regression model, for each stream-temperature characteristic at each data site, were plotted on State maps to determine if they were truly random areally or whether trends or areas with similar high or low residuals exist. The plots (not included on the maps) indicated several groupings that possibly could be used to define subdivisions.

Generally, the areas where residuals indicated subdivisions were western, eastern, and southeastern Washington. However, the quantity of data for southeastern Washington was not large enough to determine a reliable regression model if that area were used as a subdivision. Therefore, the State was divided at the crest of the Cascade Range into eastern and western Washington, with southeastern Washington included as part of eastern Washington. Data for all the temperature sites in the State were divided on this basis, and multiple-regression analyses were performed separately for each part.

TABLE 2.—*Equations for determining*

Stream-temperature characteristic	Regression						
	Regression constant	Average direction of flow of stream (degrees)	Length of river (miles)	Mean altitude of basin (ft)	Lake and pond areas (percent)	Drainage area (sq mi)	Mean annual discharge (in.)
Y	*a*	*φ*	*L*	*E*	*P*	*D*	*Q*
							Western
Amplitude	7.10	------	------	−2.56(−4)	------	------	------
Mean	9.36	------	------	−1.12(−3)	------	[2]1.08	------
Phase coefficient	4.34	------	------	------	------	------	−0.24(−2)
Standard Deviations:							
January	1.12	------	------	------	------	------	------
February	3.95	−2.56(−3)	------	------	------	−3.92(−4)	------
March	1.56	------	------	------	------	−1.38(−4)	------
April	1.64	------	------	------	------	------	------
May	2.22	------	------	------	------	------	------
June	1.99	------	------	------	------	------	------
July	1.78	------	0.40	------	−0.32	------	------
August	3.41	------	------	[2]−1.50	------	------	1.40(−2)
September	−1.26	[2].514	------	------	------	------	[2]1.53
October	2.66	------	5.64(−3)	------	------	−3.56(−4)	------
November	2.38	------	------	[2]−1.37	5.95(−2)	−2.90(−4)	------
December	1.40	------	1.52(−2)	------	------	−8.02(−4)	------
							Eastern
Amplitude	17.33	------	------	------	------	------	[2]3.46
Mean	10.28	------	------	1.15(−3)	------	------	−4.47(−2)
Phase coefficient	4.58	------	------	−6.27(−5)	−6.33(−2)	−8.24(−6)	------

[1] Number in parentheses is power of 10 by which value must be multiplied.
[2] Independent variable associated with this coefficient is a logarithm of the value.

RESULTS

The equations and standard errors of estimate resulting from the multiple-regression analysis of the stream-temperature characteristics are shown in table 2.

Of the 24 topographic and climatic characteristics tested, both as log values and as natural values, only 15 were found effective to determine the equation for one or more of the 15 stream-temperature characteristics. The most significant independent variables were channel slope (F) and drainage area (D). Each was found to be statistically significant in seven of the relations in table 2. The next most significant independent variables were mean basin altitude (E) and a function of air temperature (T_i), each found in six of the relations. The phase coefficient of air temperature and eight of the 12 mean monthly air temperatures were found to be not effective parameters and were omitted from the final analysis.

stream-temperature characteristics

coefficients [1]

Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air-temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M	Mean monthly air temperature (°C) January T_1	February T_2	August T_8	October T_{10}	Standard error of estimate
Washington									
------	------	[2]-0.83	-----	-----	-----	-----	-----	------	0.9°C
------	-6.12(-5)	------	-----	-----	-----	-----	-----	------	.7°C
------	------	------	-----	-----	-----	-----	-----	------	(8 days) .14 radians
------	------	------	-----	-----	0.25	-----	-----	------	0.4°C
------	------	[2]-0.92	-----	-----	-----	0.12	-----	------	.2°C
------	------	------	-----	-----	-----	-----	-----	------	.5°C
-4.35(-4)	------	------	-----	-----	-----	-----	-----	------	.3°C
------	-8.89(-5)	------	-----	-----	-----	-----	-----	------	.4°C
------	------	5.87(-3)	-----	-----	-----	-----	-----	------	.9°C
------	------	------	-----	-----	-----	-----	-----	------	.9°C
------	------	------	-----	-----	-----	-----	0.16	------	.3°C
[2].33	------	------	-----	-----	-----	-----	-----	------	.3°C
------	------	------	-----	-----	-----	-----	-----	-9.39(-2)	.3°C
------	[2]1.16	------	-----	-----	-----	-----	-----	------	.4°C
------	------	------	-----	-----	-----	-----	-----	------	.4°C
Washington									
------	------	[2]-1.38	-0.37	-----	-----	-----	-----	------	1.3°C
------	------	-4.12(-3)	-----	0.39	-----	-----	-----	------	.9°C
------	------	------	-----	-----	-----	-----	-----	------	(6 days) .1 radians

For the regression constants and coefficients in table 2, the form of the equation is

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 ----- b_nx_n,$$

where Y is the stream-temperature characteristic, a is the regression constant, b_n is the regression coefficient, and x_n is the topographic or climatic characteristic (which may or may not be the log of the value). An example of the calculation of mean annual stream temperature (M) for station 12–0115 (fig. 1 and tables 9, 10) follows:

From table 2, the equation is

$$\text{Mean} = 9.36 - 1.12(10^{-3})(E) + 1.08(\log D) - 6.12(10^{-5})(S).$$

From table 6, the values of mean basin altitude (E), drainage area (D), and source altitude (S) are obtained and the equation becomes:

$$\text{Mean} = 9.36 - 1.12(10^{-3})(754) + 1.08(\log 41.4) - 6.12(10^{-5})(2400).$$

The values of E, D, and S could be determined (from topographic maps) for any site on any stream in western Washington and used in the equation.

The log 41.4 = 1.617 and the equation reduces to:

$$\text{Mean} = 10.1°\text{C}.$$

For comparison, the mean annual temperature, determined from the observed data, for station 12–0115 is 10.2°C (table 7). Similarly, values for amplitude (A) and phase coefficient (C) may be determined from the equations in table 2. Mean annual discharge, the variable used to determine C at a site where no streamflow gaging station exists, may be determined by the methods reported in a study by Collings (1971, p. 14–15).

When these three temperature characteristics are calculated, a temperaure hydrograph (similar to that in fig. 2) may be plotted from the equation,

$$T = M + A[\sin(bd + C)],$$

where

$$T = 10.1 + 5.2[\sin(0.0172d + 4.20)].$$

The highest mean water temperature of the year would be

$$M + A = 10.1 + 5.2 = 15.3°\text{C}$$

and would occur on the

$$d = 365 + \frac{[(\pi/2) - \text{C}]}{b} = 365 + \frac{1.57 - 4.20}{0.0172} = 212\text{th day}$$

of the year, or July 31.

The lowest mean water temperature of the year would be

$$M - A = 10.5 - 5.2 = 4.9°\text{C}$$

and would occur on the

$$d=\frac{(3/2)\pi-C}{0.0172}=30\text{th day},$$

or January 30.

Confidence intervals about the mean-stream-temperature harmonic curve can only be determined for stream-temperature sites in western Washington. Confidence intervals derived from a generalization of the standard deviation of monthly temperatures for eastern Washington would have poor reliability because of the small number of thermograph stations. The confidence intervals about a mean harmonic curve for a western Washington temperature site are determined as follows:

1. Compute the monthly *SD* values by using the regression constants and coefficients for the monthly *SD*'s (table 2) and determining the characteristics from maps.
2. Calculate the mean monthly temperatures (table 2).
3. Select the desired percentage interval from a table of cumulative standard normal distribution functions (Hald, 1952)—for example, the 95- and 5-percent probabilities give a 90-percent interval that is about ±1.64 standard deviation's wide.
4. Compute the confidence interval about the mean monthly stream-temperature by multiplying the standard deviation interval (±1.64) by each month's *SD* and adding and subtracting this value from the mean value for that month.

The values from step 4 may be plotted above and below the mean harmonic curve to form the confidence interval for that curve.

EVALUATION OF RESULTS

Statistical evaluations were the basis for including or omitting a topographic or climatic variable from the empirical relations defined by the regression analyses. The physical reasons for a variable or variables defining a stream-temperature characteristic can be postulated only from a train of deductive reasoning, which in some cases may be extremely tenuous. Thus, the regression equations do not define the causes of the areal variations in stream-temperature characteristics. Nevertheless, they do define the basin or climatic characteristic, or group of characteristics, which give a numerical evaluation of the stream-temperature characteristic at a site where previously no stream-temperature information was available.

Mean annual streamflow was found to be a significant independent variable in several of the regression relations (table 2).

However, because of high intracorrelation with other independent variables—especially drainage area—mean annual streamflow was omitted from most of the equations. In the equations (table 2) mean annual streamflow is defined in units of inches of water and is obtained by division of the total runoff by the drainage area. It was found to be a more effective variable in the equations in this form and had lower intracorrelation coefficients with other independent variables (0.4 or less in all cases). Mean annual streamflow at sites where no streamflow records are available may be determined by use of the method described by Collings (1971, p. 14–15).

The standard errors of estimate of the equations to determine the confidence intervals about the mean-stream-temperature curves are shown in table 2. However, after computation and application to the mean curve, one finds the confidence intervals are subject to somewhat greater errors. This is because they include (1) the standard error of estimate of the equations for monthly standard deviation (table 2), (2) the determination of mean monthly values from the harmonic curve, and (3) possible undefined variations resulting from the assumptions made when the curves for monthly frequency distribution are derived. Generally, the total error involved in computation of the confidence intervals for the mean-stream-temperature harmonic curve could be as great as the sum of the errors for each of the curves used in the determination.

Standard error of estimate is a measure of the accuracy of the multiple-regression equations (table 2). It shows how well a stream-temperature characteristic is defined by the topographic and (or) climatic characteristics. Figure 8 shows graphically how well each of the stream-temperature characteristics was defined at the mean value of that characteristic. The standard error of estimate for each of the defining relations is shown in table 2. The graph (fig. 8) shows that error, expressed as a percentage, is obtained by dividing the standard error of estimate by the mean value of the respective stream-temperature characteristic. Figure 8 shows only comparisons between the precision of definition of stream-temperature characteristics for each part of the State and is not a measure of the accuracy of the total range of the variables. For example, the percentage ratio of the stream-temperature characteristic may be larger for low values and smaller for higher values.

Undoubtedly stream-temperature studies in the future could improve the generalized equations defined in this report, because (1)

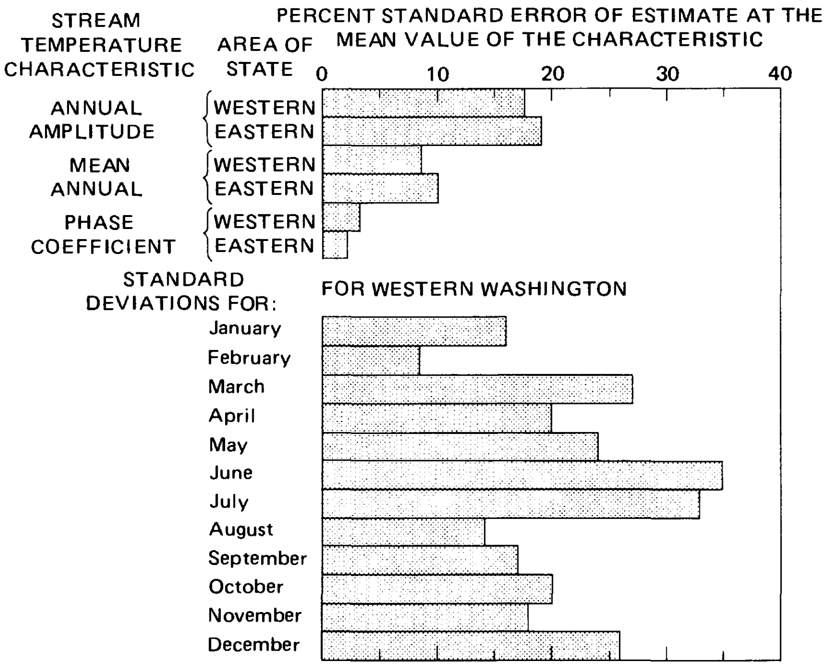

FIGURE 8.—Comparisons of standard errors of estimate, of the mean values only, of stream-temperature characteristics for eastern and western Washington.

more and longer records of stream temperatures, especially thermograph data, will be available for better areal and temporal definition, (2) new and updated topographic maps will be available to define and improve definition of the topographic basin characteristics, (3) more and longer climatic records will become available, and (4) other types of parameters and indices may possibly be defined as significant independent variables related to stream temperatures. Examples of additional parameters that might prove significant include stream-channel indices at the temperature observation site, wind velocity, cloud cover, subsurface inflow, chemical character and suspended sediment, basin geology, temperature of surrounding landmasses, and shading from vegetation or landmasses.

EFFECTS OF WATER IMPOUNDMENT ON STREAM TEMPERATURES: EXAMPLES

The effects of water impoundment on stream temperatures below an impoundment are not consistent and vary from stream to stream and dam to dam. An impoundment's effect on downstream water temperatures depends on many factors, including the size and shape of the impoundment, elevation of the release water, holding time of the water, other physical characteristics and turbidity of the water, velocities of currents within the impounded water, altitude of the impoundment's surface, and volume of water released as compared to the natural discharge of the river.

The effects of holding reservoirs on downstream water temperatures can be evaluated by use of harmonic curves of the probable maximum and minimum temperatures. Following are examples of procedures used to evaluate the effects of impoundments on downstream water temperatures.

EXAMPLE 1: EFFECTS OF A HYDROELECTRIC POWER DAM

In this example two sites below Mayfield Dam, on the Cowlitz River, are evaluated to determine the effect of a hydroelectric power dam on stream temperatures. The dam, located at Cowlitz River mile 52.0, has been in operation since 1962. Thermograph records at sites 1.4 and 34.7 miles downstream from the dam were evaluated for the 1951–68 period. The upstream site is 14–2380, Cowlitz River below Mayfield Dam ("near Mayfield" before dam construction), and the lower station is 14–2430, Cowlitz River at Castle Rock. The periods evaluated at both stations were 1951–61 before dam construction, and 1962–68 after dam construction. A third site (14–2335, Cowlitz River near Kosmos), located 4.2 river miles upstream from Mayfield Dam and unaffected by the impoundment of water, was also evaluated for these periods before and after existence of the reservoir. The Cowlitz River near Kosmos was used as a "background" evaluation, to determine if a significant natural stream-temperature trend exists for the period investigated. The probable temperature curves for the Kosmos gage before and after impoundment (table 3) were not found to be significantly different. This finding lends validity to the assumption that any changes occurring in the river temperatures below the dam after dam construction and use would be caused by the effect of the dam and its impoundment.

At each of the thermograph sites, frequency distributions were computed for maximum, mean, and minimum stream temperatures. These distributions were used to determine the 95–percent probabilities of being equal to or less than the maximum temperatures and of equaling or exceeding the minimum temperatures, for both natural and impounded conditions. The probable stream temperatures were fitted by harmonic curves; the characteristics of the curves are listed in table 3. The sets of curves for each site define a 90-percent confidence interval for stream temperatures for each condition. (This means that 95 percent of the time maximum

TABLE 3.—*Probable water-temperature characteristics below Mayfield Dam, Cowlitz River*

Water temperature	Before impoundment					After impoundment				
	Probability	Annual amplitude (°C)	Phase coefficient (radians)	Mean annual temperature (°C)	Standard error (°C)	Probability	Annual amplitude (°C)	Phase coefficient (radians)	Mean annual temperature (°C)	Standard error (°C)
14–2335. Cowlitz River below Kosmos, 4.2 miles above dam (unaffected by impoundment)										
Mean, equal to or less than	0.5	4.6	4.13	8.3	0.8	0.5	5.0	4.20	8.3	0.7
Do	.95	5.4	4.20	9.4	.7	.95	5.4	4.16	9.6	.7
Minimum, equal to or greater than	.5	4.3	4.24	7.1	.9	.5	4.4	4.30	7.3	.8
Do	.95	4.0	4.18	5.7	1.0	.95	4.0	4.28	5.7	.8
Maximum, equal to or less than	.5	5.3	4.23	9.1	1.0	.5	5.7	4.30	9.2	.9
Do	.95	5.7	4.23	10.4	1.0	.95	6.0	4.25	10.3	.9
Site 1, 14–2380. Cowlitz River below Mayfield Dam (previously "near Mayfield"), 1.4 miles below dam										
Mean, equal to or less than	0.5	5.7	4.17	9.2	1.2	0.5	5.8	3.94	10.1	1.1
Do	.95	6.2	4.21	11.0	1.4	.95	6.9	3.91	11.5	1.1
Minimum, equal to or greater than	.5	5.1	4.19	7.3	1.1	.5	5.2	3.98	9.0	1.0
Do	[1].95	4.9	4.22	5.1	1.1	[1].95	4.5	4.11	7.0	1.0
Maximum, equal to or less than	.5	6.1	4.26	10.8	1.1	.5	6.0	4.01	10.8	1.1
Do	[1].95	6.8	4.26	12.8	1.1	[1].95	6.8	3.98	12.3	1.2
Site 2, 14–2430. Cowlitz River at Castle Rock, 34.7 miles below dam										
Mean, equal to or less than	0.5	6.0	4.16	10.0	1.3	0.5	6.0	4.13	10.6	1.2
Do	.95	6.6	4.21	12.2	1.6	.95	7.1	4.15	12.5	1.2
Minimum, equal to or greater than	.5	5.5	4.23	8.5	1.3	.5	5.7	4.11	9.5	1.2
Do	[1].95	5.8	4.25	6.1	1.0	.95	4.6	4.09	7.2	1.3
Maximum, equal to or less than	.5	6.6	4.20	11.3	1.2	.5	7.0	4.15	11.9	1.5
Do	[1].95	7.8	4.18	13.7	1.4	.95	8.2	4.19	13.8	1.5

[1] Curves derived from characteristics on this line are shown in figure 9.

temperatures will be on or below the upper confidence curve, and 95 percent of the time minimum temperatures will be on or above the lower confidence curve.) The effect of the impoundment, at each of the sites below the dam as well as from site to site (fig. 9), then could be evaluated by comparison of the natural stream temperatures with the stream temperatures after dam completion.

The magnitudes and differences of the 95-percent probable minimum lowest (winter), minimum highest (summer) and maximum highest (summer) stream temperatures, and time of occurrence of these temperatures before and after water impoundment behind the dam were computed from table 3 and are shown in table 4.

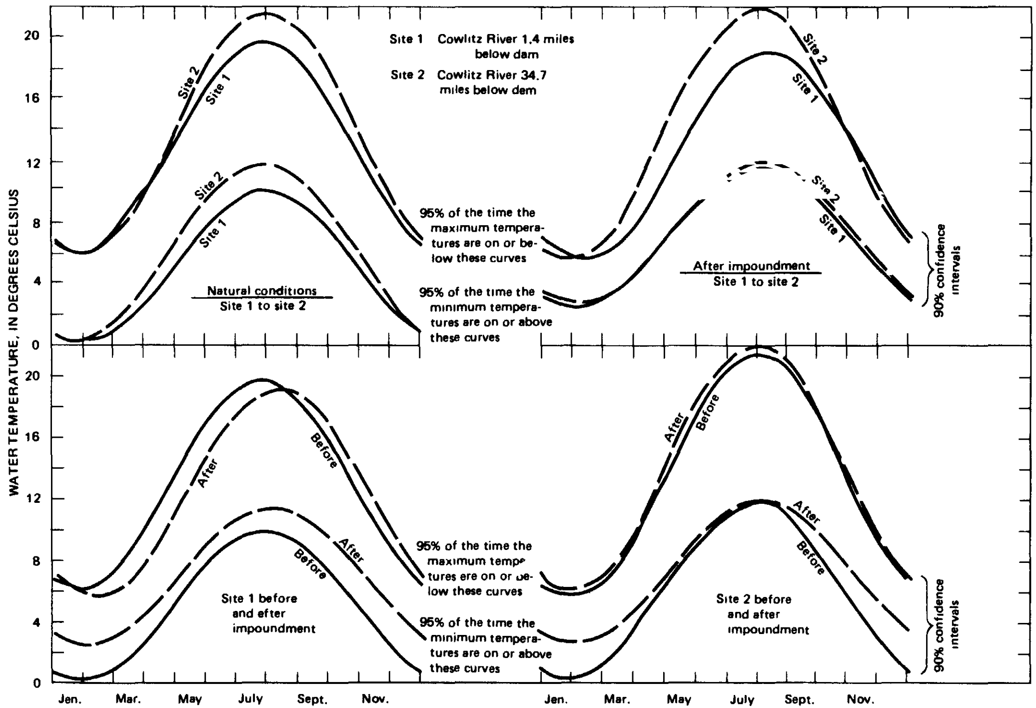

FIGURE 9.—Effects of water impoundment on stream temperatures, Cowlitz River. Graphs show the 90-percent confidence intervals about the maximum and minimum stream temperatures for natural and controlled conditions at two stream-temperature measuring sites below Mayfield Dam.

With the aid of table 4, the following inferences may be made about the effects of the dam on stream temperatures at site 1, Cowlitz River below Mayfield Dam, from natural to controlled conditions:

1. The highest 95-percent probable summer-minimum temperature increased by 1.5°C.
2. The lowest 95-percent probable winter-minimum temperature was increased by 2.3°C and occurs 7 days later.
3. The highest 95-percent probable summer-maximum temperature did not change significantly (−0.5°C), although it occurs 16 days later.

The effects of the dam on stream temperatures between Mayfield Dam (site 1) and Castle Rock (site 2) are as follows:

1. Under natural conditions, a 1.9°C increase occurred in the highest 95-percent probable summer-minimum temperature between sites 1 and 2. After impoundment the increase in the summer-minimum temperature was insignificant.
2. Under natural conditions, the lowest 95-percent probable winter-minimum temperature difference between sites was not significant (+0.1°C), nor was the difference (+0.1°C) between sites significant after impoundment. However, as stated above, the lowest minimum temperature at each site was increased by 2.3°C after impoundment.
3. Under natural conditions, the highest 95-percent probable summer-maximum temperature had a downstream increase of +1.9°C between sites, whereas after impoundment the increase was +2.9°C between sites, an increase of +1°C.

The effects of the dam on stream temperatures at site 2, Cowlitz River at Castle Rock, are inferred from table 4 as follows:

1. The highest 95-percent probably summer-minimum temperature did not change significantly (−0.1°C).
2. The lowest 95-percent probable winter-minimum temperature was increased 2.3°C, and it occurs 9 days later.
3. The highest 95-percent probable summer-maximum temperature did not change significantly (+0.5°C), nor did the time of occurrence change significantly (−1 day).

An interesting observation is that the time of occurrence of the 95-percent probable summer-maximum peak temperature at site 2 did not change significantly from before to after impoundment (August 2 to August 1, respectively) even though there was a 17-day increase at site 1 (July 28 before and August 13 after). The natural time lag in peak temperature between sites is +5 days (July 28 at site 1 and August 2 at site 2), and the controlled peak

TABLE 4.—*Evaluation of water-temperature*

95-percent probable	Site 1 From natural	Site 1 To con-trolled	Site 1 Differ-ence
Water temperature, °C			
Minimum:			
Summer	10.0	11.5	+1.5
Winter	.2	2.5	+2.3
Maximum:			
Summer	19.6	19.1	*−.5
Date of occurrence			
Minimum:			*Days*
Summer	July 30	Aug. 5	+6
Winter	Jan. 28	Feb. 4	+7
Maximum:			
Summer	July 28	Aug. 13	+16

* Value not statistically significant.

temperature at site 1 occurs 12 days later than at site 2 (August 13 at site 1 and August 1 at site 2).

EXAMPLE 2: EFFECTS OF A FLOOD-CONTROL DAM

The second example of the effects of impoundment evaluates the downstream water-temperature effects of the Howard A. Hanson Dam, a flood-control dam which also augments the natural river flows during the low-flow months. The dam is in King County on the Green River at river mile 64.5 and impounds the Howard A.

TABLE 5.—*Probable water-temperature characteristics at Green River (measuring site 12–1130) near Auburn, 32.5 miles below Howard A. Hanson Dam*

Water temperature	Probability	Annual amplitude (°C)	Phase coefficient (radians)	Mean annual temperature (°C)	Standard error (°C)
Before dam construction					
Minimum, equal to or greater than	0.5	4.7	4.22	8.0	0.6
Do	.95	4.8	4.24	6.1	.6
Maximum, equal to or less than	.5	7.0	4.33	11.8	1.4
Do	.95	8.2	4.39	14,6	1.7
After dam construction					
Minimum, equal to or greater than	0.5	5.1	4.19	8.2	0.5
Do	.95	5.8	4.31	6.7	.8
Maximum, equal to or less than	.5	7.2	4.35	12.0	1.1
Do	.95	7.8	4.39	14.4	1.0

changes below Mayfield Dam

Site 2			Natural condition			Controlled condition		
From natural	To controlled	Difference	From site 1	To site 2	Difference	From site 1	To site 2	Difference
Water temperature, °C—Continued								
11.9	11.8	*−0.1	10.0	11.9	+1.9	11.5	11.8	*+0.3
.3	2.6	+2.3	.2	.3	*+.1	2.5	2.6	*+.1
21.5	22.0	*+.5	19.6	21.5	+1.9	19.1	22.0	+2.9
Date of occurrence—Continued								
		Days			*Days*			*Days*
July 28	Aug. 6	+9	July 30	July 28	*−2	Aug. 5	Aug. 6	*+1
Jan. 27	Feb. 5	+9	Jan. 28	Jan. 27	*−1	Feb. 4	Feb. 5	*+1
Aug. 2	Aug. 1	*−1	July 28	Aug. 2	5	Aug. 13	Aug. 1	−12

Hanson Reservoir near Palmer (station 12–1058). Thermograph records at station 12–1130, Green River near Auburn (32.5 miles below the dam), were used from 1953 to present. The dam has been in operation since December 1961.

Probability distributions and the harmonic fittings of the thermograph records were computed, and the 50- and 95-percent probable maximum and minimum stream-temperature characteristics (amplitude, mean, and phase coefficient) were determined and are shown in table 5. Magnitudes, differences and times of occurrence of stream temperatures as computed from table 5 are shown in table 6.

From table 6 it is inferred that the dam affected stream temperatures from natural to controlled conditions, as follows:

1. The 95-percent probable summer-minimum was increased by 1.6°C.
2. The change in the 95-percent probable winter-minimum low temperature is not statistically significant (−0.4°C).

TABLE 6.—*Evaluation of water-temperature changes below Howard A. Hanson Dam*

95-percent probable:	Water temperature (°C)			Date of occurrence		
	Natural	Controlled	Difference	Natural	Controlled	Days Difference
Minimum:						
Summer	10.9	12.5	+1.6	July 29	July 25	−4
Winter	1.3	.9	[1] −.4	Jan. 27	Jan. 23	−4
Maximum:						
Summer	22.8	22.2	[1] −.6	July 20	July 20	0

[1] Value not statistically significant.

3. The change in the 95-percent probable summer-maximum high temperature is not statistically significant (−0.6°C).

The increase in the summer-minimum temperature, after control, is probably caused by the summer low-flow augmentation (increased volume of streamflow) of water warmed by retention in the reservoir.

SUMMARY AND CONCLUSIONS

Many of the physical, chemical, and biological properties of water are related to temperature. Thus, stream temperatures are important in water-quality control because of their infleunce on the ecosystem of streams.

Regional stream-temperature studies usually list basic data for each site. In some cases generalizations of stream temperatures are made by simple extrapolation or interpolation. In this report, however, multiple-regression techniques were used to determine the topographic and climatic-basin characteristics most effective to explain the site-to-site variations in natural stream temperatures. A procedure was developed to estimate water temperatures at sites where little or no data are now available.

The analyses performed in this study used most of the complete and essentially natural stream-temperature data available for Washington, as well as some temperature data for stream reaches that are subject to thermal modification. The regression results, therefore, are based on the most useful stream-temperature data available and provide a generalized definition of stream temperatures in the State—one of the main objectives of this study.

In general, it was found that the multiple-regression technique produces more accurate results in western than in eastern Washington. The mean annual temperature and the annual-temperature amplitude could be estimated with greater accuracy in western Washington. The more accurate definition of these two stream-temperature characteristics in the western part of the State is primarily the result of more data. The prediction of the phase coefficient is slightly less accurate in western Washington than in eastern Washington, probably because in western Washington there are more physiographic differences—the coastal lowland, the Olympic Mountains and their rain shadow, the Puget Sound lowlands, the Willapa Hills, and the western slope of the Cascade Range. Such variety results in a diverse climate which produces greater diversity in the phase coefficient. In general the accuracy of definition of the multiple-regression equations for stream temperatures in western Washington, compared to those for eastern Washington, is due to the more humid, milder coastal climate of western Washington, compared to greater natural variability in the semiarid, continental climate of eastern Washington.

The monthly standard deviation of temperatures for western Washington streams could be determined with more confidence in the winter months than in June and July.

The regression analysis showed that of the 24 topographic and climatic characteristics tested against each of the stream-temperature characteristics, 15 (six of which are a function of air temperatures) were significantly effective to determine one or more of the 15 stream-temperature characteristics. The independent variables found to occur most often as significant parameters (table 2) to define the stream-temperature characteristics are:

Topographic or climatic characteristic	Number of equations [1] where variable was found significant 95 percent of the time
Drainage area	7
Channel slope	5
Mean basin altitude	6
Mean annual streamflow	5
Altitude of data site	2
Stream length	3
Source altitude of stream	3
Area of lakes and ponds	3
Direction (orientation) of streamflow	2
Mean air temperature:	
Amplitude	1
Annual	1
January	1
February	1
August	1
October	1

[1] Usually more than one variable is found in an equation (table 2).

Data for the topographic and climatic characteristics evaluated in this investigation are not costly to acquire compared to the parameters that may be used to determine, for example, an energy budget. These data for this investigation are obtained from topographic maps, air-temperature isothermal maps (figs. 4, 5, 6, and 7), and from mean annual flow equations determined previously by the author (Collings, 1971, p. 14–15). In contrast, an energy budget, used to obtain temperature-prediction equations, requires relatively expensive instrumentation to determine incoming solar radiation, effective back radiation, energy losses from evaporation and conduction, and energy advected into the water by tributary streams and precipitation. However, energy-budget studies are much more sophisticated and the results are more comprehensive—evaluation of stratification, heat-exchange coefficients, mixing rates, and other physical characteristics of a stream which are concerned with its temperature.

The generalization procedures in this report are valuable for relatively inexpensive feasibility and comparison studies to determine if additional, more intensive, investigations (such as an energy-budget study) are warranted. For example, the generalization procedures could be used for fish-hatchery site-feasibility studies, reconnaissance of downstream water-temperature effects of dams or tributary inflow, and (or) the adequacy of waters for cooling purposes in industrial plants.

Although not a major objective of this report, the statewide analysis has identified areas where basic stream-temperature data are deficient. The residual values of the stream-temperature characteristics generally show that basic temperature data are lacking in the Olympic Peninsula in western Washington and the southeastern and north-central parts of eastern Washington.

The two examples of the evaluation of stream temperatures below water impoundments (tables 3 and 5) show how the natural temperature regime of a river is affected by damming. The investigation of the impoundment by Mayfield Dam on the Cowlitz River showed an increase of probable winter-minimum stream temperatures below the dam, whereas the investigation of the impoundment by Howard A. Hanson Dam on the Green River showed a statistically insignificant decrease in probable winter-minimum stream temperatures below the dam. However, the summer-minimum stream temperature at the Green River site was increased, whereas the change in the summer-minimum temperature of the Cowlitz River at Castle Rock (site 2) was insignificant. The lower site on the Cowlitz River and the site on the Green River are about the same distance downstream from their respective dams. The opposite effects that the impoundments apparently have on minimum stream temperatures of the rivers is attributed to the difference in dam function; Mayfield Dam on the Cowlitz River is used to produce hydroelectric power, while Howard A. Hanson Dam on the Green River is used for flood control and low-flow augmentation.

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TABLES 7-10

TABLE 7.—*Stream-temperature characteristics, western Washington thermograph stations*

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M	Standard deviations of monthly stream temperatures (°C)											
					January T_1	February T_2	March T_3	April T_4	May T_5	June T_6	July T_7	August T_8	September T_9	October T_{10}	November T_{11}	December T_{12}
12-0115	Willapa River at Lebam	5.3	4.13	10.2	2.8	2.0	1.1	1.4	2.0	2.2	2.7	2.3	1.7	1.3	2.3	1.5
0275	Chehalis River near Grand Mound	7.9	4.31	11.6	2.5	2.5	1.6	1.7	2.1	3.7	2.9	2.8	1.8	1.6	2.1	1.4
0600	South Fork Skokomish River near Potlatch	5.2	4.12	9.0	1.2	2.1	1.5	1.7	1.3	2.9	2.8	3.2	1.1	1.3	1.6	1.0
0615	Skokomish River near Potlatch	3.4	4.27	9.2	1.4	.8	1.4	1.8	3.0	2.7	2.7	1.2	1.3	1.5	1.4	1.2
0625	Purdy Creek near Union	2.5	4.54	8.8	.8	1.5	1.5	.9	.6	1.0	.6	.1	1.0	.9	.7	1.0
0825	Nisqually River near National	3.6	4.34	6.5	1.7	1.4	1.6	1.1	1.8	2.2	2.1	1.7	1.8	1.7	1.9	1.6
0830	Mineral Creek near Mineral	5.9	4.16	9.0	2.0	1.6	1.4	1.8	2.0	2.2	2.0	2.8	1.9	1.6	2.3	1.3
1130	Green River near Auburn	5.4	4.21	9.9	1.4	2.2	1.4	1.8	2.1	3.5	3.0	2.0	1.8	1.4	2.2	2.0
1175	Cedar River near Landsburg	3.7	4.24	8.9	.8	1.2	1.2	1.6	1.5	1.3	1.1	1.8	2.1	2.7	1.2	1.1
1350	Wallace River at Gold Bar	5.4	4.15	9.0	1.3	1.3	1.2	1.7	1.4	2.4	2.4	2.6	2.3	1.6	2.1	2.0
1640	Jim Creek near Arlington	6.0	4.23	9.0	2.0	2.5	1.3	1.2	1.4	2.8	3.6	2.3	1.0	1.6	2.4	2.0
1655	North Fork Stillaguamish River near Darrington	4.4	4.01	7.6	.6	1.0	1.4	1.5	1.1	2.6	3.2	1.7	3.6	1.7	2.2	2.0
1685	Pilchuck Creek near Bryant	6.3	4.14	9.1	1.7	1.9	1.9	1.6	3.4	4.6	3.9	3.0	2.2	1.2	1.7	1.6
1790	Skagit River above Alma Creek, near Marblemount	3.2	3.70	7.1	1.1	1.4	1.4	1.2	.7	1.1	1.5	1.3	1.0	.9	1.3	1.3
1825	Cascade River at Marblemount	3.3	4.15	6.5	1.3	1.4	1.4	1.1	1.4	1.8	2.1	2.2	2.4	1.7	1.4	.9
2005	Skagit River near Mount Vernon	4.5	4.02	8.7	.4	1.0	.4	1.2	1.7	1.8	1.6	1.9	2.2	1.1	1.1	.1
14-1100	Klickitat River near Glenwood	5.2	4.21	6.3	.8	1.4	.9	.4	1.1	1.8	1.4	1.2	.8	1.3	1.7	1.7
1130	Klickitat River near Pitt	5.6	4.33	8.7	1.7	1.9	1.3	1.2	1.7	2.1	1.8	2.0	1.3	1.3	1.8	1.7
2205	Lewis River at Ariel	4.2	3.60	9.1	1.8	2.0	1.7	1.6	.9	.8	1.5	2.8	3.0	1.9	3.3	2.1
2225	East Fork Lewis River near Heisson	6.0	4.21	9.6	2.2	1.9	1.3	1.9	3.1	3.0	3.8	2.5	2.4	1.7	2.3	1.9
2235	Kalama River below Italian Creek, near Kalama	4.5	4.16	8.8	1.3	1.9	1.2	1.4	2.2	2.9	2.7	1.8	1.4	1.4	2.1	1.3
2325	Cispus River near Randle	4.2	4.11	6.9	1.7	1.5	.8	.9	1.2	2.1	2.0	1.7	1.5	1.6	1.7	.9
2335	Cowlitz River near Kosmos	4.9	4.12	8.1	2.0	1.3	1.0	1.3	1.3	2.9	3.3	1.8	2.1	1.3	1.6	1.2
2355	West Fork Tilton River near Morton	5.7	4.02	8.0	2.4	2.2	2.0	1.8	1.8	5.0	4.5	2.6	2.2	1.5	2.5	1.9
2380	Cowlitz River below Mayfield Dam	6.0	3.92	9.8	1.5	2.0	1.6	1.5	1.5	3.0	3.7	2.2	1.6	1.6	1.6	1.6
2425	Toutle River near Silver Lake	5.8	4.10	9.5	1.7	1.9	1.8	1.8	1.7	3.3	4.6	2.9	1.6	1.4	2.0	2.1
2430	Cowlitz River at Castle Rock	6.1	4.08	10.4	2.0	2.2	2.2	2.0	1.9	2.8	4.0	3.5	2.4	1.6	2.0	1.8
2450	Coweman River near Kelso	6.6	4.30	10.5	2.5	2.2	1.9	2.5	2.5	2.8	3.0	2.4	2.3	1.8	2.4	1.3
2460	Abernathy Creek near Longview	4.6	4.18	9.4	2.3	1.5	2.6	2.4	1.5	1.2	2.4	2.1	1.5	2.0	2.2	2.2
2475	Elochoman River near Cathlamet	5.3	4.27	10.0	2.1	2.0	2.2	1.4	2.1	2.5	2.4	2.4	2.3	1.7	2.1	2.0
2505	West Fork Grays River near Grays River	5.0	4.07	10.2	1.5	1.9	1.5	1.7	2.4	3.3	2.9	2.9	1.7	1.9	1.4	1.2

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	WESTERN WASHINGTON			
12-0095	Bear Branch near Naselle	3.9	4.03	9.9
0100	Naselle River near Naselle	5.2	4.24	10.3
0105	Salmon Creek near Naselle	4.8	4.17	10.1
0107	South Fork Naselle River near Naselle	5.9	3.92	10.8
0110	North Nemah River near South Bend	5.1	4.14	11.1
0112	Williams Creek near South Bend	3.8	4.06	9.7
0120	Fork Creek near Lebam	5.1	4.13	10.1
0135	Willapa River near Willapa	6.7	4.13	11.6
0145	South Fork Willapa River near Raymond	4.0	4.22	10.1
0151	Clearwater Creek near Raymond	3.6	4.03	9.5
0152	Smith Creek near Raymond	4.0	4.28	9.9
0155	North River near Brooklyn	5.5	4.22	10.2
0170	North River near Raymond	5.5	4.13	10.6
0200	Chehalis River near Doty	6.2	4.23	10.3
0210	South Fork Chehalis River at Boistfort	7.4	4.35	11.0
0240	South Fork Newaukum River near Onalaska	5.9	4.24	9.7
0245	North Fork Newaukum River near Forest	6.4	4.32	11.2
0250	Newaukum River near Chehalis	7.5	4.21	11.1
0260	Skookumchuck River near Centralia	5.6	4.24	9.1
0300	Rock Creek at Cedarville	5.1	4.20	9.3
0310	Chehalis River at Porter	7.4	4.11	11.3
0325	Cloquallum Creek at Elma	5.2	4.21	10.4
0342	East Fork Satsop River near Elma	4.5	4.33	9.8
0350	Satsop River near Satsop	5.4	4.33	10.2
0354	Wynoochee River near Grisdale	4.4	3.83	8.6
0360	Wynoochee River above Save Creek, near Aberdeen	5.1	4.23	8.8
0374	Wynoochee River above Black Creek, near Montesano	6.3	4.16	10.8
0390	Humptulips River near Humptulips	6.4	4.22	10.3
0393	North Fork Quinault River near Amanda Park	4.2	3.88	6.2
0395	Quinault River at Quinault Lake	5.9	4.08	10.5
0410	Hoh River near Forks	3.4	4.25	8.2
0412	Hoh River at U.S. Highway 101, near Forks	4.1	4.29	8.7
0415	Soleduck River near Fairholm	4.7	4.07	7.1
0430.8	East Fork Dickey River near LaPush	6.1	4.24	9.9
0431	Dickey River near LaPush	5.2	4.35	10.1
0433	Hoko River near Sekiu	5.5	4.29	10.0
0434.3	East Twin River near Pysht	4.5	4.18	8.4
0455	Elwha River at McDonald Bridge, near Port Angeles	4.9	4.01	8.2
0475	Siebert Creek near Port Angeles	5.4	4.29	7.7
0480	Dungeness River near Sequim	4.3	4.18	7.0
0505	Snow Creek near Maynard	5.6	4.19	8.4
0540	Duckabush River near Brinnon	3.8	4.06	7.3
0545	Hamma Hamma River near Eldon	2.8	3.95	7.3
0546	Jefferson Creek near Eldon	4.3	3.97	8.0
0565	North Fork Skokomish River below Staircase Rapids, near Hoodsport	4.0	4.00	6.7
0595	North Fork Skokomish River near Potlatch	4.4	4.30	10.2
0598	South Fork Skokomish River near Hoodsport	3.3	3.96	6.9
0605	South Fork Skokomish River near Union	4.7	4.11	9.1
0626	Weaver Creek near Potlatch	1.6	4.35	8.8
0655	Gold Creek near Bremerton	4.8	4.40	9.4
0685	Dewatto Creek near Dewatto	4.1	4.26	9.2
0700	Dogfish Creek near Poulsbo	4.0	4.33	9.2
0720	Chico Creek near Bremerton	6.5	4.27	10.7
0730	Burley Creek at Burley	3.2	4.43	9.5
0735	Huge Creek near Wauna	2.9	4.38	9.1

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	WESTERN WASHINGTON-Continued			
12-0765	Goldsborough Creek near Shelton	5.0	4.38	9.8
0784	Kennedy Creek near Kamilche	5.4	4.32	10.3
0790	Deschutes River near Rainier	5.6	4.28	10.0
0800	Deschutes River near Olympia	5.7	4.51	11.4
0810	Woodland Creek near Olympia	4.0	4.62	9.7
0865	Nisqually River at La Grande	3.9	3.74	7.6
0880	Ohop Creek near Eatonville	6.9	4.28	10.7
0895	Nisqually River at McKenna	5.8	4.24	10.1
0902	Muck Creek at Roy	7.7	4.38	12.2
0911	Flett Creek at Tacoma	3.0	4.55	11.4
0912	Leach Creek near Fircrest	4.2	4.40	12.4
0913	Leach Creek near Steilacoom	3.1	4.30	10.1
0915	Chambers Creek below Leach Creek, near Steilacoom	4.9	4.36	11.5
0920	Puyallup River near Electron	3.3	4.35	5.8
0935	Puyallup River near Orting	3.6	4.23	7.6
0940	Carbon River near Fairfax	3.6	4.19	7.0
0944	South Prairie Creek near Enumclaw	4.4	4.17	6.6
0950	South Prairie Creek at South Prairie	5.1	4.21	8.6
0966	White River near Greenwater	4.3	4.40	4.6
0970	White River at Greenwater	3.7	4.20	6.2
0975	Greenwater River at Greenwater	4.7	4.15	6.5
0985	White River near Buckley	4.2	4.16	7.1
0993	Boise Creek above reservoir, near Enumclaw	4.0	4.17	7.3
0994	Boise Creek below millpond, near Enumclaw	5.7	4.17	11.8
0995	Boise Creek near Enumclaw	6.2	4.25	12.1
1005	White River near Sumner	6.5	4.22	11.8
1015	Puyallup River at Puyallup	5.5	4.21	9.5
1034	Green River below Intake Creek, near Lester	5.9	3.86	7.5
1035	Snow Creek near Lester	5.1	4.06	6.3
1040	Friday Creek near Lester	4.7	4.02	6.0
1045	Green River near Lester	5.7	4.01	8.1
1047	Green Canyon Creek near Lester	3.6	4.06	7.5
1050	Smay Creek near Lester	3.7	4.03	5.8
1057.1	North Fork Green River near Lemolo	4.3	4.10	7.0
1059	Green River below Howard A. Hanson Dam	5.3	3.91	8.2
1067	Green River at purification plant, near Palmer	6.0	3.97	8.6
1073	Icy Creek near Black Diamond	1.3	3.13	8.0
1085	Newaukum Creek near Black Diamond	5.4	4.54	10.2
1126	Big Soos Creek above hatchery, near Auburn	5.2	4.40	10.1
1133.5	Green River at Tukwila	5.6	4.21	10.5
1135	North Fork Cedar River near Lester	4.4	4.03	6.0
1140	South Fork Cedar River near Lester	4.5	4.11	5.8
1145	Cedar River below Bear Creek,near Cedar Falls	5.0	4.15	6.5
1150	Cedar River near Cedar Falls	4.4	3.98	6.9
1155	Rex River near Cedar Falls	5.7	4.09	7.0
1165	Cedar River at Cedar Falls	6.7	3.93	8.9
1170	Taylor Creek near Selleck	3.4	4.16	7.4
1185	Rock Creek near Maple Valley	2.1	4.16	9.0
1190	Cedar River at Renton	5.6	4.30	10.2
1196	May Creek at mouth, near Renton	4.6	4.44	9.2
1197	Coal Creek near Bellevue	4.5	4.45	9.9
1200	Mercer Creek near Bellevue	5.6	4.43	10.2
1205	Juanita Creek near Kirkland	4.3	4.36	10.2
1210	Issaquah Creek near Issaquah	5.8	4.27	10.3
1216	Issaquah Creek near mouth, near Issaquah	6.0	4.42	10.1

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	WESTERN WASHINGTON--Continued			
12-1230	Cottage Lake Creek near Redmond	5.2	4.40	10.9
1240	Evans Creek above mouth, near Redmond	4.6	4.40	9.6
1252	Sammamish River near Woodinville	6.2	4.17	11.5
1255	Bear Creek at Woodinville	4.9	4.40	9.6
1260	North Creek near Bothell	5.8	4.33	10.6
1265	Sammamish River at Bothell	5.8	4.31	11.1
1271	Swamp Creek at Kenmore	5.6	4.35	9.8
1280	Thornton Creek near Seattle	4.9	4.38	10.7
1330	South Fork Skykomish River near Index	4.8	4.05	7.8
1345	Skykomish River near Gold Bar	4.7	4.08	7.8
1375	Sultan River near Startup	4.4	4.18	7.1
1410	Woods Creek near Monroe	5.8	4.30	9.6
1413	Middle Fork Snoqualmie River near Tanner	5.0	4.02	7.6
1420	North Fork Snoqualmie River near Snoqualmie Falls	4.5	3.99	7.0
1430	North Fork Snoqualmie River near North Bend	4.6	4.10	8.2
1434	South Fork Snoqualmie River above Alice Creek,near Garcia	5.4	4.18	7.7
1436	South Fork Snoqualmie River at Edgewick	4.4	4.08	7.9
1440	South Fork Snoqualmie River at North Bend	4.6	4.04	8.8
1445	Snoqualmie River near Snoqualmie	4.8	4.10	8.4
1455	Raging River near Fall City	5.6	4.24	9.4
1460	Patterson Creek near Fall City	4.7	4.27	9.5
1470	Griffin Creek near Carnation	6.0	4.40	10.1
1475	North Fork Tolt River near Carnation	4.0	4.26	7.6
1480	South Fork Tolt River near Carnation	6.0	3.98	8.8
1485	Tolt River near Carnation	4.2	4.13	8.2
1487	Stossel Creek near Carnation	5.9	4.56	9.8
1490	Snoqualmie River near Carnation	5.8	4.26	9.8
1505	Cherry Creek near Duvall	5.8	4.22	10.7
1508	Snohomish River near Monroe	5.8	4.26	9.5
1530	Little Pilchuck Creek near Lake Stevens	6.2	4.35	9.9
1570	Quilceda Creek near Marysville	4.0	4.34	9.5
1610	South Fork Stillaguamish River near Granite Falls	5.3	4.13	8.1
1650	Squire Creek near Darrington	4.1	4.13	7.2
1670	North Fork Stillaguamish River near Arlington	5.5	4.06	8.5
1720	Big Beaver Creek near Newhalem	3.6	4.20	5.0
1735	Ruby Creek below Panther Creek, near Newhalem	5.2	4.18	5.5
1755	Thunder Creek near Newhalem	3.1	4.07	5.1
1775	Stetattle Creek near Newhalem	3.8	4.00	6.0
1780	Skagit River at Newhalem	3.5	3.67	6.9
1781	Newhalem Creek near Newhalem	4.1	4.08	5.8
1860	Sauk River above Whitechuck River near Darrington	3.6	4.17	6.4
1895	Sauk River near Sauk	4.5	4.07	7.6
1918	Sulphur Creek near Concrete	3.5	4.12	5.7
1935	Baker River at Concrete	4.1	3.74	8.4
1940	Skagit River near Concrete	3.6	4.08	8.7
1960	Alder Creek near Hamilton	3.6	4.20	8.4
1962	Day Creek below Day Lake, near Lyman	8.5	4.36	1.1
1964	Day Creek near Hamilton	6.3	4.08	8.4
1998	East Fork Nookachamps Creek near Big Lake	5.0	3.98	6.3
2015	Samish River near Burlington	5.7	4.40	10.3
2050	North Fork Nooksack River below Cascade Creek, near Glacier	3.0	4.27	5.4
2072	North Fork Nooksack River near Deming	4.7	4.04	7.8
2080	Middle Fork Nooksack River near Deming	3.9	4.06	6.9
2090	South Fork Nooksack River near Wickersham	6.1	4.03	8.2
2095	Skookum Creek near Wickersham	5.0	4.24	7.5

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	WESTERN WASHINGTON--Continued			
12-2105	Nooksack River at Deming	5.2	4.18	8.1
2115	Nooksack River near Lynden	5.0	4.28	8.3
2120	Fishtrap Creek at Lynden	5.3	4.44	10.2
14-1117	Butler Creek near Goldendale	9.2	4.23	9.4
1120	Little Klickitat River near Goldendale	8.4	4.21	9.0
1123	Spring Creek near Blockhouse	1.7	3.28	10.4
1124	Mill Creek near Blockhouse	5.7	4.26	8.7
1125	Little Klickitat River near Wahkiacus	8.0	4.28	10.1
1213	White Salmon River below Cascades Creek, near Trout Lake	3.9	4.21	4.1
1214	White Salmon River above Trout Lake Creek, near Trout Lake	3.5	4.29	5.1
1215	Trout Lake Creek near Trout Lake	6.9	4.30	7.1
1220	White Salmon River near Trout Lake	4.7	4.28	6.0
1229	White Salmon River at BZ Corner	2.7	4.43	6.1
1235	White Salmon River near Underwood	2.8	4.35	7.6
1255	Little White Salmon River near Cook	2.0	4.38	7.1
1270	Wind River above Trout Creek, near Carson	4.3	4.15	7.8
1285	Wind River near Carson	4.2	4.09	7.9
1435	Washougal River near Washougal	5.8	4.14	9.6
2120	Salmon Creek near Battle Ground	5.2	4.26	9.7
2132	Lewis River near Trout Lake	4.7	4.11	5.9
2135	Big Creek below Skookum Meadow, near Trout Lake	4.0	4.08	3.9
2140	Rush Creek above Meadow Creek, near Trout Lake	5.2	3.84	3.8
2145	Meadow Creek below Lone Butte Meadow, near Trout Lake	2.1	4.27	3.3
2150	Rush Creek above falls, near Cougar	2.3	4.06	4.4
2155	Curly Creek near Cougar	2.3	4.03	4.2
2160	Lewis River above Muddy River, near Cougar	4.4	4.18	6.1
2168	Pine Creek near Cougar	4.0	4.03	6.0
2215	Cedar Creek near Ariel	5.6	4.36	10.5
2255	Lake Creek near Packwood	6.7	4.03	8.3
2260	Lake Creek at mouth,near Packwood	4.7	4.18	7.5
2265	Cowlitz River at Packwood	5.5	4.18	7.5
2362	Tilton River above Bear Canyon Creek, near Cinebar	5.8	4.09	9.4
2364	Cinnabar Creek near Cinebar	4.3	3.98	8.0
2370	Klickitat Creek at Mossyrock	6.1	4.29	11.1
2375	Winston Creek near Silver Creek	5.8	4.22	9.7
2390	Salmon Creek near Toledo	7.8	4.28	11.4
2435	Delameter Creek near Castle Rock	5.4	4.11	10.1
2482	Jim Crow Creek near Grays River	8.1	4.16	13.1
2490	Grays River above South Fork, near Grays River	5.2	4.08	9.5
	EASTERN WASHINGTON			
12-3960	Calispell Creek near Dalkena	8.4	4.26	8.4
3965	Pend Oreille River below Box Canyon, near Ione	9.1	4.10	10.2
3969	Sullivan Creek above Outlet Creek, near Metaline Falls	5.2	4.13	5.2
3971	Outlet Creek near Metaline Falls	7.1	4.18	9.1
3980	Sullivan Creek at Metaline Falls	6.8	3.97	7.3
3985	Pend Oreille River below Z Canyon, near Metaline Falls	9.8	4.09	9.7
3986	Pend Oreille River at international boundary	8.4	4.12	9.5
4015	Kettle River near Ferry	7.3	4.22	7.8
4045	Kettle River near Laurier	7.2	4.23	7.7
4075	Sheep Creek at Springdale	7.2	4.53	8.5
4075.2	Deer Creek near Valley	7.4	4.39	8.2
4077	Chewelah Creek at Chewelah	7.4	4.29	8.6
4080	Colville River at Blue Creek	8.6	4.36	9.0
4084.2	Haller Creek near Arden	7.3	4.43	7.5
4085	Mill Creek near Colville	6.4	4.26	8.2

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	EASTERN WASHINGTON--Continued			
12-4087	Mill Creek at mouth	7.1	4.34	9.0
4090	Colville River at Kettle Falls	9.0	4.38	9.3
4195	Spokane River above Liberty Bridge, near Otis Orchards	9.7	4.12	10.7
4225	Spokane River at Spokane	7.2	4.09	10.0
4240	Hangman Creek at Spokane	11.1	4.41	11.5
4270	Little Spokane River at Elk	9.6	4.40	9.6
4310	Little Spokane River at Dartford	7.7	4.43	9.2
4345	Sanpoil River near Keller	8.3	4.34	8.6
4394	Okanogan River at Zosel millpond, at Oroville	11.8	4.17	11.0
4395	Okanogan River at Oroville	11.2	4.24	11.4
4423	Sinlahekin Creek above Chopaka Creek, near Loomis	6.9	4.32	8.0
4425	Similkameen River near Nighthawk	7.8	4.20	7.9
4441	Whitestone Creek near Tonasket	9.9	4.50	10.4
4450	Okanogan River near Tonasket	9.3	4.34	9.6
4473	Okanogan River near Malott	9.2	4.26	10.0
4496	Beaver Creek below South Fork, near Twisp	5.8	4.31	4.7
4499.5	Methow River near Pateros	7.0	4.24	7.6
4510	Stehekin River at Stehekin	5.5	4.16	6.2
4528	Entiat River near Ardenvoir	5.4	4.34	5.4
4540	White River near Plain	4.3	4.22	4.9
4570	Wenatchee River at Plain	5.7	4.10	6.9
4580	Icicle Creek above Snow Creek, near Leavenworth	5.3	4.31	5.5
4590	Wenatchee River at Peshastin	6.6	4.18	6.9
4614	Mission Creek above Sand Creek, near Cashmere	7.9	4.31	7.4
4625	Wenatchee River at Monitor	6.9	4.28	7.4
4648	Coal Creek at Mahler	9.5	4.34	9.7
4650	Crab Creek at Irby	7.9	4.40	8.8
4670	Crab Creek near Moses Lake	10.1	4.45	10.8
4685	Park Creek below Park Lake, near Coulee City	9.2	4.30	10.4
4705	Rocky Ford Creek near Ephrata	3.4	4.33	9.0
4715	Crab Creek near Warden	7.3	4.42	8.9
4726	Crab Creek near Beverly	9.8	4.50	10.7
4838	Naneum Creek near Ellensburg	6.4	4.22	5.9
4885	American River near Nile	3.8	4.20	4.4
5020	Ahtanum Creek at The Narrows, near Tampico	6.6	4.16	7.1
5050	Yakima River near Parker	7.4	4.21	10.3
5105	Yakima River near Kiona	9.2	4.44	11.5
13-3347	Asotin Creek below Kearney Gulch, near Asotin	7.8	4.36	, 9.9
3445	Tucannon River near Starbuck	8.5	4.43	12.2
3460	Palouse River near Colfax	11.9	4.50	11.0
3461	Palouse River at Colfax	10.6	4.37	11.1
3480	South Fork Palouse River at Pullman	9.7	4.34	10.9
3485	Missouri Flat Creek at Pullman	9.5	4.46	10.8
3492.1	Palouse River below South Fork, at Colfax	10.6	4.35	11.5
3494	Pine Creek at Pine City	9.1	4.47	10.0
3505	Union Flat Creek near Colfax	11.1	4.54	11.3
3510	Palouse River at Hooper	11.1	4.40	12.6
3525	Cow Creek at Hooper	9.6	4.33	11.9
3530	Snake River below Ice Harbor Dam	9.9	3.96	12.5

TABLE 8.—*Stream-temperature characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Station name	Annual amplitude (°C) A	Phase coefficient (radians) C	Mean annual (°C) M
	EASTERN WASHINGTON--Continued			
14-0130	Mill Creek near Walla Walla	5.1	4.31	8.9
0135	Blue Creek near Walla Walla	6.0	4.67	9.8
0160	Dry Creek near Walla Walla	8.9	4.44	11.1
0165	East Fork Touchet River near Dayton	7.1	4.32	10.1
0170	Touchet River at Bolles	9.8	4.44	12.2
0185	Walla Walla River near Touchet	10.3	4.40	12.2
0343.5	Alder Creek at Alderdale	8.7	4.46	12.7
0366	Rock Creek near Roosevelt	8.7	4.32	13.9

TABLE 9.—*Topographic and climatic drainage-basin characteristics, western Washington thermograph stations*

[Characteristics given below were significantly related (tested at the 95-percent confidence level) to one or more stream-temperature characteristics. Column P (below): for computation purposes, value of 0.001 is given for basins with no lake or pond areas]

Station number	Average direction of flow of stream (degrees) Ø	Length of river, (miles) L	Mean altitude of basin (ft) E	Lake and pond areas (percent) P	Drainage area (sq mi) D	Mean annual discharge (in.) Q	Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M	Mean monthly air temperature (°C): January T_1	February T_2	August T_8	October T_{10}
12-0115	295	10.5	754	0.01	41.4	59	154	2,400	115	6.5	10.7	4.4	4.5	16.9	12.3
0275	306	52	800	.03	895	42	123	2,400	8.1	6.8	11.0	4.2	4.6	17.3	11.8
0600	137	16.7	2,505	.02	63.4	123	456	4,300	80	7.5	10.4	3.2	3.5	17.8	11.5
0615	144	28.9	1,370	.02	227	80	10	4,300	35.1	7.3	10.7	3.5	4.0	17.3	11.4
0625	10	1	38	.001	1.3	278	29	200	4	7.3	10.7	3.5	4.0	17.3	11.4
0825	252	21.2	4,020	.38	133	75	1,450	7,000	91.2	8.3	9.1	.8	1.0	15.7	9.6
0830	324	13	2,740	.07	75.2	66	1,340	4,240	155	8.3	10.0	1.5	2.0	16.0	9.9
1130	288	59.4	2,400	.60	399	47.4	60	4,300	36	7.3	11.5	3.8	4.1	19.0	13.0
1175	280	27.6	2,400	2.17	122	77.2	600	3,000	58.9	7.3	9.5	2.7	3.0	[illegible]	11.0
1350	262	9.4	2,660	.79	19	102	200	4,500	319	7.5	11.4	3.8	4.2	18.4	12.5
1640	247	17.4	1,400	.82	46.2	54.8	110	4,240	158	7.8	10.6	2.5	3.5	17.9	11.8
1655	252	18.5	2,340	.001	82.2	90	410	4,500	180	8.6	9.8	1.0	1.8	17.9	11.0
1685	225	15.5	1,290	2.6	52	67.8	140	1,305	81.7	7.2	10.7	2.5	3.8	[illegible]	[illegible]
1790	230	40.4	5,000	5.6	1,274	6,090	359	2,500	68	9.5	10.8	1.5	2.0	19.6	12.2
1825	297	2.4	4,400	.17	168	81.1	380	8,261	107	9.3	10.4	1.2	1.5	19.2	11.8
2005	270	94.8	1,250	3.0	3,093	72.1	43	2,500	34.4	6.7	10.5	3.8	4.2	17.0	12.0
14-1100	179	37.6	4,520	.28	360	30.8	1,703	8,200	47.9	10.2	8.7	-1.0	-.5	19.2	[illegible]
1130	204	88.1	3,140	.09	1,297	16.7	289	8,200	44.8	10.2	10.8	.5	2.0	20.2	12.5
2205	247	71.0	1,788	11.8	731	88.7	44	12,310	43.4	7.6	11.3	3.5	4.0	18.5	13.1
2225	282	21.5	1,940	.01	125	81	367	3,840	93	7.7	11.0	3.5	3.7	18.4	12.9
2235	260	41	1,880	.01	198	84.1	20	9,670	80.3	7.2	10.9	3.6	4.3	17.6	11.8
2325	284	30	4,130	.15	321	56	1,222	7,300	117.3	8.5	10.5	2.4	1.8	18.8	13.3
2335	252	56.2	--	--	1,042	65.2	759	9,364	36.8	7.9	10.4	2.8	2.5	18.2	12.1
2355	157	6.5	2,450	.12	16.4	93.8	1,150	4,320	359	8.2	10.6	3.0	3.3	17.0	10.7
2380	[illegible]	93.5	3,150	.15	1,400	59.2	227	9,360	12.8	7.9	10.5	3.5	3.5	18.0	12.0
2425	278	40.1	2,310	.93	474	57.4	407	5,200	87.1	7.5	10.5	3.1	3.3	18.1	12.5
2430	172	127	2,540	.26	2,238	55.0	20.2	9,364	10.8	7.4	10.9	3.4	3.8	17.9	12.2
2450	263	25.7	1,390	.08	119	45.6	100	3,920	62.8	7.3	10.8	3.7	4.3	17.3	11.6
2460	151	9.0	1,120	.01	20.3	64.6	70	1,840	108	7.1	10.6	3.7	4.3	17.2	11.6
2475	208	16.5	1,190	.01	65.8	75	29.7	1,920	60.8	6.9	10.5	3.8	4.3	17.2	11.7
2505	176	6.5	1,180	.01	15.2	96.7	71	2,632	187	6.9	10.5	3.8	3.8	17.1	12.3

TABLE 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*

[Characteristics given below were significantly related (tested at the 95-percent confidence level) to one or more stream-temperature characteristics. Column P (below): for computation purposes, value of 0.001 is given for basins with no lake or pond areas]

Station number	Characteristic										
	Average direction of flow of stream (degrees)	Length of river, (miles)	Mean altitude of basin (ft)	Lake and pond areas (percent)	Drainage area (sq mi)	Mean annual discharge (in.)	Site altitude (ft)	Source altitude (ft)	Fall or slope of river (ft per mile)	Air temperature annual amplitude (°C)	Mean annual air temperature (°C)
	Ø	L	E	P	D	Q	G	S	F	T_A	T_M
					WESTERN WASHINGTON						
12-0095	297	7.3	494	0.001	11.7	72	15	800	77	6.5	10.3
0100	225	18.6	910	.01	54.8	106	24	2,650	75.3	6.7	10.4
0105	229	13.5	480	.01	16.4	87.2	80	2,150	51.8	6.7	10.4
0107	357	5.7	348	.001	17.9	76	20	400	30.4	6.7	10.4
0110	307	7.4	689	.01	18	84	60	700	58.6	6.3	10.5
0112	270	7.3	666	.001	9.4	74.2	60	1,760	115	6.2	10.5
0120	322	8.4	738	.001	20.4	95.8	155	2,250	216	6.5	10.7
0135	275	25.2	641	.01	130	66.1	5.7	2,400	18	6.3	10.9
0145	91	13.3	585	.001	27.8	78.6	155	1,760	48	6.2	10.9
0151	20	3	622	.001	4.0	74	150	1,040	222	6.0	10.8
0152	255	16.5	424	.01	57.7	54.9	100	1,120	12	6.0	10.8
0155	244	6.9	660	.001	29.8	51.4	190	1,680	188	6.3	10.9
0170	280	22	250	.01	219	59.5	7	1,680	20	6.0	10.4
0200	2	21.5	1,000	.01	113	68.4	302	2,400	55	6.7	10.9
0210	1	19.8	830	.001	48	53.3	255	1,840	40	7.0	11.0
0240	230	14.4	1,280	.1	42.4	63.4	540	3,760	167	7.7	10.7
0245	260	12.4	1,220	.001	31.5	45.2	380	2,560	96	7.5	10.8
0250	261	31.4	900	.02	155	42.5	190	3,760	46	7.0	11.1
0260	288	17.6	1,700	.01	61.7	55.4	300	3,440	92	7.6	11.0
0300	98	7.2	525	.01	24.8	44.1	70	791	80	6.4	10.9
0310	188	83.6	700	.12	1,294	40.3	25	2,400	8	6.4	10.9
0325	215	14.3	410	.63	64.9	50.0	20	480	25	6.6	10.8
0342	212	15.2	650	.95	65.9	75.2	205	2,890	32	6.9	10.6
0350	193	28	500	.25	299	91.8	30	2,890	19	6.7	10.8
0354	195	14.4	2,074	.01	41.4	162.7	640	4,050	122	8.5	10.5
0360	200	23.6	2,000	.001	74.1	161.5	492	4,050	63	7.8	10.2
0374	191	55.8	900	.01	155	109	40	4,050	19	6.8	10.9
0390	217	35.4	1,000	.01	130	133	117	3,360	25	6.0	9.8
0393	207	13	3,280	.08	74.1	146	620	5,300	250	9.5	11.1
0395	232	36.5	2,700	2.08	264	144	185	7,320	64	8.0	10.8
0410	260	33.5	3,000	.21	208	131.2	320	7,700	72	7.0	10.2
0412	263	43.4	2,620	.17	253	131.4	164	7,700	68	6.5	10.0
0415	313	16.9	2,900	.48	83.8	98.9	1,060	5,400	146	7.5	9.9
0430	234	15.5	532	.16	39.8	87.1	70	1,920	31	5.5	9.6
0431	220	1.8	440	1.2	86.3	83.2	50	800	12	5.5	9.6
0433	8	18.4	805	.001	51.2	92.2	50	2,300	30	5.0	8.5
0434	10	6.5	1,280	.001	14	60.8	10	3,700	297	7.3	9.7
0455	344	34.4	3,700	.23	269	74.4	200	5,200	69	7.5	10.3
0475	359	8.8	1,550	.01	15.5	17	225	5,450	321	5.7	9.5
0480	40	20	4,500	.06	156	33.3	569	7,000	187	6.6	9.8
0505	91	6.6	1,800	.001	11.2	19.5	220	3,050	388	7.0	10.0
0540	85	19.5	4,100	.30	66.5	83.8	241	5,000	159	7.7	10.4
0545	73	11.5	3,830	.50	51.3	91.1	510	5,200	377	7.9	10.5
0546	64	9.7	2,660	.43	21.6	86.8	500	5,100	412	7.9	10.5
0565	147	12.8	3,700	.17	57.2	115	762	6,400	177	8.3	10.7
0595	195	6.7	2,665	.10	18	--	64	320	22	7.4	10.5
0598	134	8.5	1,920	.24	26	146.7	750	4,100	220	8.4	10.6
0605	135	24	2,100	.25	76.3	119	110	4,100	63	7.4	10.5
0626	10	--	--	.001	2.42	--	40	420	--	7.3	10.6
0655	206	1.5	1,120	.01	1.51	49	751	880	36	7.6	11.1

TABLE 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Characteristic										
	Average direction of flow of stream (degrees) Ø	Length of river, (miles) L	Mean altitude of basin (ft) E	Lake and pond areas (percent) P	Drainage area (sq mi) D	Mean annual discharge (in.) Q	Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M
				WESTERN WASHINGTON--Continued							
12-0685	226	7.6	376	0.71	18.4	48.7	55	440	36	7.5	10.8
0700	178	3.0	289	.001	5.01	16.1	20	170	49	7.3	11.1
0720	85	6.1	400	9.5	15.3	27.6	50	900	100	7.7	11.2
0730	180	5.3	250	.001	10	--	10	300	43	7.0	11.6
0735	150	7.5	316	.21	6.5	24.1	100	460	55	7.0	11.5
0765	82	7.5	420	1.0	39.3	34.6	205	480	32	7.1	10.7
0784	61	9.7	700	4.85	17.4	46.9	110	720	60	6.9	10.6
0790	311	25.9	1,340	.63	89.8	38.0	350	3,280	17	7.6	11.3
0800	303	45.9	950	1.10	160	34.7	95	3,280	30	6.8	10.5
0810	335	9.0	189	6.93	24.6	14.5	25	325	12	7.0	10.8
0865	285	37.7	3,200	1.79	292	65	490	7,000	85	8.4	10.5
0880	230	6	1,600	.61	34.5	26.3	520	580	6	8.4	10.0
0895	295	54.9	2,740	1.48	517	--	275	7,000	62	7.5	11.4
0902	268	6.7	350	1.0	86.8	9.8	310	425	8	7.2	11.4
0910	270	--	400	2.1	90.4	12.4	140	500	--	7.0	11.8
0911	180	--	--	--	8.01	12.3	200	--	--	7.5	12.0
0913	270	--	--	--	5.88	21.9	140	--	--	7.5	12.0
0915	265	--	385	1.75	104	14.7	100	500	--	7.5	12.0
0920	304	20.2	4,100	.54	92.8	77.7	1,640	10,300	224	8.1	8.0
0935	316	23.5	3,000	.82	172	54.7	358	10,300	182	7.4	10.6
0940	287	16.8	400	.16	78.9	72.6	1,213	9,200	394	7.5	9.5
0944	312	6.6	3,650	.41	22.4	62.8	1,420	5,600	414	7.7	9.5
0950	302	16.5	2,300	.64	79.5	38.5	430	5,600	174	7.2	10.4
0966	50	8.4	7,100	.003	16.2	95.1	3,8[illegible]	14,408	1,000	9.6	5.3
0970	355	31.1	4,700	.46	216	53	1,725	14,408	151	9.4	7.4
0975	302	20.2	4,200	.27	73.5	38	1,725	6,130	129	9.5	7.4
0985	310	48.7	3,800	.30	401	49.5	790	14,408	83	7.5	10.0
0993	275	4.5	2,260	.001	4.6	--	1,435	3,840	462	7.7	9.8
0994	275	6.5	1,800	.75	8.3	--	1,000	3,840	390	7.7	9.8
0995	273	9.2	1,480	.51	12.3	--	740	3,840	238	7.4	10.0
1005	306	71.2	3,326	2.2	470	18.1	58	14,408	60	6.9	10.5
1015	311	41.8	2,500	.31	948	47.7	20	10,300	78	6.9	10.5
1034	17	8.0	3,680	.001	34.8	52.8	1,800	5,520	615	9.5	4.6
1035	230	3.7	3,370	.03	11.5	71.3	1,950	3,840	476	9.0	4.3
1040	185	3.1	3,190	.02	4.67	79.0	1,760	4,440	757	8.8	4.2
1045	289	15	3,190	.02	96.2	50.9	1,480	5,520	259	9.3	4.3
1047	187	3	2,950	.001	3.23	52.1	1,480	4,100	818	9.0	4.2
1050	60	4.6	3,220	.001	8.56	81.3	1,900	4,040	500	9.5	4.4
1057	200	8.1	2,890	.78	16.5	68.5	1,250	4,160	250	7.5	9.6
1059	293	14.7	--	--	221	62.8	990	5,520	176	7.5	9.6
1067	292	35.9	3,100	.09	231	50.9	860	5,520	118	7.2	9.7
1073	175	.4	--	--	.1	--	540	640	.2	6.9	10.0
1085	331	12.8	883	.01	27.4	32.5	310	2,860	82	6.9	10.0
1126	256	13.5	450	1.7	66.7	23	70	420	25	7.0	11.3
1133	303	63	--	--	440	45.1	22	5,520	37	7.1	11.2
1135	254	3.7	3,830	.01	9.3	105.3	2,360	3,600	317	8.8	5.8
1140	342	4	3,500	.01	6.0	85.6	2,300	4,500	317	8.7	5.8
1145	300	7.1	3,460	.01	25.4	96.1	1,880	3,600	189	8.6	7.2
1150	299	12.2	3,230	1.43	40.7	83.2	1,560	3,600	116	8.4	7.8
1155	321	6.4	3,360	.001	13.4	100	1,700	4,500	386	8.2	8.1

TABLE 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Characteristic										
	Average direction of flow of stream (degrees) Ø	Length of river, in miles L	Mean altitude of basin (ft) E	Lake and pond areas (percent) P	Drainage area (sq mi) D	Mean annual discharge (in.) Q	Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M
					WESTERN WASHINGTON--Continued						
12-1165	302	21.7	2,800	3.26	84.2	50.3	910	3,600	58	7.4	8.7
1170	350	8.2	2,300	.001	17.2	81.3	940	3,600	289	7.3	9.3
1185	5	7.2	690	.08	12.6	22.5	425	860	37	7.5	10.4
1190	289	53.1	1,790	1.64	186	51.2	15.2	3,600	41	7.2	11.1
1196	298	8.4	550	.006	12.7	23.8	25	1,450	41	6.9	11.2
1197	312	6.4	770	.001	6.8	25.1	50	1,300	221	6.8	11.3
1200	202	3.9	305	.001	12	22.5	20	380	65	7.0	11.4
1205	240	3.2	235	.001	6.43	22.9	20	460	83	7.0	11.3
1210	312	10	940	.37	27	34.8	210	2,700	153	7.3	10.5
1216	335	15.7	930	.37	54.7	29.5	40	2,700	92	7.2	11.0
1230	178	7.5	375	1.78	10.7	17.2	210	600	42	7.0	11.1
1240	240	8.6	365	.07	13.0	22.6	50	640	74	7.2	11.1
1252	339	29.1	58.2	5.44	15.7	28.7	20	2,700	24	7.0	11.2
1255	189	9.2	358	.001	15.3	21.2	30	490	47	7.0	11.2
1260	173	9.9	390	2.14	24.6	18.8	70	550	49	7.4	11.2
1265	331	34.3	500	4.24	212	23.5	17	2,700	16	7.5	11.2
1270	172	13.5	394	.61	23.1	22.8	3	600	43	7.5	11.3
1280	95	6.5	312	.15	12.1	12.9	40	440	65	7.5	11.5
1330	292	27.9	3,800	.90	355	92.9	575	4,950	88	8.0	11.4
1345	282	36	3,700	.73	535	99.4	209	4,950	63	7.6	11.4
1375	262	18.3	3,120	.40	74.5	143	750	4,250	94	7.7	11.3
1410	169	14.2	625	1.19	56.4	35.1	100	440	25	7.2	10.8
1413	263	29.6	3,710	1.3	154	110	780	6,020	117	8.0	8.0
1420	232	17.3	3,200	.78	64	109	1,130	5,700	85	7.8	10.5
1430	213	24.2	3,100	1.67	95.7	89.8	470	5,700	68	7.5	9.5
1434	283	13.7	3,420	.31	41.6	99.6	1,480	5,450	155	8.5	7.2
1436	294	21.7	3,330	.30	65.9	--	577	5,450	107	7.5	8.0
1440	296	27.2	2,900	.51	81.7	89.4	432	5,450	102	7.2	9.0
1445	267	44.8	3,300	1.14	375	91.4	120	6,020	72	7.5	10.5
1455	345	12.5	1,460	.01	30.6	65.3	250	3,000	179	7.4	10.5
1460	130	7.1	410	.001	15.5	28.2	70	560	74	7.4	10.7
1470	245	10.8	781	.24	17.1	31.1	120	1,580	53	7.6	10.7
1475	254	15.2	2,590	.001	39.9	140	600	5,640	10.6	7.7	10.8
1480	273	3.9	2,940	.03	19.7	140.5	1,300	2,980	294	8.0	11.0
1485	260	18.3	2,300	.12	81.4	112	348	5,640	111	7.6	10.6
1487	182	5.5	790	2.7	5.58	40.4	340	580	27	7.5	10.6
1490	275	60.8	2,400	.7	603	86	50	6,020	40	7.5	10.6
1505	196	8.2	880	2.0	19.2	38.6	90	950	98	7.2	10.7
1508	280	58.2	--	--	1,537	89.0	13.2	4,950	21	7.1	10.8
1530	185	8.7	376	.09	17	22.6	200	560	40	7.8	11.2
1570	260	5.4	220	.01	15.4	22.7	28.2	395	8	7.7	10.9
1610	282	33.2	2,600	.08	119	122	310	6,610	62	8.1	10.6
1650	348	10.2	2,530	.01	20	122	490	6,600	308	8.6	9.8
1670	279	40	2,300	.01	262	91.3	89	3,210	35	7.6	10.5
1720	120	16	4,400	.01	63.2	112	1,600	3 900	140	9.6	9.9
1735	271	14.1	5,700	.05	206	42.5	1,640	6,690	285	9.8	9.8
1755	339	14.4	5,800	.10	105	84.6	1,220	6,330	274	9.4	10.0
1775	137	7.7	5,000	.10	22	112	925	6,640	500	9.4	10.3
1780	240	32.7	5,000	2.21	1,175	51.6	402	2,500	68	9.8	10.9
1781	352	7.3	4,140	.31	27.9	85.1	1,080	7,280	663	9.8	10.9

TABLE 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Characteristic										
	Average direction of flow of stream (degrees) Ø	Length of river, (miles) L	Mean altitude of basin (ft) E	Lake and pond areas (percent) P	Drainage area (sq mi) D	Mean annual discharge (in.) Q	Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M
					WESTERN WASHINGTON--Continued						
12-1860	319	19.8	3,700	0.13	152	100	930	7,360	84	8.9	9.5
1895	329	44.4	3,900	.01	714	82.9	266	7,360	40	9.1	10
1918	310	8.5	4,350	.001	8.36	76.2	1,750	9,700	866	8.7	9.4
1935	190	32.8	--	1.52	297	120	173	8,240	51	8.0	10.4
1940	297	69.4	4,100	1.23	1,737	74.7	130	2,500	27	7.9	10.4
1960	195	6.5	1,280	.001	10.7	42.9	125	1,350	197	7.4	10.4
1962	332	4.0	2,610	3.81	6.6	123.2	1,600	4,320	240	7.4	10.5
1964	332	9.9	2,350	.77	32.3	114.9	140	4,320	187	7.1	10.4
1998	260	3.8	2,700	.003	3.56	87.7	1,700	4,000	456	6.9	10.5
2015	218	19.6	580	1.82	87.8	36	45	1,650	19	6.5	10.3
2050	280	17.6	4,300	.19	105	97.9	1,245	6,400	106	6.7	10.0
2072	272	36.7	3,270	.18	282	74.2	345	6,400	71	7.8	10.2
2080	280	16.8	3,640	.06	73.3	90.8	580	10,500	344	7.6	9.5
2090	283	25.8	3,000	.29	103	95.9	385	5,300	58	7.0	9.9
2095	258	9.5	3,020	.09	23.1	78.7	400	5,600	334	6.9	9.9
2105	288	43.1	3,000	.24	584	77.5	204	6,400	62	7.5	9.5
2115	291	63.1	--	--	648	77.2	24.4	6,400	41	7.4	10
2120	230	8.2	154	1.26	22.3	18.1	110	260	23	7.2	9.7
14-1117	138	9.7	3,620	.001	11.6	15.3	2,200	5,100	256	10.1	9.4
1120	219	15.6	3,160	.01	83.5	11.2	1,690	4,600	131	9.8	9.5
1123	180	4.2	2,160	.001	2.75	68.9	1,620	2,170	105	9.7	9.3
1124	210	12.4	3,230	.23	26.9	4.5	1,600	5,600	241	9.7	9.2
1125	254	31.6	2,600	.04	280	8.5	570	4,600	45	9.8	9.0
1213	201	10	5,190	.003	32.4	61.1	3,080	7,900	477	10	9.7
1214	166	17	4,500	.001	64.9	49.3	2,050	7,900	267	9.8	9.5
1215	132	15	3,450	.54	69.3	51.7	2,000	3,950	149	9.8	9.6
1220	145	20.9	3,940	.20	185	28	1,780	7,900	210	9.8	9.3
1229	171	32	3,470	.14	269	40.9	705	7,900	133	9.6	9.5
1235	181	42.5	3,220	.26	386	39.6	113	7,900	106	9.4	9.4
1255	179	16.5	2,750	.23	134	52.8	150	4,240	126	8.9	9.4
1270	170	17.7	2,740	.03	108	65.5	890	3,050	111	8.6	10.2
1285	145	27.7	2,460	.03	225	69.2	113	3,050	66	8.6	9.9
1435	241	22.2	1,610	.01	108	100	175	3,440	66	7.6	10.5
2120	328	4.9	1,000	.01	18.3	43.3	355	2,225	313	7.5	10.8
2132	234	22	3,950	.002	127	73	1,500	12,307	300	9.7	10.7
2135	271	6	3,780	.01	132	61	3,213	4,700	167	9.6	10.7
2140	300	5.4	4,490	3.1	5.9	55.7	3,400	4,750	346	9.5	10.7
2145	358	6	3,980	2.1	11.7	108.4	3,200	4,800	239	9.5	10.8
2150	300	8.4	4,000	.96	26	86.6	2,260	4,750	321	9.5	10.7
2155	310	6.2	2,960	.001	11.6	72.4	2,490	5,000	403	9.5	10.7
2160	236	32.8	3,540	.13	22.7	73.5	1,080	12,307	178	9.5	10.8
2168	165	13.5	3,181	.15	131	85.6	1,200	4,040	131	9.6	10.8
2215	287	16.5	980	.23	40.8	--	287	1,940	104	7.7	11.2
2255	313	8.0	4,700	4.2	19.2	70.6	2,845	6,990	310	8.5	9.5
2260	313	12.2	4,170	2.8	26.5	61.4	1,190	6,990	275	8.4	9.2
2265	223	23.5	4,230	.45	287	77.3	1,048	9,200	182	8.3	9.8
2362	268	211	2,330	.13	141	81.1	600	3,300	60	8.2	10.6
2364	186	5	1,830	.001	4.55	86.5	940	3,560	405	8.2	10.6

TABLE 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Characteristics										
	Average direction of flow of stream (degrees) Ø	Length of river, (miles) L	Mean altitude of basin (ft) E	Lake and pond areas (percent) F	Drainage area (sq mi) D	Mean annual discharge (in.) Q	Site altitude (ft) G	Source altitude (ft) S	Fall or slope of river (ft per mile) F	Air temperature annual amplitude (°C) T_A	Mean annual air temperature (°C) T_M
				WESTERN WASHINGTON--Continued							
14-2370	20	3	985	0.01	3.29	34.1	668	1,000	49	8.0	10.4
2375	291	10.6	1,640	.01	37.8	36.3	470	2,320	136	7.9	10.4
2390	266	23.8	630	.001	77.6	25.9	110	2,500	44	7.7	11.1
2435	114	6.7	906	.01	19.6	59.2	75	1,500	139	7.2	10.9
2482	182	4.0	490	.001	5.48	78.8	25	1,175	237	6.9	10.4
2490	216	11	1,350	.001	39.9	115	350	276	170	7.0	10.6
				EASTERN WASHINGTON							
12-3960	190	12.2	3,650	.41	68.3	13.6	2,070	5,167	126	11.2	7.0
3965	160	75.5	2,025	1.9	24,900	15.5	2,012	2,051	1	12.2	8.2
3969	251	15.7	4,760	1.7	70.2	18.5	2,540	6,100	121	12.3	8.1
3971	347	14.7	4,200	4.2	51.5	19.7	2,550	5,200	196	12.3	8.1
3980	270	19.6	4,380	1.5	142	19.4	2,050	6,100	170	12.3	8.2
3985	180	82.4	2,000	1.7	25,200	14.4	1,720	2,050	.8	12.5	8.3
3986	180	91.4	1,850	1.85	25,200	12.5	1,000	2,050	.5	12.5	8.3
4015	165	98.5	4,560	.05	2,220	9.2	1,840	6,000	42	11.8	6.5
4045	175	130	4,560	.33	3,800	9.0	1,426	6,000	35	12.3	8.2
4075	248	7.8	2,390	.001	48.2	3.5	1,980	2,880	55	11.7	7.4
4075.2	91	11.8	3,160	.001	36	6.8	2,060	4,400	82	11.5	7.6
4077	193	17.6	3,160	.001	94.1	5.1	1,660	5,100	138	11.4	7.7
4080	332	66.6	--	.01	428	4.4	1,620	4,400	10	11.4	8.0
4084	80	9	2,570	.001	37	2.6	1,600	4,480	175	11.5	9.1
4085	248	14.1	3,510	.01	83.0	7.9	1,950	5,100	103	11.7	9.0
4087	241	22.5	3,240	.001	146	--	1,540	5,100	81	11.5	9.0
4090	327	91.3	3,000	.61	1,007	3.9	1,500	4,400	2	11.5	8.7
4195	280	124	3,600	1.6	3,880	21.1	2,000	4,700	--	11.8	10.4
4225	261	144	3,550	1.42	4,290	18.3	1,697	4,700	21	11.5	10.3
4240	330	70.8	--	.001	689	4.9	1,720	4,000	13	11.5	10.0
4270	224	1.22	2,800	1.33	115	5.2	1,870	4,720	63	10.9	4.7
4310	214	32.4	2,400	.54	665	5.2	1,590	4,720	33	11.2	9.5
4345	176	58.1	3,900	.69	880	--	1,460	6,300	27	12.0	10.1
4394	179	43.1	6,000	1.1	3,210	--	900	1,120	6	11.4	10.8
4395	179	43.2	6,000	1.1	3,210	2.8	900	1,120	6	11.4	10.8
4423	38	23.5	4,850	.19	256	--	1,150	7,920	204	11.5	9.5
4425	25	117	5,110	.22	3,550	7.6	1,140	6,500	40	11.2	10.7
4441	71	10.9	2,190	4.9	39.5	--	1,180	4,040	175	11.6	10.0
4450	182	69.2	4,310	.55	7,270	4.8	861	1,123	4	12.1	10.1
4473	201	106	4,000	.4	8,210	5	792	1,123	4	12.2	10.2
4496	230	8.7	5,020	.05	58	--	2,800	5,680	320	12.1	6.5
4499	162	77.4	4,780	.11	1,780	10.1	900	6,600	30	12.7	10.3
4510	131	22.5	5,130	.28	372	46.7	1,100	7,120	100	10.4	9.3
4528	146	34.4	5,230	.03	207	24.1	1,563	8,800	114	11.0	9.4
4540	150	20	4,590	.25	150	73.9	1,880	7,030	107	9.4	7.5
4570	152	32.8	4,540	1.3	591	44.8	1,805	5,800	59	9.6	9.5
4580	111	25	5,260	.48	193	37.9	1,450	5,500	107	11.5	10.3
4590	142	56	4,590	.94	1,000	36.6	1,028	5,800	43	11.0	10.3
4614	349	11.8	3,550	.003	40	4.3	1,750	6,800	400	11.8	10.0
4625	142	70.3	--	--	1,301	32.2	680	5,800	32	11.5	9.8

Table 10.—*Topographic and climatic drainage-basin characteristics, irregularly measured temperature stations, Washington*—Continued

Station number	Characteristics										
	Average direction of flow of stream (degrees)	Length of river, in miles	Mean altitude of basin (ft)	Lake and pond areas (percent)	Drainage area (sq mi)	Mean annual discharge (in.)	Site altitude (ft)	Source altitude (ft)	Fall or slope of river (ft per mile)	Air temperature annual amplitude (°C)	Mean annual air temperature (°C)
	Ø	L	E	F	D	Q	G	S	F	T_A	T_M
EASTERN WASHINGTON--Continued											
12-4648	215	16	--	--	64.7	--	2,000	2,500	33	11.1	9.1
4650	264	70.2	2,200	0.42	1,042	1.01	1,386	2,775	13	11.4	9.6
4670	230	85.3	2,150	12.6	2,228	--	1,070	2,775	12	11.5	11.2
4685	209	4	1,950	3.4	317	2.16	1,092	2,200	7	11.7	9.6
4705	115	2.3	1,200	.001	12.0	90.9	1,065	1,150	10	12.6	11.7
4715	225	--	--	--	3,650	--	880	--	--	10.6	11.0
4726	262	37.4	--	--	4,177	--	500	1,040	5	11.4	12.8
4838	177	16.3	--	--	69.5	10.9	2,500	5,840	190	11.1	10.8
4885	65	24	4,860	.18	78.9	34.6	2,700	5,300	62	10.1	7.5
5020	84	23.5	--	--	119	--	1,830	6,970	102	10.5	9.5
5050	153	108.8	--	--	3,660	--	886	3,500	14.2	11.3	9.9
5105	79	174.8	--	--	5,615	--	454	3,500	11.0	10.5	12.5
13-3347	61	24	3,550	.001	170	5.6	1,090	6,100	146	10.6	8.3
3445	283	50	3,000	.001	431	5 2	730	6,200	73	10.9	13.0
3460	245	55	3,060	.01	491	8.8	2,005	3,500	18	10.5	9.1
3461	283	58.6	3,050	.01	497	8.3	1,957	3,500	18	10.2	9.1
3480	279	21.6	2,770	.01	132	3.8	2,326	4,990	12	10.4	8.9
3485	272	13.8	2,670	.01	27.1	3.8	2,326	3,120	30	10.4	8.9
3492	275	58.9	2,990	.01	796	5.6	1,932	3,500	19	10.2	9.1
3494	276	18.5	2,200	.02	302	1.9	2,012	2,420	18	10.6	9.5
3505	316	44.4	2,680	.01	189	2.6	1,868	3,100	21	10.2	9.2
3510	247	124	2,410	.21	2,500	3.3	1,040	3,500	14	10.8	11.6
3525	180	59.6	--	--	679	.5	1,070	2,300	18	10.8	11.6
3530	221	--	--	--	108,500	--	300	--	--	10.9	13.8
14-0130	286	13.6	3,950	.01	59.6	19.1	2,000	5,890	176	11.3	12.3
0135	290	8.4	3,190	.001	17.0	12.3	1,700	4,650	294	10.4	12.6
0160	282	16.4	2,360	.01	48.4	5.4	1,200	4,650	176	11.0	12.7
0165	333	17.6	3,750	.001	102	16.2	1,868	5,600	170	10.2	10.3
0170	282	35.6	2,950	.01	361	7.2	1,150	5,600	87	9.9	12.9
0185	252	54.4	1,600	.15	1,657	4.1	495	5,700	111	9.9	12.8
0343	145	30	2,400	.001	197	.7	275	3,800	112	10.9	14.5
0366	145	21.8	2,390	.001	213	2.1	400	3,650	147	10.6	14.4

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