THE EFFECTS OF MULTIPURPOSE RESERVOIRS ON THE WATER TEMPERATURE OF THE NORTH AND SOUTH SANTIAM RIVERS, OREGON

By R. Peder Hansen and Milo D. Crumrine

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Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
inch (in)	25.4	millimeter
	Area	
square foot (ft^2)	0.9294	square meter
square mile (mi^2)	2.590	square kilometer
acre	0.4047	hectare (ha)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	Volume	
acre-foot (acre-ft)	1,233	cubic meter
	Temperature	
degree Fahrenheit (°F)	°C = 5.9/x (°F-32)	Celsius (°C) degree

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

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ABSTRACT

Releases from reservoirs affect water temperatures downstream of the reservoir. A one-dimensional, unsteady-state, Lagrangian transport model using the equilibrium temperature approach (with air temperature to estimate equilibrium temperature) was used to evaluate the effects of U.S. Army Corps of Engineers' dams and resulting reservoirs (projects) on the North Santiam River downstream of Big Cliff Dam (River Mile 57.2) to Green's Bridge (River Mile 14.6), and on the South Santiam River downstream of Foster Dam (River Mile 36.7) to near Jefferson (River Mile 1.4).

For the 5 years simulated, Corps of Engineers' projects on the North Santiam River caused water temperatures 42.6 miles downstream to be cooler than water temperatures prior to construction of the projects an average of 134 days and warmer an average of 71 days. Maximum temperature effects were 4.7 degrees Celsius warmer and 8.7 degrees Celsius cooler. Using the same criteria as the North Santiam for the 5 years simulated, Corps of Engineers' projects on the South Santiam River caused water temperatures 35.6 miles downstream to be cooler an average of 91 days and warmer an average of 66 days. Maximum temperature effects were 4.2 degrees Celsius cooler and 5.7 degrees Celsius warmer.

Low-flow augmentation has a cooling effect because outflow temperatures are less than inflow temperatures, and outflow volumes exceed inflow volumes. Evacuation of reservoir water to prepare for flood control has a warming effect when heat stored in the reservoir from the summer is released (inflow water temperatures and volumes are less than outflow water temperatures and volumes). Flood-control operations have little or no effect on the North and South Santiam Rivers.

INTRODUCTION

Water temperature is an important water-quality characteristic in streams because the rates of most chemical and biological reactions are temperature dependent. As an example, dissolved oxygen in water decreases and fish metabolic rate increases as water temperature increases. Water temperature has a direct influence on the quality of water for domestic supplies, fish, waste assimilation, and industrial and agricultural use.

Dams capable of releasing water from several levels with different temperatures can provide cooler or warmer water temperatures downstream at critical times of fish spawning, rearing, or migration. Federal projects on the Willamette River system do not have this selective withdrawal capability. (The term project is used to represent dam and reservoir throughout this report.) Evaluation of the feasibility of constructing multilevel water-withdrawal structures at Federal projects requires an accurate understanding of the temperature regime downstream of a reservoir under present and planned withdrawal conditions.

This study was done in cooperation with the Portland District of the U.S. Army Corps of Engineers as part of the Corps' Willamette System Temperature Control Study (WSTCS). Morse and others (1988) summarize the objective of WSTCS for the Santiam Basin. The objective of this study was to determine the feasibility of using selective withdrawal from Detroit Lake on the North Santiam River and Green Peter and Foster Lakes on the South Santiam River to control water temperatures in the North and South Santiam Rivers. Stream-temperature and atmospheric condition data were collected to calibrate and validate a mathematical temperature model for the North Santiam River from downstream of Big Cliff Dam (RM [River Mile] 57.2) to Green's Bridge (RM 14.6) and for the South Santiam River from downstream of Foster Dam (RM 36.7) to near Jefferson (RM 1.4). The location of the study area is shown in figure 1.

Problem

The U.S. Army Corps of Engineers has constructed four dam and reservoir projects in the Santiam River basin. At present, water is withdrawn from the hypolimnion of each reservoir. The effects of releases from Corps of Engineers' reservoirs on the water temperatures downstream in the Santiam River basin have not been fully determined. The U.S. Army Corps of Engineers would like to determine if operation of selective withdrawal structures can control effects of projects on downstream water temperatures in a manner to enhance fishery habitat. In order to accomplish this, reliable predictions for downstream river temperatures without projects must first be obtained. The evaluation includes the determination of the downstream temperature effects and how far downstream water temperatures are affected (the point at which the difference between with-project and without-project water temperatures is negligible).

Purpose

This report documents the results of a study to quantify the effects of Corps of Engineers' reservoirs on the water temperatures of the North and South Santiam Rivers. The results of this study will aid the Corps of Engineers in determining the feasibility of using selective withdrawal from Corps' reservoirs to control water temperatures downstream of the projects. It is not within the scope of this report to test flow conditions beyond what was experienced under present operation guidelines.

Approach

Effect of projects on water temperature in a drainage basin can be determined by measuring and comparing temperatures before and after significant basin changes. However, comparison of pre- and post-basin activity changes in water temperature also includes the differences in water temperature due to variations in atmospheric conditions. The atmospheric variability was removed by modeling basin water temperatures with and without the basin changes for the same atmospheric conditions.

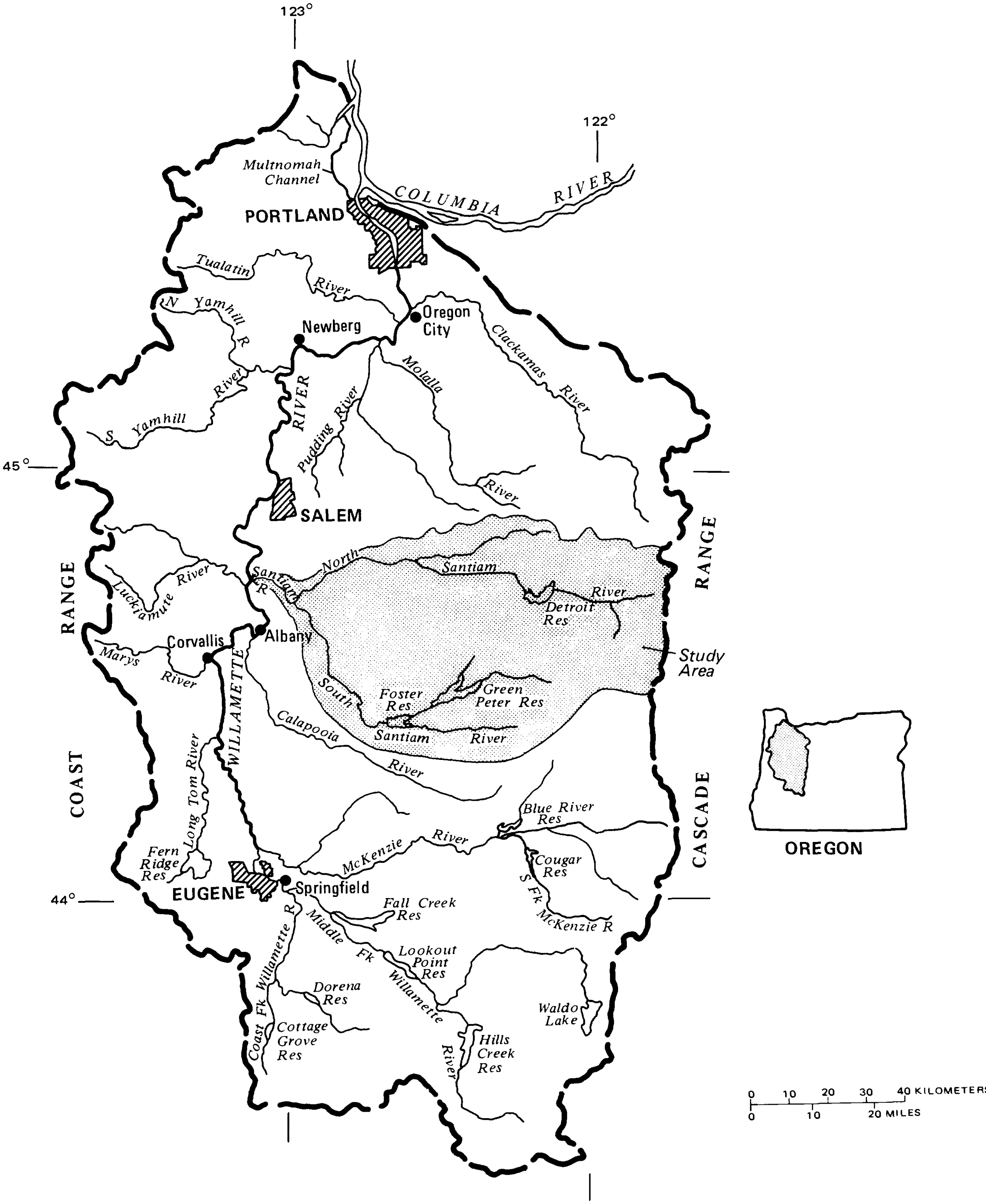

Figure 1.--Willamette River basin, Oregon; principal rivers and reservoirs; and location of study area.

Acknowledgments

This study was done in cooperation with the U.S. Army Corps of Engineers, Portland District. We would like to thank Thomas E. Morse of the Corps of Engineers for his input and many valuable discussions.

A temperature model as described by Jobson (1980) was calibrated to simulate daily mean water temperatures with data collected in the Santiam Basin. This model has been shown to produce accurate results in a nearby river basin of similar character (Hansen, 1988). Windspeed and air temperature were the meteorological inputs to the model. Stream width information was obtained from aerial photos and supplemented with field measurements. Stream cross-sectional areas were determined from field measurements and extrapolated using topographic maps. Comparisons between simulated and recorded water temperatures were made to determine model accuracy. Additional simulations were made with model input adjusted to approximate basin conditions without projects. Comparisons between simulations with and without Corps' projects were made to determine the magnitude and downstream extent of the projects' effects on the water temperature of the North and South Santiam River.

PHYSICAL SETTING

Geography and geology

The North and South Santiam Rivers and their tributaries drain the western slopes of the Cascade Range from Olallie Butte to Three Fingered Jack. The North and South Santiam Rivers join to form the Santiam River about two miles south of the town of Jefferson (fig. 2). The Santiam River then flows about 12 miles before its confluence with the Willamette River.

The geology of the Santiam River basin consists primarily of sedimentary, volcanic, and alluvial rock units. The oldest rock units are of volcanic origin and are located generally in the upper reaches of the drainage basin. The upper basin canyons are carved in volcanic flows and tuffs. The lower reaches of the basin are made up of alluvial deposits, principally of volcanic sand and gravel.

Elevations within the Santiam River basin range from 10,497 feet above sea level at the summit of Mt. Jefferson to 156 feet above sea level at the basin mouth. The North and South Santiam Rivers travel through mostly forested canyons and valleys a total distance of 85 and 55 miles, respectively, before reaching the Santiam River. Both rivers wind through rolling hills covered with a mixture of oak, maple, fir, and agricultural crops in their lower valleys.

Climate

The Santiam River basin has a temperate marine climate characterized by dry summers and wet winters. About 80 percent of the normal precipitation falls between October and May. Mean annual rainfall ranges from about 45 inches near Jefferson to more than 100 inches in the higher elevations of the basin headwaters.

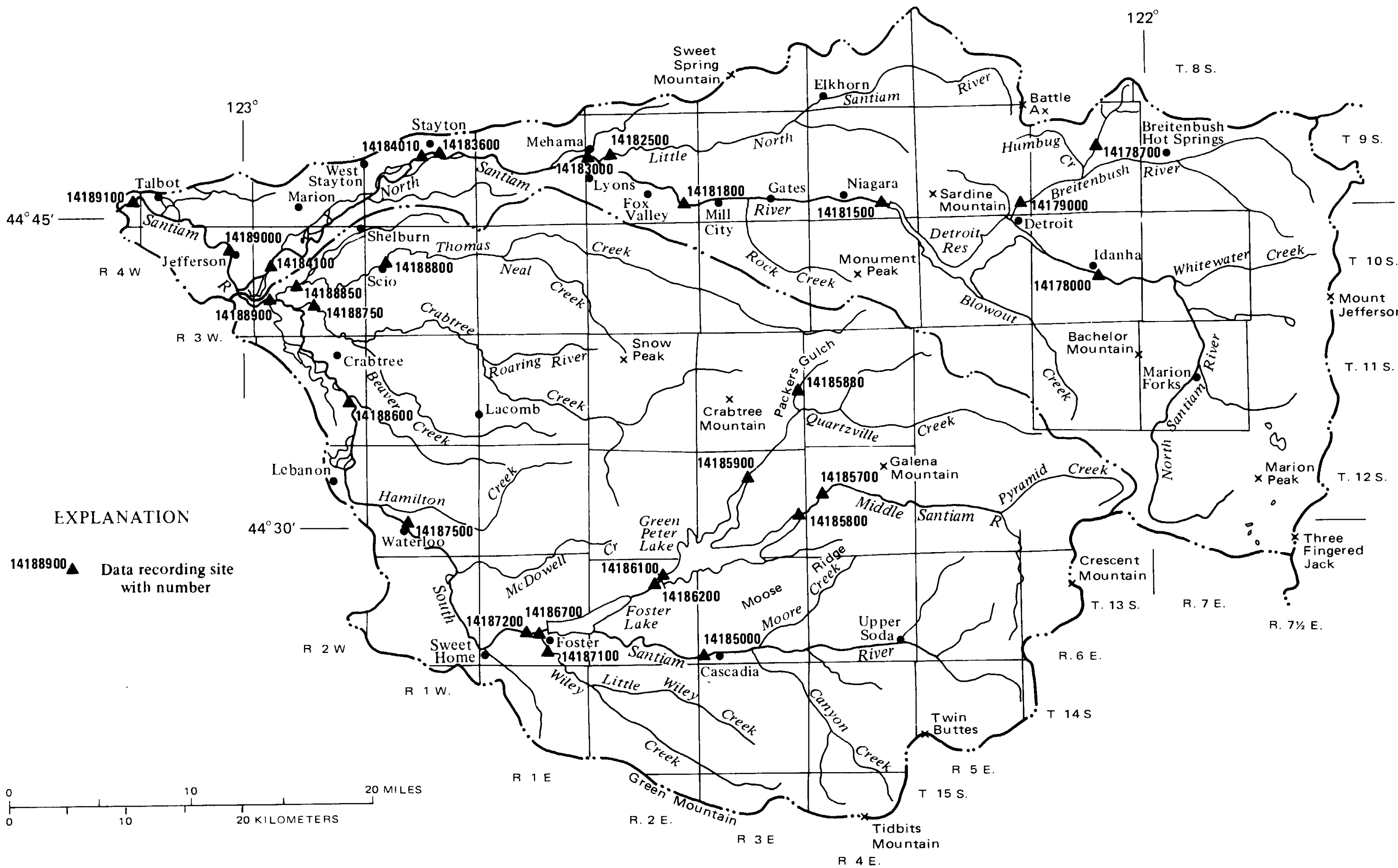

Figure 2.--Location of data collection sites in the Santiam River basin.

The normal annual air temperature at Salem (the nearest first order weather station) is 52 degrees Fahrenheit. Normal monthly air temperatures range from 39 degrees Fahrenheit in January to 67 degrees Fahrenheit in July. The city of Salem lies outside the Santiam Basin, approximately 26 miles north of the basin mouth.

Description of North Santiam River System

The headwaters of North Santiam River originate at the base of Marion Peak in the Cascade Mountains. The North Santiam River drains 437 mi^2 (square miles) from its headwaters to Detroit Dam. As the North Santiam River flows in a northwest direction to Detroit Lake (RM 69), it is joined by Whitewater Creek, Marion Forks, and other smaller tributaries that drain from the Cascades. Blowout Creek from the south and Breitenbush River from the west join the North Santiam River at Detroit Lake.

Breitenbush River drains about a 110 mi^2 area along the Cascades from Olallie Butte to Mount Jefferson. Breitenbush Hot Springs, a tributary to Breitenbush River at RM 10, is one of the larger hot springs in the Cascades. Water from the hot springs have little temperature affect on the river because of the large amount of freshwater being drained from the Cascades.

As the North Santiam River leaves Detroit Lake, flows are reregulated by Big Cliff Dam (RM 58.1) and reservoir. Below Big Cliff Dam, the North Santiam River flows in a westward direction for a distance of about 20 miles in a steep canyon with only small tributary inflows. At RM 39, the Little North Santiam River joins the North Santiam River. The Little North Santiam River drains an area of 110 mi^2 of mountainous region located west of the Cascades and north of Detroit Lake.

At Mehama (RM 38.7), the North Santiam River enters rolling foothills where much of the area is used for ranching and farming. Downstream from Mehama to near Jefferson (RM 14.6), the North Santiam has many diversions for public water supply, small power-generation systems, and irrigation. The North Santiam River joins the South Santiam River at (RM 11.7) to form the Santiam River. The total drainage area for the North Santiam River is 742 mi^2.

Description of South Santiam River System

The South Santiam River flows westward from its headwaters to Foster Lake, where it is joined by the Middle Santiam River. The South Santiam River above Foster Lake drains 287 mi^2, and begins in the mountains west of the Cascades between Crescent Mountain and Twin Buttes.

The Middle Santiam River begins in the mountain range to the west of the Cascades in the vicinity of Galena and Crescent Mountain. It flows westward into Green Peter Lake at (RM 5.7) draining 227 mi^2 and includes Quartzville and Pyramid Creeks.

From Foster Lake to its confluence with the North Santiam River, the South Santiam River flows through rolling hills with many farms and ranches. It is joined by Wiley Creek (RM 37.4), Crabtree Creek, (RM 4.3), Thomas Creek (RM 3.0), and other small tributaries. There are some diversions in the vicinity of Lebanon (RM 18.0) for irrigation, industry, and water supply. The total drainage for the South Santiam River at the confluence with the North Santiam River is 1,041 mi^2.

Reservoirs

The U.S. Army Corps of Engineers' projects in the Santiam Basin are Detroit and Big Cliff located on the North Santiam River, Green Peter located on the Middle Santiam River, and Foster located on the South Santiam River. Each project consists of a hydroelectric dam and resulting lake. Project statistics were obtained from U.S. Army Corps of Engineers (1977).

The two North Santiam River Corps of Engineers' projects control runoff from about 450 mi^2 of drainage area. Detroit Lake, the larger reservoir, provides 455,000 acre-ft (acre-feet) of storage (at maximum pool elevation) for the purposes of flood control, navigation improvement, power generation, recreation, and pollution abatement. Big Cliff Lake is used to re-regulate water releases from the Detroit project for power generation and has only 4,740 acre-ft of storage (at full pool elevation). Detroit Dam rises 360 feet above the streambed and has a 100,000 kilowatt generating capacity. Big Cliff Dam is 126 feet high and has an 18,000 kilowatt generating capacity.

The South Santiam River has two of Corps Engineers' projects that control runoff from 494 mi^2 of drainage area. Green Peter Lake, located on the Middle Santiam River, provides 430,000 acre-ft of storage (at maximum pool elevation) for the purpose of flood control, irrigation, navigational improvement, power generation, and recreation. Foster Dam, located 8 miles downstream of Green Peter Dam on the South Santiam River, provides 60,700 acre-ft of storage (at maximum pool elevation) for the purpose of flood control, irrigation, navigational improvement, power generation, recreation, and re-regulation for Green Peter project. Green Peter Dam is 360 feet high with a 80,000 kilowatt generating capacity and Foster Dam is 126 feet high with a 20,000 kilowatt generating capacity.

DATA NETWORK

Data used in this study were from long-term stream gage and temperature-recording locations, temporary recording sites, and miscellaneous field measurements. The location of long-term stream gages and water temperature recorders plus the temporary additional sites are shown in figure 2. A list of the long-term stations and the period of record for each variable is shown in table 1.

Data were collected at several additional sites during the period of this study from April 1985 to November 1986. In addition to water-temperature, wind velocity and air-temperature data were collected at three sites. Relative humidity, atmospheric radiation, and vapor pressure data were collected at one site. A list of additional sites and the period of record for each variable are shown in table 2.

Table 1.--List of long-term stations and period of record for each variable

[Q = discharge, Temp = temperature]

Station number	Location description	Parameter	Statistic	Period of record Begin Year Month	Period of record End Year Month
14178000	North Santiam River below Boulder Creek near Detroit	Temp	Max	1951 04	Present
		Temp	Min	1951 04	Present
		Temp	Mean	1951 04	Present
		Q	Mean	1928 10	Present
14178700	East Humbug Creek near Detroit	Q	Mean	1978 08	Present
14179000	Breitenbush River above French Creek, near Detroit	Temp	Max	1953 10	Present
		Temp	Min	1953 10	Present
		Temp	Mean	1953 10	Present
		Q	Mean	1932 06	Present
14181500	North Santiam River at Niagara	Temp	Max	1953 01	Present
		Temp	Min	1953 01	Present
		Temp	Mean	1953 01	Present
		Q	Mean	1938 10	Present
14182500	Little North Santiam River near Mehama	Temp	Max	1985 05	1986 09
		Temp	Min	1985 05	1986 09
		Temp	Mean	1985 05	1986 09
		Q	Mean	1931 10	Present
14183000	North Santiam River at Mehama	Temp	Max	1985 05	1986 09
		Temp	Min	1985 05	1986 09
		Temp	Mean	1985 05	1986 09
		Q	Mean	1921 09	Present
14185000	South Santiam River below Cascadia	Temp	Max	1962 06	Present
		Temp	Min	1962 06	Present
		Temp	Mean	1974 10	Present
		Q	Mean	1935 09	Present
14185700	Middle Santiam River near Upper Soda	Q	Mean	1980 10	Present
14185800	Middle Santiam River near Cascadia	Temp	Max	1962 10	1981 09
			Min	1962 10	1981 09
			Mean	1962 10	1981 09
		Q		1963 08	1981 09
14185880	Packers Gulch near Cascadia	Q		1983 07	1986 10

Table 1.--List of long-term stations and period of record for each variable--Continued

Station number	Location description	Para-meter	Sta-tistic	Period of record: Begin Year Month	Period of record: End Year Month
14185900	Quartzville Creek near Cascadia	Temp	Max	1963 08	Present
		Temp	Min	1963 08	Present
		Temp	Mean	1974 10	Present
		Q	Mean	1963 08	Present
14187100	Wiley Creek at Foster	Q	Mean	1973 09	Present
14187200	South Santiam River near Foster	Temp	Max	1973 07	Present
		Temp	Min	1973 07	Present
		Temp	Mean	1974 10	Present
		Q	Mean	1973 07	Present
14187500	South Santiam River at Waterloo	Temp	Max	1963 10	Present
		Temp	Min	1963 10	Present
		Temp	Mean	1974 10	Present
		Q	Mean	1923 07	Present
14188800	Thomas Creek near Scio	Temp	Max	1962 10	1975 09
		Temp	Min	1962 10	1975 09
		Temp	Mean	1962 10	1975 09
		Q	Mean	1962 10	Present
14189000	Santiam River at Jefferson	Temp	Max	1963 10	Present
		Temp	Min	1963 10	Present
		Temp	Mean	1974 10	Present
		Q	Mean	1939 10	Present

Table 2.--List of additional sites and period of record for each variable

Station number	Location description	Parameter	Period of record Begin Year Month	Period of record End Year Month
14181800	North Santiam River at Fishermans Bend near Mehama	Water temperature	1985 05	1985 11
			1986 03	1986 11
14182500	Little North Santiam River near Mehama	Water temperature	1985 05	1986 11
14183000	North Santiam River at Mehama	Water temperature	1985 05	1986 11
14183600	North Santiam River at Stayton	Water temperature	1985 05	1985 09
			1985 09	1985 11
		Air temperature	1985 05	1985 09
			1985 09	1985 11
		Wind velocity	1985 05	1985 09
			1985 09	1985 11
14184010	North Santiam River at West Stayton	Water temperature	1986 05	1986 11
		Air temperature	1986 05	1986 11
		Wind velocity	1986 05	1986 11
14184100	North Santiam River near Jefferson	Water temperature	1985 04	1986 11
14186200	Middle Santiam River below Green Peter Lake near Foster	Water temperature	1986 04	1986 12
14186700	South Santiam River at Foster	Water temperature	1985 05	1985 11
14188600	South Santiam River near Lebanon	Water temperature	1985 06	1985 08
			1986 03	1986 11
14188750	Crabtree Creek near Crabtree	Water temperature	1985 04	1986 02
14188850	Thomas Creek near Crabtree	Water temperature	1985 04	1986 11
		Air temperature	1985 04	1986 11

Table 2.--List of additional sites and period of record for each variable--Continued

Station number	Location description	Parameter	Period of record Begin Year Month		Period of record End Year Month	
14188900	South Santiam River below Thomas Creek near Jefferson	Water temperature	1985	04	1986	09
		Air temperature	1985	04	1986	09
		Humidity	1985	04	1986	09
		Atmospheric radiation	1985	04	1986	09
		Wind velocity	1985	04	1986	09
14189100	Santiam River near Talbot	Water temperature	1986	03	1986	10

Field surveys were made to obtain channel top-width, cross-section, and water-temperature data. Water-temperature surveys were made July 22 to 24, 1986, on the South Santiam River in the reach from Foster Dam (RM 37.7) to near Jefferson (RM 1.4). Water temperature survey data for the North Santiam River were obtained from a report by Laenen and Hansen (1985) and supplemented by float surveys from July 29 to 31, 1986, in the reach from Fisherman's Bend Park (RM 42.0) to near the confluence with the Willamette River (RM 0.4).

During water-temperature surveys, an attempt was made to float with the stream current and record water temperatures at regular intervals. The purpose was to follow a water parcel and observe how it heated or cooled in response to atmospheric conditions, tributary inflow, streambank canopy, and streambed character (riffle or pool).

Water-temperature cross sections were made at selected locations to determine horizontal and vertical variations in temperature (fig. 3). The uniform temperature distribution shown in the cross sections indicate that a one-dimensional representation of water temperature is justified for the North and South Santiam Rivers.

TEMPERATURE MODEL

The temperature model used in this study was developed and documented by Jobson (1980). It simulates one-dimensional, unsteady temperature, in steady-state flow, using the Lagrangian, or moving, reference frame. In the Lagrangian framework, an individual fluid parcel is followed and those factors affecting temperature change are applied.

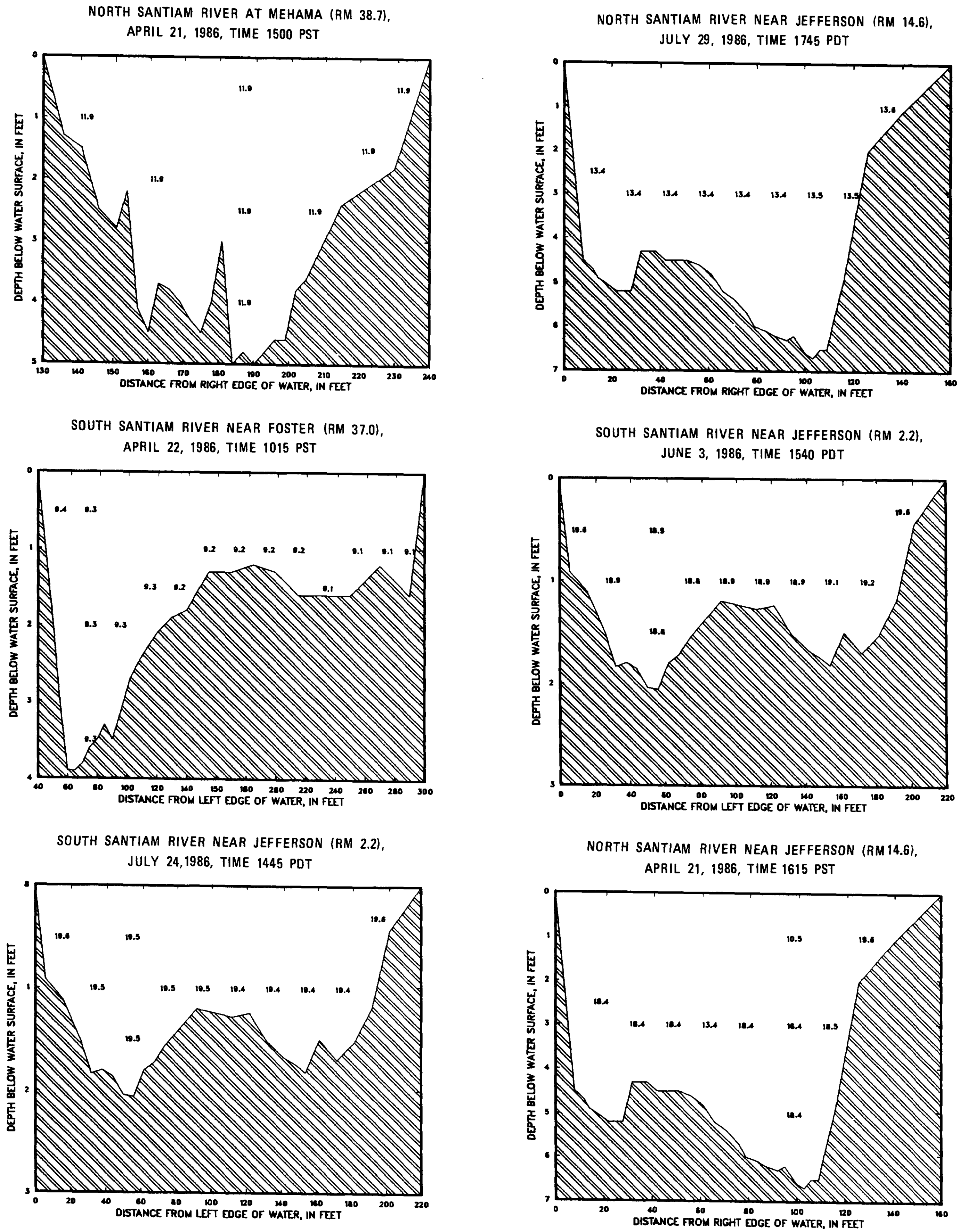

Figure 3.--Water-temperature cross sections at selected sites in the Santiam River basin.

The version of Jobson's Lagrangian Transport model (LTM) used to simulate water temperature is based on the equilibrium temperature approach. Equilibrium temperature is defined as the temperature at which there is no net heat transfer across the air-water interface; that is, the amount of heat entering the water body through the air-water interface is equal to the amount of heat leaving the water body through the air-water interface. The equilibrium temperature is the theoretical temperature toward which the water should approach if conditions were to stay stable long enough. The equilibrium temperature equation takes the form:

$$H = -K (T - Te), \qquad (1)$$

where H is the amount of heat entering the water body across the air-water interface, K is a variable heat exchange coefficient, T is the water temperature, and Te is the equilibrium temperature. Equation 1 shows that if the equilibrium temperature is greater than the water temperature, the water temperature will increase. Conversely, if the equilibrium temperature is less than the water temperature, the water temperature will decrease. The rate of increase or decrease is dependent on K, the heat exchange coefficient. Jobson (1980 p. 34-35) showed K is dependent on water temperature and windspeed. A complete derivation of the equilibrium temperature equation and the heat exchange coefficient can be found in Jobson (1980).

Comparisons of long-term (weekly or monthly mean) air and water temperatures at a site unaffected by reservoirs or thermal additions show that the water temperature usually approaches the air temperature within 1 or 2 degrees Celsius (Jobson, 1980, p. 31-33; Moore, 1967, p. K21-K22). Thus, air temperature can be used to approximate equilibrium temperature.

Assumptions

The assumptions for the version of LTM used here are:

(1) The stream is completely mixed with no lateral or vertical variation in water temperature so that a single measurement of water temperature in a cross section is representative of the cross section as a whole (one dimensional representation).

(2) Air-water interface heat exchange is the dominant heat-transfer process. Bed conduction and biochemical reaction contributions can be neglected.

(3) Tributary sources and diversion sinks are considered, but ground-water inflow and precipitation are neglected.

(4) The equilibrium temperature approach is valid.

(5) Air temperature can be used to estimate equilibrium temperature for the time-step length used.

These assumptions did not place severe restrictions on the model's ability to simulate the system; accordingly, LTM was used to simulate daily mean water temperatures of the North and South Santiam Rivers.

Data requirements

LTM requires inputs of equilibrium temperature (air temperature), windspeed, initial upstream water temperature, and tributary inflow temperature for each time step. To model unsteady discharge, LTM also requires inputs of top width, cross-sectional area, velocity, and tributary-inflow discharge for each time step at each grid point. (Grid points are location numbers.) LTM uses the average of consecutive grid points to define parcel properties. Grid points also are used to add tributary inflow and subtract diversion outflow. Individual grid-point properties need not be identical to site measured properties. However, individual grid-point properties must be chosen so that the average properties of consecutive grid points represent the stream reach to be modeled.

Although atmospheric data were collected within the basin, the requirement to simulate additional years beyond the data-collection period preempted the use of those data for the model. The daily mean air temperature and windspeed used in the model were obtained from the National Weather Service station at McNary Field in Salem.

Daily mean water temperatures and flows from U.S. Geological Survey gaging stations just below Corps of Engineers' projects were used as initial conditions for with-project simulations. Reservoir inflow stations were used as initial conditions for without-project simulations. Model inputs of daily mean discharge and water temperature to account for flow and thermal additions in the downstream direction were obtained from U.S. Geological Survey stations on tributaries.

Short periods of missing daily mean water-temperature data were accounted for by substituting values from a comparable nearby station. Longer periods of missing data were estimated from a linear regression developed using a comparable station. Daily mean water temperatures for sites without a comparable nearby station were extended using harmonic analysis.

The hydraulic model, HYDRAUX, required cross-sectional data in the form of horizontal distance from initial point and elevation and Manning's roughness coefficients for each grid point. HYDRAUX was calibrated by adjusting Manning's roughness coefficients at each grid point until simulated travel times corresponded with those observed by Harris (1968) at a specific flow. Validation consisted of comparing simulated with observed travel times at a second selected flow from Harris (1968).

The procedure followed for each simulation was to run HYDRAUX for the time period desired to calculate top width, cross-sectional area, and velocity at each grid point for each time step. LTM then was used to simulate daily mean water temperatures at desired locations. With- and without-project simulations were performed for the North and South Santiam Rivers for each of the 5 years.

Calibration and validation

Calibration for the North and South Santiam River was performed with data collected in 1986 and validated with 1985 data. An ETW effective top-width parameter was introduced to account for the increased surface area available for air-water heat transfer (Hansen, 1986, 1988). Calibration consisted of adjusting the ETW parameter values to minimize the mean absolute difference (MAD) between modeled and recorded water temperatures at RM 38.5 and RM 14.6 on the North Santiam River and at RM 23.4 and RM 1.4 on the South Santiam River. ETW values ranged from 2.5 to 1.8 on the North Santiam, while a constant value of 1.5 was used on the South Santiam. The results of calibration and validation appear in table 3.

Table 3.--Differences between simulated and recorded daily mean water temperatures of the North and South Santiam Rivers at selected locations for the calibration and validation periods

[Positive differences indicate model overestimates of recorded temperatures, while negative differences indicate underestimates of recorded temperatures. MAD - mean absolute difference between modeled and recorded temperatures. This is a measure of the "absolute" accuracy of the model]

Station	Differences between modeled and recorded daily mean water temperature, in degrees Celsius				Number of data for comparison
	Average	Maximum	Minimum	MAD	
North Santiam					
River mile 38.5					
Calibration	-0.3	1.5	-1.7	0.5	252
Validation	-.4	2.0	-2.2	.7	211
River mile 14.6					
Calibration	-.5	2.0	-1.7	.7	238
Validation	-.4	1.6	-1.9	.7	220
South Santiam					
River mile 23.4					
Calibration	.0	2.2	-1.2	.5	351
Validation	-.2	2.0	-1.9	.7	365
River mile 1.4					
Calibration	-.2	3.1	-2.2	.7	273
Validation	-.4	2.9	-2.6	.8	249

Even with the addition of the ETW parameter, water temperatures usually were under-predicted. Daily mean water temperatures were predicted to within a MAD of 0.8 degrees Celsius at all four locations. For comparison, recorded water temperatures are published by the Geological Survey to the nearest 0.5 degrees Celsius.

DETERMINATION OF PROJECT EFFECTS

Effects of project releases were determined by comparing modeled water temperatures at the same location for two senarios; with the projects present, and without the projects present. This approach was used to focus on the effects of the projects under identical atmospheric conditions. Comparison of pre- and post-project water temperatures show the combined effects of projects and annual variations in climate. Comparison of model simulated with- and without-project water temperatures focuses on the changes in flow and temperature due to the presence of projects. Project effects thus are neither masked nor magnified by differences in air temperature and wind speed between years or by long-term climatic changes.

Simulations with projects present used reservoir release water temperatures and flows as initial conditions. Simulations without projects present used water temperatures and flows from a gage upstream of the project as initial conditions. Pre-project maps provided data for the cross sections needed for HYDRAUX and LTM to route flows and water temperatures through the project reach.

Five calendar years were modeled to estimate the effects of Corps of Engineers projects over a variety of hydrologic and atmospheric conditions. The years chosen were 1977, 1983, 1984, 1985, and 1986. Calendar years were used instead of water years to satisfy cooperator needs. The year 1977 was chosen because it was a drought year, 1983 had a cool, wet summer, 1984 had a wet spring, and 1985 and 1986 were the data-collection years of the study.

For each year, simulations were made for with- and without-project conditions. The results of these simulations were compared and the difference between with-project and without-project conditions for each daily mean value was computed. Positive differences infer a warming effect while negative differences imply a cooling effect. Differences less than model accuracy (0.8 MAD) are not considered significant.

This study concentrated on the downstream effects of Corps of Engineers' projects in the Santiam River basin. Additional information and data regarding flows and reservoir temperatures can be found in Morse and others, 1988.

North Santiam River

Effects of releases from Corps of Engineers' projects on the daily mean water temperatures of the North Santiam River were examined at three locations: the U.S. Geological Survey gaging station just downstream from Big Cliff Dam (RM 57.3), the U.S. Geological Survey gaging stations at Mehama (RM 38.5), and at Green's Bridge (RM 14.6). Because residence time for water in Big Cliff is usually less than 24 hours, outflow from Big Cliff is assumed to be equivalent to outflow from Detroit. Project effects at each location for each of the selected years are shown in figure 4. Selected statistics for project effects for the years simulated are summarized in table 4.

Comparisons among sites show that the overall average annual effect on the North Santiam River (indexed by the average of the daily mean water-temperature differences) actually increases for some distance below the projects before the effect begins to decrease (table 4). In contrast, the average daily effect (indicated by MAD) decreases with distance downstream. These results indicate that warming effects dissipate more rapidly than cooling effects in the upper reaches of the North Santiam River. Warming and cooling effects attenuate with distance downstream, as evidenced by the decrease in range between the maximum and minimum annual temperatures with distance downstream.

Corps of Engineers projects in the Santiam River basin follow the same general schedule of operations. Annual variations in response to varying hydrologic conditions occur, but the general reservoir rule curve is (Morse, and others, 1988);

- o major flood control - December 1 to January 31 (projects at minimum levels)

- o conservation storage - February 1 to May 31 (reservoir filling)

- o conservation holding - June 1 to August 31 (maintain pool level or use for low-flow augmentation)

- o conservation release - September 1 to November 30 (lower pool to minimum levels)

Detroit Lake, with a surface area of nearly 3,500 acres at conservation-holding pool level, stores large amounts of heat in the waters of the epilimnion during the summer. Detroit Reservoir is also deep enough that stratification occurs and water temperatures remain cool below the thermocline. Because Detroit Reservoir has only bottom withdrawal capability, water is withdrawn from the hypolimnion (below the thermocline). Thus, during summer inflow water temperatures exceed outflow water temperatures causing cooling effects downstream of the project. From September to November, inflow water temperatures would normally be cooler than outflow water temperatures and, during these months, water temperatures may decrease as water moves downstream. This is in contrast to unregulated streams where water temperatures generally increase as water moves downstream.

Project operations result in downstream water temperature effects. Cooling effects occur during conservation holding and low-flow augmentation periods because inflow water temperatures exceed outflow temperatures and outflow volumes exceed inflow volumes. Warming effects occur when reservoir levels are drawn down in the fall in preparation for the flood control season and outflow water temperatures are warmer than those of inflow. During the flood-control season, the reservoirs store water only during storms, and inflow volume equals outflow volume. As a result, inflow temperatures usually are near outflow temperatures.

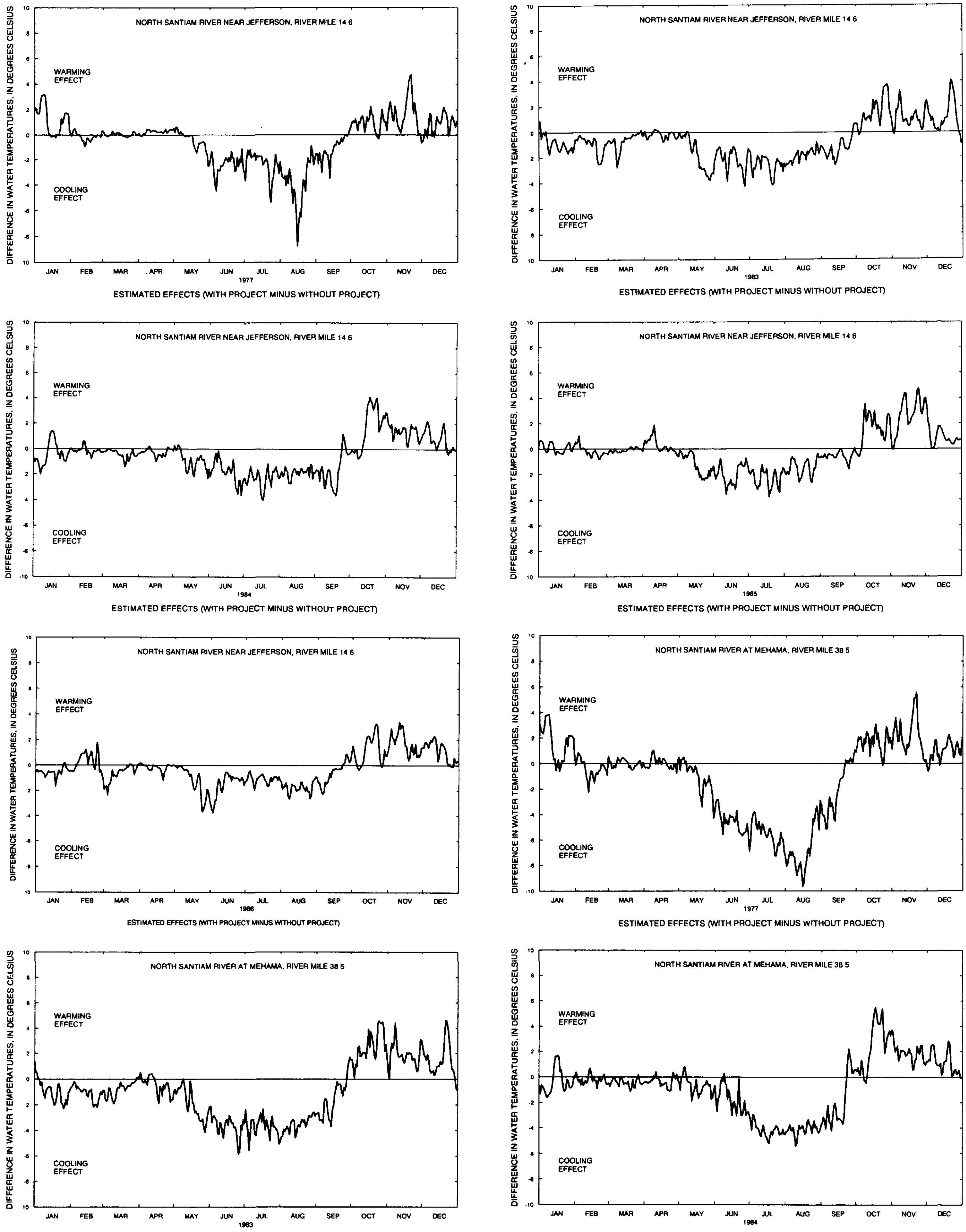

Figure 4.--Difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' reservoirs at selected sites on the North Santiam River for selected years.

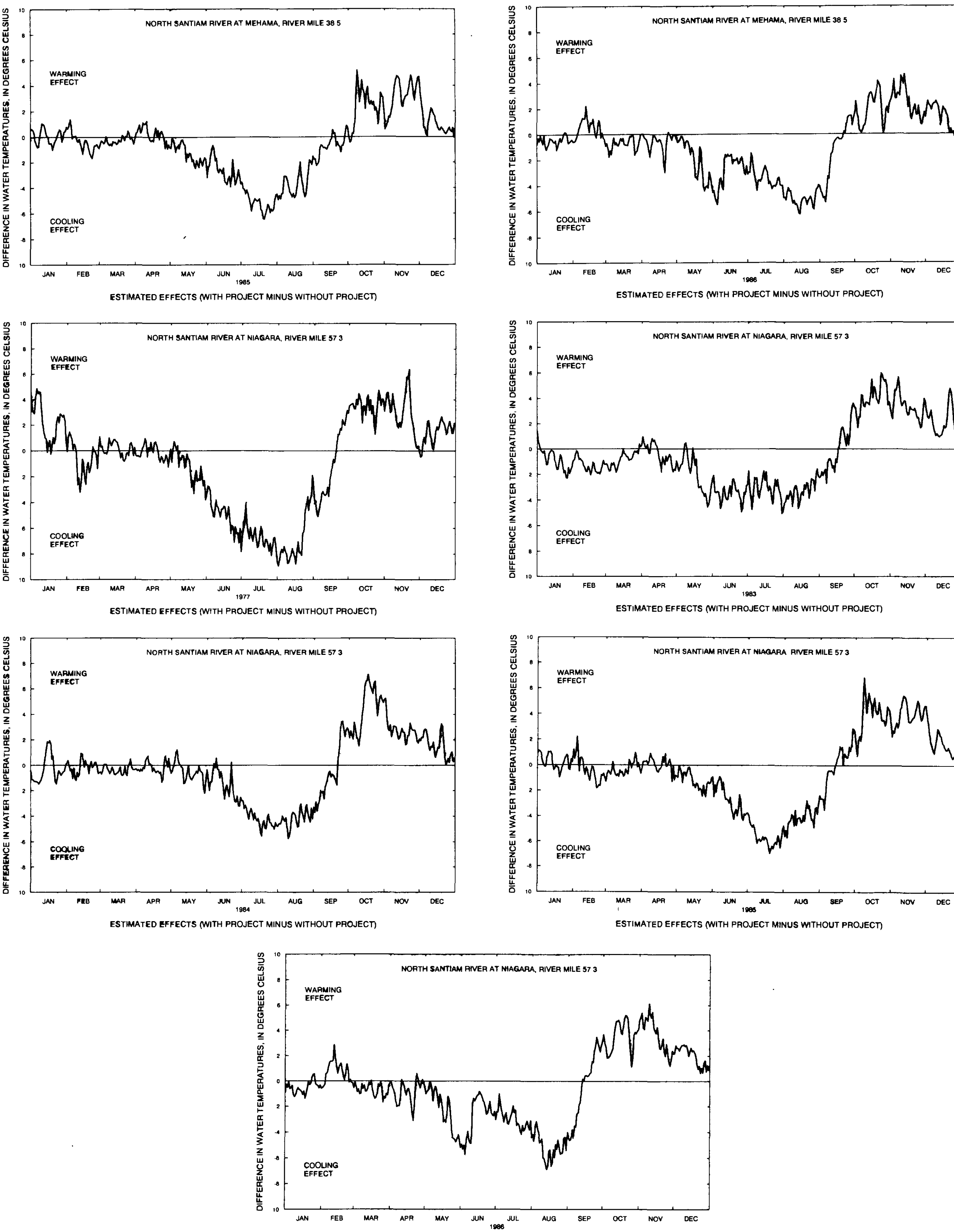

Figure 4.--Difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' reservoirs at selected sites on the North Santiam River for selected years--Continued.

Table 4.--Selected statistics for the difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' (COE) reservoirs at selected locations on the North Santiam River for selected years

[MAD - mean absolute difference of daily mean water temperature for year (this value is always positive)]

Site and year	Differences between simulated water with, and without, COE projects, in degrees Celsius: Average	Minimum	Maximum	MAD
River mile 57.3				
1977	-1.0	-8.9	6.4	2.9
1983	-.5	-5.0	6.0	2.2
1984	-.3	-5.8	7.1	2.0
1985	-.4	-7.0	6.8	2.2
1986	-.5	-6.9	6.1	2.3
River mile 38.5				
1977	-1.2	-9.7	5.6	2.4
1983	-1.0	-5.8	4.6	2.0
1984	-.7	-5.4	5.5	1.8
1985	-.6	-6.4	5.2	1.9
1986	-.9	-6.2	4.7	2.0
River mile 14.6				
1977	-.4	-8.7	4.7	1.3
1983	-.7	-4.3	4.0	1.4
1984	-.5	-4.0	4.1	1.2
1985	-.2	-3.8	4.7	1.2
1986	-.3	-3.8	3.4	1.0

However, some short-term warming effects occur during extreme cold periods, because inflow water temperatures approach the freezing point while reservoir release temperatures remain near 4 degrees Celsius. During conservation storage (late winter and spring), inflow temperatures are near outflow temperatures and project effects are minimal.

Comparison of effects among years in table 4 show that during dry years, projects have larger cooling effects than in wet years. This is evidenced by 1977 having the greatest magnitude of cooling effect. Increased periods of low-flow augmentation causes greater volumes of cooler water to be released than would normally be in the streams. During cool and (or) wet years (1983, 1984), the cooling effect is lessened as low-flow augmentation is unnecessary.

The number of days projects on the North Santiam River had warming or cooling effects for each year at RM 14.6 are given in table 5. The average number of days with warming or cooling effects for the 5 years simulated also is computed and tabulated.

South Santiam River

Effects of releases from Corps of Engineers' projects on the daily mean water temperatures of the South Santiam River were examined at three locations: (1) the U.S. Geological Survey gaging station just downstream from Foster Dam (RM 36.7), (2) the U.S. Geological Survey gaging station at Waterloo (RM 23.4) and (3) near Jefferson (RM 1.4). Project effects at each location for each of the selected years are shown in figure 5. Selected statistics for project effects for the years simulated are summarized in table 6.

Differences between with- and without-project simulations show the combined effects of both reservoirs. No simulations were performed for the effects of individual projects on the South Santiam River, even though each project has the potential for construction of selective withdrawal towers. One reason for not examining individual project effects is that residence time in Foster Lake (approximately 11 days for 1,500 cubic feet per second releases at the conservation holding level) is long enough that benefits of selective withdrawal from Green Peter Lake may be lost or greatly diminished.

Table 5.--Number of days U.S. Army Corps of Engineers' projects have downstream warming or cooling effects on the North Santiam River at RM 14.6 for selected years. Warming, or cooling effects are defined as days when the difference between with- and without-project simulations is greater than, or less than, 0.8 degrees Celsius, respectively

Year	Number of days	
	Warming effect	Cooling effect
1977	79	116
1983	64	170
1984	61	147
1985	67	107
1986	82	129
Average	71	134

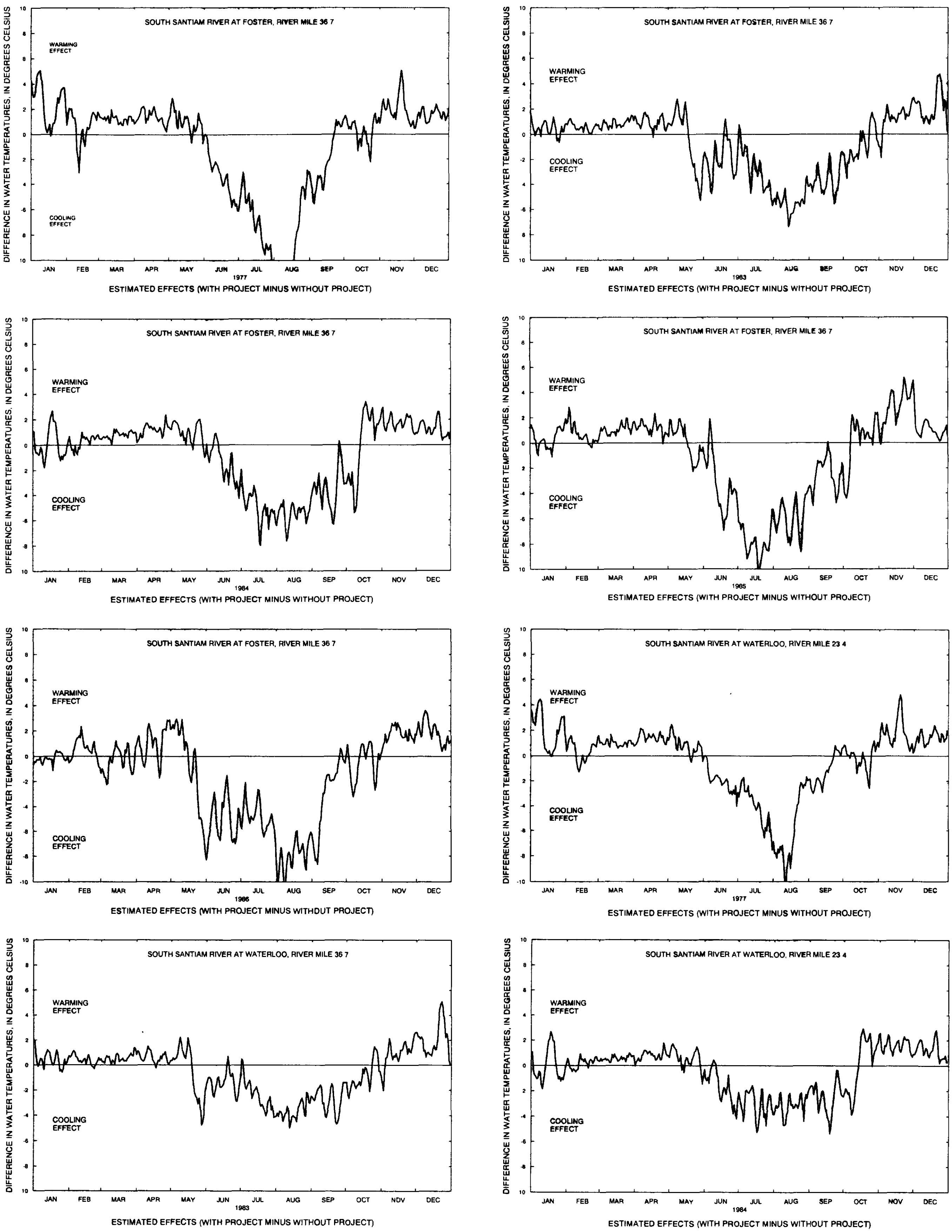

Figure 5.--Difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' reservoirs at selected sites on the South Santiam River for selected years.

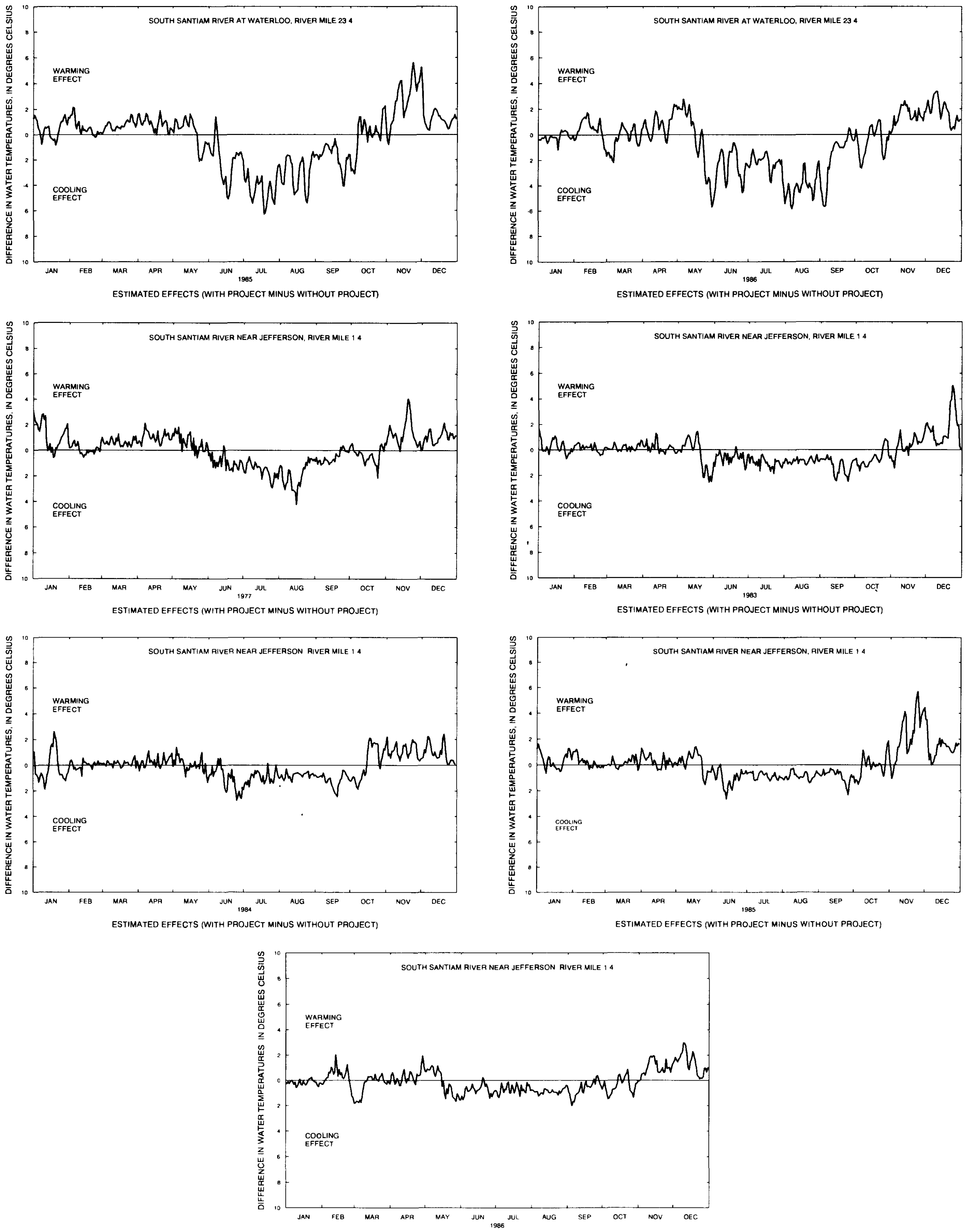

Figure 5.--Difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' reservoirs at selected sites on the South Santiam River for selected years--Continued.

Table 6.--Selected statistics for the difference between simulated water temperatures with, and without, U.S. Army Corps of Engineers' (COE) reservoirs at selected locations on the South Santiam River for selected years

[MAD - mean absolute difference of daily mean water temperature for year (this value is always positive)]

Site and year	Differences between simulated water with, and without, COE projects, in degrees Celsius			
	Average	Minimum	Maximum	MAD
River mile 36.7				
1977	-1.0	-14.8	5.0	1.0
1983	-.8	-7.4	4.7	2.0
1984	-.8	-8.0	3.4	2.2
1985	-1.4	-10.4	5.2	2.5
1986	-1.5	-10.7	3.6	2.7
River mile 23.4				
1977	-.4	-10.7	4.8	2.0
1983	-.6	-5.0	5.1	1.6
1984	-.4	-5.4	2.9	1.6
1985	-.4	-6.3	5.6	1.7
1986	-.6	-5.8	3.4	1.6
River mile 1.4				
1977	.0	-4.2	4.0	1.0
1983	-.2	-2.5	5.0	.8
1984	-.1	-2.7	2.6	.8
1985	-.1	-2.6	5.7	.9
1986	-.1	-2.0	3.0	.7

Projects on the South Santiam River follow the general release schedule outlined for the North Santiam River. As on the North Santiam River, project effects can be linked directly to project operations.

Comparison of effects among sites shows that the overall average annual effect and the average daily effect on the South Santiam River decreases with distance downstream (table 6). Little overall annual average effect was found near Jefferson, 35.3 miles downstream of Foster. An overall annual average effect near zero indicates that the annual heat budget near Jefferson remains the same with or without U.S. Army Corps of Engineers' projects. There is, however, a significant redistribution of the heat since average daily effects near Jefferson exceed 0.7 degrees Celsius in each of the 5 years simulated.

The number of days projects on the South Santiam River had warming (greater than 0.8 degrees Celsius difference between with- and without-project simulations) or cooling (less than -0.8 degrees Celsius difference) effects for each year at RM 14.6 are given in table 7. The average number of days with warming or cooling effects for the 5 years simulated is also computed and tabulated.

Table 7.--Number of days U.S. Army Corps of Engineers' projects have downstream warming or cooling effects on the South Santiam River for selected years. Warming, or cooling, effects are defined as days when the difference between with- and without-project simulations is greater than, or less than, 0.8 degrees Celsius, respectively

	Number of days	
Year	Warming effect	Cooling effect
1977	99	95
1983	42	102
1984	60	96
1985	78	77
1986	49	86
Average	66	91

As was concluded for the North Santiam River, droughts increase the magnitude of cooling effects for the South Santiam River. Projects on the South Santiam River have a greater cooling effect but a lesser warming effect just downstream of the dams than projects on the North Santiam River. The major reason is that North Santiam projects are at a higher elevation and natural water temperatures are cooler than South Santiam projects.

SUMMARY

A one-dimensional, unsteady-state Lagrangian transport model based on the equilibrium temperature approach was used to evaluate the effects of Corps of Engineers' multipurpose water projects on the North and South Santiam Rivers. Data were collected from May 1985 to September 1986 to calibrate and validate the model. Using these data, daily mean water temperatures were predicted to within 0.8 degrees Celsius mean absolute difference 42.6 and 35.3 miles downstream of dams on the North and South Santiam Rivers, respectively.

Projects were found to have an average daily effect of more than ± 0.7 degrees Celsius 35.3 miles downstream of projects on the South Santiam River and more than ± 1.0 degrees Celsius 42.6 miles downstream of projects on the North Santiam River. This effect decreased from a maximum average daily effect of almost ± 3.0 degrees Celsius just downstream of Foster and Big Cliff Dams.

For the 5 years simulated, Corps of Engineers' projects on the North Santiam River caused water temperatures 42.6 miles downstream to be cooler than water temperatures prior to construction of the projects, an average of 134 days and warmer an average of 71 days. Maximum temperature effects were 4.7 degrees Celsius warmer and 8.7 degrees Celsius cooler. Corps of Engineers' projects on the South Santiam River caused water temperatures 35.6 miles downstream to be cooler an average of 91 days and warmer an average of 66 days. Maximum temperature effects were 4.2 degrees Celsius cooler and 5.7 degrees Celsius warmer.

Project operations affect downstream water temperatures. Once reservoirs have filled and inflow temperatures exceed outflow temperatures, projects have a cooling effect. Low-flow augmentation has a cooling effect because outflow temperatures are less than inflow temperatures, and outflow volumes exceed inflow volumes. Evacuation of reservoir water in fall months to prepare for flood control has a warming effect when heat stored in the reservoir from the summer is released (inflow water temperatures and volumes are less than outflow water temperatures and volumes). Flood-control operations have little or no effect on the North and South Santiam Rivers.

Extremes in annual climatic variations can exacerbate project effects. During droughts, cooling effects increase primarily because of low-flow augmentation. During cool, wet years, the cooling effect is lessened. During extreme cold, projects have a warming effect as reservoir-release water temperatures remain near 4 degrees Celsius.

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SUPPLEMENTAL DATA TABLES

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1965 TO SEPTEMBER 1966
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2190	2350	1410	1870	959	1040	1150	2050	1970	956	959	960
2	2110	1870	1030	1160	1060	1070	1130	1750	2030	939	978	958
3	2100	2060	1920	1170	1000	1190	946	1650	1470	956	981	955
4	2150	2220	1660	892	958	2230	1000	2380	1020	953	982	951
5	2130	2200	1680	1070	1020	2950	1130	3070	1020	945	854	954
6	2130	2350	1770	1140	1040	3170	1840	2430	1020	942	984	962
7	2130	2360	2590	3590	981	4160	3010	2750	1020	914	982	966
8	1980	3510	1880	7710	1030	1520	4390	4150	995	919	979	965
9	2140	4890	2180	9530	1050	1770	4370	3130	1000	921	973	967
10	2150	3560	1660	9560	1050	1040	4390	3240	991	919	962	966
11	2170	2150	1390	7660	1050	1030	4850	4470	998	929	958	968
12	2180	3160	1410	4530	1020	1020	5390	3030	999	893	968	972
13	2180	4140	1460	3980	981	1050	4730	2930	954	879	971	980
14	2190	4050	940	4890	1030	1420	4250	3030	1020	875	964	853
15	2260	3950	926	4240	972	1060	4120	3030	998	927	962	940
16	2200	3520	905	5300	973	1040	4130	2910	1040	966	972	944
17	2240	3230	891	5340	1090	946	4290	3110	968	937	970	1550
18	2210	3260	905	5160	1090	932	3940	2890	931	942	978	1590
19	2240	3330	877	868	967	934	3320	2950	941	946	988	1940
20	2270	3880	856	1430	996	1000	2530	3070	941	940	985	2060
21	2210	3810	863	1920	1050	992	2080	3060	959	929	981	2110
22	2290	5260	828	1630	1090	998	2070	3020	917	941	978	2070
23	2220	6310	807	1590	1100	1050	2080	3020	917	932	975	2160
24	2270	5310	758	1720	1070	1070	2100	2980	920	931	988	2020
25	2230	5360	751	1770	1030	1050	2120	3010	919	926	976	2110
26	2270	4470	779	2050	1020	1090	2090	3000	917	915	982	2040
27	2310	1340	1170	1960	1040	1140	2830	3090	914	931	978	2200
28	2250	2130	1730	1370	1490	1130	2640	3000	903	969	960	2020
29	2340	5010	3440	1450	---	1050	2520	2850	923	973	961	2160
30	2260	2940	3980	1420	---	1030	2160	2660	915	994	963	2160
31	2290	---	2660	1510	---	1000	---	2960	---	981	964	---
TOTAL	68290	103980	46106	99480	29207	42172	87596	90670	31530	29020	30056	43451
MEAN	2203	3466	1487	3209	1043	1360	2920	2925	1051	936	970	1448
MAX	2340	6310	3980	9560	1490	4160	5390	4470	2030	994	988	2200
MIN	1980	1340	751	868	958	932	946	1650	903	875	854	853
AC-FT	135500	206200	91450	197300	57930	83650	173700	179800	62540	57560	59620	86190

CAL YR 1965 TOTAL 818364 MEAN 2242 MAX 16500 MIN 743 AC-FT 1623000
WTR YR 1966 TOTAL 701558 MEAN 1922 MAX 9560 MIN 751 AC-FT 1392000

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2490	2220	990	938	678	541	456	491	1760	1740	999	1740
2	2020	2970	878	946	678	547	467	485	1740	1240	999	1600
3	2000	2090	895	946	656	541	444	491	1720	946	990	999
4	2040	1650	878	946	656	534	417	485	1760	999	999	955
5	1970	2060	929	946	663	534	428	473	2020	1040	1030	1710
6	2060	2150	887	938	656	534	462	456	2460	999	1020	1640
7	2100	2090	938	929	663	547	479	439	2540	972	1020	1050
8	2060	2240	938	929	685	515	439	473	1970	972	1020	1700
9	2070	2240	946	929	678	503	503	491	1560	972	1020	1620
10	2020	2180	929	929	678	528	485	497	1700	981	1020	1210
11	2040	2340	929	929	670	522	473	573	1530	981	1020	1440
12	2100	2110	929	955	670	522	456	614	1560	1030	1020	2110
13	2100	2760	946	946	670	522	467	635	1230	990	1010	2130
14	2010	2760	938	938	670	522	462	614	1040	981	1440	1500
15	2100	2750	938	938	663	515	467	627	1200	972	2100	2050
16	2110	2990	938	938	670	515	473	649	1030	990	2070	2240
17	2070	2850	929	938	670	515	473	790	1040	999	1510	1450
18	2110	2750	938	938	663	663	467	790	1020	999	2090	1440
19	2160	2930	920	955	663	509	450	790	1040	999	2060	2100
20	2010	2870	920	929	663	509	456	1080	1030	990	1190	2130
21	2190	2900	929	929	670	509	462	1060	1030	999	1460	1570
22	2180	2940	920	929	670	491	462	1070	1070	1510	2040	2090
23	2150	2960	946	929	670	444	473	1060	1070	1780	2100	2230
24	2110	2090	946	929	663	411	473	1050	1040	1200	1510	2260
25	2150	1280	929	790	663	395	479	1050	1040	1010	1770	2280
26	2160	1220	938	685	663	395	473	1270	1060	981	1630	2230
27	2160	1180	955	685	678	456	473	1710	1040	1020	1010	2690
28	2130	1220	999	670	593	566	473	2010	1010	1010	1050	3030
29	2160	1300	946	642	---	515	473	2100	972	972	1560	3000
30	2140	1040	929	649	---	503	473	2040	1460	1010	1660	3110
31	2070	---	929	649	---	433	---	2100	---	999	1040	---
TOTAL	65240	67130	28899	27266	18633	15756	13938	28463	41742	33283	42457	57304
MEAN	2105	2238	932	880	665	508	465	918	1391	1074	1370	1910
MAX	2490	2990	999	955	685	663	503	2100	2540	1780	2100	3110
MIN	1970	1040	878	642	593	395	417	439	972	946	990	955
AC-FT	129400	133200	57320	54080	36960	31250	27650	56460	82800	66020	84210	113700

CAL YR 1976 TOTAL 739299 MEAN 2020 MAX 8370 MIN 878 AC-FT 1466000
WTR YR 1977 TOTAL 440111 MEAN 1206 MAX 3110 MIN 395 AC-FT 873000

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1982 TO SEPTEMBER 1983
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2450	2980	4960	3110	1160	1590	7320	1050	2050	1460	1120	1110
2	2490	2940	4630	3090	1120	1590	8500	1050	1770	2480	1200	1090
3	2450	3030	2170	3090	1080	1570	7900	1170	1220	2680	1330	1210
4	2440	2990	2750	2020	1100	1550	6060	1210	1010	2420	1150	1640
5	2450	2990	4810	1600	1070	1520	3970	1170	991	1710	1060	2030
6	2500	3010	5140	1220	1060	1550	2720	1530	995	1560	1080	2320
7	2500	2970	5170	1110	1050	1630	1170	1950	1460	1520	1080	2340
8	2540	2990	5080	4820	1040	5180	1290	1900	1500	1520	1050	2310
9	2620	3720	5060	8860	1290	5230	1150	1950	1470	1430	1070	2600
10	2540	3690	5050	11300	1060	5270	1020	2450	1520	1410	1070	2660
11	2530	3690	5110	11800	1080	4910	1090	2910	3400	1260	1070	2640
12	2560	3660	4560	11700	1050	3930	1040	2320	2660	1240	1070	2700
13	2540	3650	4560	9160	1020	3450	1060	2090	1440	1640	1020	3030
14	2460	3720	4740	4880	1640	4170	1030	2020	996	1460	1010	3080
15	2520	3830	4930	4960	2200	4120	1070	1820	1000	1450	1050	2970
16	2590	3560	1290	4980	2180	3340	1050	1940	1190	1430	1030	2920
17	2560	3550	978	5030	2280	2670	1060	3870	1320	1420	1040	2860
18	2490	3670	3150	5130	777	2050	1060	4090	1340	1460	1060	2890
19	2610	3980	6130	4920	4370	1810	1100	2580	1430	2010	1050	2870
20	2630	4560	7000	4670	10100	1780	1110	2240	1620	2450	1020	2900
21	2610	4640	7940	4720	9820	1390	1060	2320	1980	2350	1050	2460
22	2630	4640	8620	2990	5880	1000	1090	2390	2350	1690	1060	2450
23	2660	4700	8850	2890	6870	974	1100	2800	2300	1200	1130	2550
24	2640	4660	6960	2800	6280	1040	1070	2850	2310	1110	1060	2560
25	2670	4140	6970	3020	5210	974	1080	2820	2010	1290	1080	2600
26	2670	4110	7070	2950	4060	979	1040	2900	1990	1530	1060	2580
27	3000	4180	5550	3010	3250	963	1070	3150	1500	1690	1110	2560
28	2980	4340	4710	2980	2340	1110	1090	2880	1040	1330	1110	2520
29	2110	4320	4760	2970	---	1180	996	2710	1170	1280	1100	2520
30	3060	4940	4810	2980	---	2060	1070	2560	1130	1150	1160	2440
31	3030	---	3150	2600	---	3740	---	2590	---	1220	1130	---
TOTAL	80530	113850	156658	141360	81437	74320	62436	71280	48162	49850	33680	73410
MEAN	2598	3795	5053	4560	2908	2397	2081	2299	1605	1608	1086	2447
MAX	3060	4940	8850	11800	10100	5270	8500	4090	3400	2680	1330	3080
MIN	2110	2940	978	1110	777	963	996	1050	991	1110	1010	1090
AC-FT	159700	225800	310700	280400	161500	147400	123800	141400	95530	98880	66800	145600

CAL YR 1982 TOTAL 979810 MEAN 2684 MAX 13600 MIN 892 AC-FT 1943000
WTR YR 1983 TOTAL 986973 MEAN 2704 MAX 11800 MIN 777 AC-FT 1958000

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1983 TO SEPTEMBER 1984
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2390	2580	4730	5090	2460	1000	1340	1210	4190	2000	1050	1500
2	2450	2790	4790	4540	2450	977	1150	1760	2920	1670	1040	1520
3	2480	2900	4830	4030	1710	1080	1310	2710	2930	1280	1040	1390
4	2410	3070	4880	5110	1460	986	1320	3400	3210	1220	1050	1990
5	2360	3010	4970	4980	1060	939	1100	3490	4280	1210	1030	2080
6	2400	3150	5090	4900	1040	949	1070	3360	4330	1310	1010	2120
7	2390	2990	4050	4850	1050	995	998	2900	4520	1580	1010	2140
8	2400	3070	2940	4860	1050	984	1170	2930	4380	1540	1020	2290
9	2400	3020	2940	4850	1030	1040	1050	2820	4300	1530	1010	2250
10	2400	3010	3110	4900	1020	1160	1470	2960	4230	1520	1010	2350
11	2390	3080	2950	4960	1050	1210	2230	3900	4390	1470	998	2660
12	2520	3040	4040	4950	1190	1320	2270	3070	4270	1100	1000	2810
13	2490	3110	5200	4370	1270	2140	3040	2970	3040	1160	1010	2790
14	2370	3070	5010	3090	1020	2840	2830	3100	2580	1320	1010	2970
15	2480	3060	4200	2980	3090	3190	2910	3920	2340	1310	1010	2830
16	2460	3120	4800	2600	4560	4210	2120	3960	2260	1320	1000	2970
17	2410	3100	5280	2350	4400	4180	2060	3850	2250	1250	1010	2960
18	2510	3070	5340	2360	3080	4170	2060	2900	2270	1220	1010	2990
19	2380	4730	5310	1970	3000	4250	2060	2040	1800	1150	1010	3000
20	2360	4800	5140	1570	3020	4240	2080	2160	2320	1070	1010	3010
21	2270	4680	4890	1580	3010	4300	1920	2550	2430	1110	1010	2990
22	2240	4640	4880	1650	2430	4220	1880	3110	3740	1090	1010	2890
23	2360	4680	2950	1730	1860	4150	1700	3470	2780	1040	999	2970
24	2230	4920	2950	2390	1910	3630	1080	3430	2430	1030	996	2980
25	2260	4720	2970	3010	1410	2860	1100	3930	2510	1040	994	2940
26	2310	4680	2970	3060	1300	3310	1140	3300	1950	1060	997	2520
27	2370	4710	3020	4400	1270	3750	994	3010	2350	1040	988	2380
28	2400	4730	2310	4250	1010	3490	1050	3010	2820	1030	1250	2120
29	2440	4720	1830	3680	979	3060	1030	2460	2440	1040	1480	2290
30	2540	4720	3440	2530	---	2210	1020	4290	2150	1060	1410	2310
31	2610	---	5170	2470	---	1690	---	4140	---	1030	1540	---
TOTAL	74480	110970	126980	110060	55189	78530	48552	96110	92410	38800	33012	75010
MEAN	2403	3699	4096	3550	1903	2533	1618	3100	3080	1252	1065	2500
MAX	2610	4920	5340	5110	4560	4300	3040	4290	4520	2000	1540	3010
MIN	2230	2580	1830	1570	979	939	994	1210	1800	1030	988	1390
AC-FT	147700	220100	251900	218300	109500	155800	96300	190600	183300	76960	65480	148800

CAL YR 1983 TOTAL 948365 MEAN 2598 MAX 11800 MIN 777 AC-FT 1881000
WTR YR 1984 TOTAL 940103 MEAN 2569 MAX 5340 MIN 939 AC-FT 1865000

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2410	2980	2170	1810	1010	1030	1020	1800	2540	1050	1110	1040
2	2520	3890	4800	1820	1020	1070	1010	2030	2470	1030	1100	1040
3	2420	1230	5040	1570	1010	1020	1010	2550	2500	1020	1030	1030
4	2560	2890	5050	1370	1000	1030	1030	3010	2020	1020	1030	1030
5	2510	6770	5130	1520	994	1020	1050	3110	2000	1030	1030	1040
6	2510	10200	5210	1320	989	1020	1040	3130	2840	1020	1050	1050
7	2550	9730	3090	1430	992	1030	1050	3220	4510	1020	1020	1060
8	2520	10100	1870	1420	995	1020	1050	2950	4390	1020	1050	1050
9	2600	9570	1830	1280	994	1000	1060	2650	4040	1050	1070	1550
10	2510	4490	2600	1190	1000	1020	1070	2350	4520	1350	1090	2130
11	2400	2740	3090	1090	1020	1010	1040	1910	4530	1020	1100	2250
12	2460	4140	3130	1160	1090	994	1540	1700	4440	1020	1110	2430
13	2500	4840	3020	1130	1040	1010	2300	1730	3170	1010	1040	2410
14	2510	9520	2950	1130	1010	1010	2560	1750	2920	1030	1030	2450
15	2560	10300	2860	1120	1010	1020	2930	1770	2260	1020	1030	2390
16	2390	10300	2870	1150	998	1010	3080	2090	2170	1030	1020	2440
17	2390	10200	2900	1100	1010	996	2580	2370	2260	1020	1020	2470
18	2440	10100	2070	1220	1020	1020	2150	3060	1880	1040	1020	2840
19	2550	7940	1570	1220	1030	1050	1980	3160	1760	1030	1020	2850
20	2570	5330	1570	1220	1010	1030	1900	3230	1700	1070	1020	2820
21	2600	4870	1610	1250	1010	1030	1950	3080	1500	1100	1040	2790
22	2500	4810	1610	1170	1010	1020	1930	3980	1500	1110	1030	2810
23	2470	4860	1630	1490	982	1040	1510	3950	1510	1110	1040	2820
24	2510	4930	1690	1110	973	1020	1570	3970	1370	1140	1010	2840
25	2540	4940	2000	1110	975	1030	1750	3220	1470	1100	1010	2770
26	2750	4990	2170	1060	1010	1020	1640	2680	1360	1100	1030	2730
27	3010	5270	1960	1070	998	1000	1490	2770	1330	1090	1020	2790
28	3310	5330	1750	1010	987	1010	1580	2550	1040	1090	1020	2560
29	3140	3820	1900	1030	---	1020	1530	2200	1030	1100	1020	2490
30	3080	2230	1810	1070	---	1010	1620	2540	1050	1110	1020	2510
31	3040	---	1840	1030	---	1000	---	2500	---	1100	1010	---
TOTAL	80830	183310	82790	38670	28187	31610	49020	83010	72080	33050	32240	64480
MEAN	2607	6110	2671	1247	1007	1020	1634	2678	2403	1066	1040	2149
MAX	3310	10300	5210	1820	1090	1070	3080	3980	4530	1350	1110	2850
MIN	2390	1230	1570	1010	973	994	1010	1700	1030	1010	1010	1030
AC-FT	160300	363600	164200	76700	55910	62700	97230	164700	143000	65550	63950	127900

CAL YR 1984 TOTAL 974603 MEAN 2663 MAX 10300 MIN 939 AC-FT 1933000
WTR YR 1985 TOTAL 779277 MEAN 2135 MAX 10300 MIN 973 AC-FT 1546000

Table 8.--Records of water discharge for North Santiam River at Niagara (14181500) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2280	3230	2580	2070	3040	12200	1020	1040	2110	1030	989	972
2	2310	3190	1060	2700	3090	12000	1040	1030	2030	1020	990	1010
3	2330	3280	1710	3180	3030	12000	1020	1030	1970	1020	1000	971
4	2330	3210	2550	2920	2100	10000	1020	989	2010	1020	997	1080
5	2280	3210	1780	3180	1680	4690	1010	976	1980	997	985	1200
6	2330	3270	2100	3190	1600	4470	1020	991	1470	1000	989	1370
7	2360	2480	3030	3140	1060	4660	1040	985	1120	1020	1000	1360
8	2380	3770	3030	3170	1070	4810	1120	1430	1140	1240	1010	1560
9	2180	4840	3010	3210	1050	6300	1060	1560	1170	1530	1010	1700
10	2180	4800	2950	3180	1050	5310	1030	1900	1120	1060	1000	1800
11	2750	4750	2470	3180	1010	4510	1030	1940	1140	1030	1000	1780
12	2980	4770	1700	3160	1170	4540	1060	1910	1100	1020	988	1750
13	3080	4780	1690	3210	1070	3260	1070	2390	1140	1020	966	1760
14	3100	4820	1660	3150	1090	3000	1130	2460	1130	1030	962	1740
15	3120	3890	1640	3170	1130	3220	1100	2490	1180	1050	973	1750
16	3120	3320	1290	3160	1650	3210	1050	2420	1160	1060	962	1750
17	3130	3110	1050	4180	1420	2410	1100	1780	1630	1030	971	1760
18	3030	3550	1090	5360	1070	1530	1050	1710	1610	1000	959	1750
19	2990	4830	1120	5370	3150	1100	1050	1720	1230	994	959	1720
20	3040	4940	1220	5320	4650	1080	1030	1890	1060	993	984	1840
21	3070	4920	1070	5230	4870	1080	1040	1770	995	990	982	1860
22	3000	4970	1080	5380	2280	1070	1030	2070	1000	985	976	1860
23	3190	4980	1050	5460	2110	1060	1020	2040	997	962	975	1840
24	3230	5060	1500	4020	4720	1050	1030	2080	1010	970	973	2010
25	3720	4150	2070	3130	10700	1050	1030	2160	997	988	978	1980
26	3780	3120	2140	3090	11900	1050	1040	1900	999	987	969	2150
27	3130	3160	2040	3170	12000	1100	1050	1900	1010	990	960	2680
28	3250	2910	2030	3050	12100	1030	1070	1520	1020	998	961	2550
29	3190	2930	2060	3100	---	1040	1080	1080	1020	977	979	2440
30	3180	2980	2070	3070	---	1020	1070	1890	1020	988	985	3090
31	3180	---	2040	3170	---	1030	---	2100	---	993	969	---
TOTAL	89220	117220	57880	111070	96860	115880	31510	53151	38568	31992	30401	53083
MEAN	2878	3907	1867	3583	3459	3738	1050	1715	1286	1032	981	1769
MAX	3780	5060	3030	5460	12100	12200	1130	2490	2110	1530	1010	3090
MIN	2180	2480	1050	2070	1010	1020	1010	976	995	962	959	971
AC-FT	177000	232500	114800	220300	192100	229800	62500	105400	76500	63460	60300	105300

CAL YR 1985 TOTAL 696667 MEAN 1909 MAX 5060 MIN 973 AC-FT 1382000
WTR YR 1986 TOTAL 826835 MEAN 2265 MAX 12200 MIN 959 AC-FT 1640000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1965 TO SEPTEMBER 1966
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2140	2320	2170	3070	2010	2130	3330	2680	2440	1120	1040	1020
2	2110	1940	2420	3570	1860	1850	3330	2580	2280	1170	1050	1020
3	2050	2150	2720	4620	1780	1760	2610	2890	1880	1600	1060	1010
4	2110	2790	2760	5560	1720	2660	2470	3660	1410	1360	1060	1010
5	2190	2530	2560	5600	1890	3600	2640	4580	1290	1240	933	1010
6	2160	2510	2570	11000	1930	3910	3540	4160	1320	1210	1060	1010
7	2110	2480	3280	8210	1840	5010	4580	3500	1340	1140	1060	1010
8	2000	3270	2960	11700	1810	3360	5970	4990	1330	1120	1050	1010
9	2090	4700	2810	12800	2050	8500	5750	4130	1340	1120	1050	1010
10	2110	3980	2420	11900	2160	5990	6300	3890	1430	1110	1040	1020
11	2110	3130	2010	10100	2030	3790	7450	4870	1590	1110	1030	1030
12	2150	4920	1910	6690	2030	3110	7620	3530	1540	1070	1040	1040
13	2140	6060	1910	6110	1830	3840	6260	3460	1420	1030	1040	1050
14	2150	5130	1500	8840	1860	4650	5280	3420	1400	1030	1040	920
15	2430	4480	1360	8500	1760	4070	5250	3360	1380	1050	1030	1000
16	2360	3990	1300	8140	1660	3300	5380	3330	1420	1110	1040	920
17	2350	3500	1260	7310	1710	2710	5420	3490	1330	1080	1030	1550
18	2320	3480	1260	6840	1780	2520	4940	3240	1210	1060	1040	1710
19	2290	3510	1220	2770	1620	2720	4120	3350	1210	1070	1050	1920
20	2310	4220	1170	2320	1920	2730	3380	3480	1180	1070	1050	2080
21	2230	5590	1190	2880	2050	2630	2860	3600	1170	1040	1040	2150
22	2280	6630	1150	2580	2150	2350	2800	3570	1130	1050	1040	2050
23	2240	7680	1120	2460	2260	2260	2770	3390	1130	1040	1040	2170
24	2240	5930	1500	2880	2160	2260	2860	3300	1120	1050	1050	2050
25	2220	5780	1330	2950	2000	2390	3000	3460	1100	1040	1040	2110
26	2250	5430	1300	3160	1930	2760	2940	3510	1090	1020	1050	2070
27	2290	2320	2040	3010	1920	3090	3350	3500	1080	1020	1050	2220
28	2260	2430	6280	2470	2350	3130	3250	3330	1090	1060	1040	2050
29	2280	5100	5630	2450	---	3080	3080	3160	1100	1060	1030	2170
30	2270	3600	5990	2530	---	3120	2780	2930	1070	1080	1020	2170
31	2250	---	3830	2590	---	2880	---	3150	---	1070	1020	---
TOTAL	68490	121580	72930	175610	54070	102160	125310	109490	40820	34400	32213	44560
MEAN	2209	4053	2353	5665	1931	3295	4177	3532	1361	1110	1039	1485
MAX	2430	7680	6280	12800	2350	8500	7620	4990	2440	1600	1060	2220
MIN	2000	1940	1120	2320	1620	1760	2470	2580	1070	1020	933	920
AC-FT	135800	241200	144700	348300	107200	202600	248600	217200	80970	68230	63890	88380

CAL YR 1965 TOTAL 1091193 MEAN 2990 MAX 25500 MIN 891 AC-FT 2164000
WTR YR 1966 TOTAL 981633 MEAN 2689 MAX 12800 MIN 920 AC-FT 1947000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2440	3420	1130	1250	894	2740	1730	1500	2740	1850	1060	1820
2	2080	3420	1040	1280	885	2140	1760	2330	2540	1470	1060	1910
3	2050	2620	1040	1270	868	2140	1570	3500	2470	1110	1050	1240
4	2020	1890	1010	1250	851	1780	1610	3070	3500	1170	1040	1270
5	1980	2170	1060	1200	859	1590	2020	2640	3710	1190	1080	1920
6	1980	2280	1010	1180	859	1660	2560	2220	3670	1150	1060	2070
7	2070	2200	1040	1160	851	2710	2890	1940	3620	1130	1060	1320
8	2050	2310	1100	1140	868	3620	2920	1760	2980	1110	1070	1700
9	2070	2300	1180	1140	859	3380	2310	1760	2330	1110	1050	1860
10	2020	2220	1110	1120	868	2570	1820	2220	2330	1110	1070	1320
11	2050	2420	1090	1130	877	2110	1600	2410	2080	1110	1060	1500
12	2070	2100	1090	1190	877	2370	1520	2050	2070	1140	1060	2010
13	2110	2740	1090	1770	912	2080	1690	1800	1770	1110	1050	2280
14	2020	2800	1090	1700	921	1800	1610	1660	1450	1090	1340	1590
15	2070	2940	1080	1520	894	1590	1460	1810	1560	1080	1940	1980
16	2100	3770	1070	1460	885	1450	1540	1840	1410	1090	2130	2370
17	2070	3340	1070	1390	877	1350	1410	3190	1380	1100	1560	1520
18	2070	3420	1070	1360	868	1520	1310	3030	1320	1110	1920	1550
19	2140	3380	1060	1370	859	1590	1190	2460	1340	1110	2190	2070
20	1990	3220	1050	1310	859	1620	1140	2410	1310	1090	1290	2490
21	2140	3130	1050	1260	912	1470	1140	2330	1300	1080	1400	2200
22	2160	3150	1040	1240	1040	1470	1180	2220	1310	1450	1890	2490
23	2110	3130	1080	1220	1060	1740	1360	2100	1320	1780	2190	2760
24	2130	2340	1100	1200	1070	1570	1570	2020	1270	1360	1650	3770
25	2490	1620	1100	1110	1070	1390	1760	1890	1250	1100	1780	3360
26	2570	1380	1590	921	1170	1290	1650	2230	1260	1070	1920	2980
27	2360	1340	2330	921	1600	2470	1410	2690	1230	1100	1160	3110
28	2250	1350	1770	903	3920	2190	1360	3170	1200	1070	1230	3520
29	2230	1400	1500	877	---	1860	1360	3070	1150	1060	1820	3650
30	2220	1250	1350	868	---	1650	1370	2920	1490	1070	2620	3990
31	2200	---	1280	877	---	1550	---	2890	---	1060	1520	---
TOTAL	66310	75050	36670	37587	29333	60460	49820	73130	58360	36630	45320	67620
MEAN	2139	2502	1183	1212	1048	1950	1661	2359	1945	1182	1462	2254
MAX	2570	3770	2330	1770	3920	3620	2920	3500	3710	1850	2620	3990
MIN	1980	1250	1010	868	851	1290	1140	1500	1150	1060	1040	1240
AC-FT	131500	148900	72730	74550	58180	119900	98820	145100	115800	72660	89890	134100

CAL YR 1976 TOTAL 1066540 MEAN 2914 MAX 13400 MIN 1010 AC-FT 2115000
WTR YR 1977 TOTAL 636290 MEAN 1743 MAX 3990 MIN 851 AC-FT 1262000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2710	4140	7420	4030	2440	3240	11400	1640	2780	2430	1510	1420
2	2750	3880	8220	4000	2120	3140	12700	1620	2490	4440	1550	1360
3	2710	3800	12600	4340	2000	2960	11700	1720	1850	4470	1610	1420
4	2710	3700	11800	10900	1940	3050	9280	1770	1500	3670	1480	1770
5	2690	3910	9330	9800	1850	3050	6550	1650	1440	2860	1400	2200
6	2770	5180	10700	16600	1910	3830	4880	2020	1420	2440	1350	2520
7	3310	4520	8450	14900	2180	4180	2830	2780	1770	2260	1340	2560
8	3730	4130	7280	12500	2580	8620	2590	3200	1890	2240	1350	2530
9	3520	4580	6720	14000	4510	9430	2350	3440	1830	2170	1320	2790
10	3140	4530	6370	15200	3860	10100	2160	3800	2370	2070	1320	2940
11	3030	4440	6300	15000	4040	8590	2160	4210	4190	1820	1330	2940
12	2960	4320	5540	14400	4210	6710	2010	3830	3820	1760	1310	3010
13	2900	4270	5690	12000	4380	5790	1930	3280	2240	2350	1260	3320
14	2760	4260	6240	7180	4420	7140	1830	3160	1540	2810	1240	3360
15	2790	4380	8290	6770	4590	6960	1840	4200	1510	2500	1250	3320
16	2830	4150	8140	6710	4590	5900	1820	5030	1610	2330	1240	3240
17	2930	5090	5330	6700	6700	4610	1870	5850	1730	2200	1230	3160
18	2970	6830	5760	6800	8750	3760	1990	6080	1880	2200	1250	3190
19	2980	6850	8500	6950	7960	3290	2070	4190	2520	2960	1260	3200
20	2960	6860	9650	6490	14700	3030	2100	3540	3020	4290	1190	3200
21	2950	6610	11100	6400	14200	2660	2110	3440	3070	3910	1230	2790
22	3020	6220	11800	4590	11700	2130	2070	3430	3180	3060	1210	2680
23	3690	6020	11500	4340	11300	2270	2050	3700	3200	2110	1300	2820
24	3420	5860	9440	4540	10100	2360	1970	3880	3500	1880	1250	2790
25	3310	5160	8950	4660	8410	2670	1840	3780	2990	1940	1260	2840
26	3570	5070	8930	4580	6760	2550	1730	3810	2800	2120	1230	2860
27	4240	5180	7430	4830	5310	2580	1650	3960	2390	2270	1270	2840
28	4180	6220	6160	4620	4470	2710	1670	3730	1650	1870	1290	2750
29	9420	6820	6120	4430	---	4600	1590	3500	1710	1760	1500	2760
30	5800	7630	6090	4340	---	11100	1630	3280	1670	1590	1610	2650
31	4570	---	4360	4170	---	9090	---	3350	---	1600	1440	---
TOTAL	107320	154610	250210	246770	161980	152100	104370	106870	69560	78380	41380	81230
MEAN	3462	5154	8071	7960	5785	4906	3479	3447	2319	2528	1335	2708
MAX	9420	7630	12600	16600	14700	11100	12700	6080	4190	4470	1610	3360
MIN	2690	3700	4360	4000	1850	2130	1590	1620	1420	1590	1190	1360
AC-FT	212900	306700	496300	489500	321300	301700	207000	212000	138000	155500	82080	161100

CAL YR 1982 TOTAL 1474470 MEAN 4040 MAX 15900 MIN 1060 AC-FT 2925000
WTR YR 1983 TOTAL 1554780 MEAN 4260 MAX 16600 MIN 1190 AC-FT 3084000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2590	3080	6040	7460	3340	2740	2890	3230	5520	2950	1150	1550
2	2680	3320	6060	6630	3240	2990	2550	5390	4150	2510	1160	1590
3	2690	4370	6090	9320	2500	2740	2510	6470	3900	1940	1150	1460
4	2650	5620	6040	9780	2100	2450	2540	6330	4950	1790	1140	1950
5	2550	4490	6290	8080	1700	2170	2280	6000	7780	1720	1140	2160
6	2620	6350	6790	7290	1580	2120	2210	5690	8050	1770	1120	2310
7	2590	5330	6210	6890	1550	2140	2310	4970	9670	1950	1120	2410
8	2600	4590	5770	6740	1530	2110	3510	4740	8760	1970	1120	2520
9	2600	4180	5050	6410	1550	2250	3090	4570	7760	2040	1110	2420
10	2600	4070	6960	6630	1550	2470	3910	4430	7190	2000	1110	2490
11	2580	4230	5640	7080	1740	2620	4420	6120	6710	2010	1100	2790
12	2720	4240	5740	6740	5970	2650	4800	5470	6400	1480	1090	2940
13	2690	4510	9140	5990	12900	3790	5410	4840	4840	1540	1100	2970
14	2560	4830	12000	4340	6180	5040	5160	5170	4000	1650	1100	3130
15	2670	5780	9080	3960	5950	5460	5440	5940	3620	1650	1090	3010
16	2690	5520	7950	3550	7550	6600	4250	6100	3340	1640	1090	3120
17	2630	6590	7530	3110	6760	6490	3720	5700	3250	1560	1090	3130
18	2720	6980	7260	2990	5090	6520	3560	4550	3160	1510	1090	3170
19	2630	7910	6920	2650	4600	7410	3560	3480	2670	1450	1080	3160
20	2560	8740	6600	2160	4700	7770	3690	3810	3320	1340	1090	3180
21	2480	7280	6060	2220	5210	8620	3420	3800	5920	1350	1080	3200
22	2770	6580	5930	2880	4350	8010	3190	4550	6350	1310	1080	3080
23	2870	6720	3980	3340	3620	7150	3070	6430	4750	1250	1080	3290
24	2550	9760	3580	6330	3930	6150	2240	5770	3920	1220	1070	3240
25	2570	8220	3700	8640	3760	5140	2090	6200	3750	1210	1070	3170
26	2580	7110	3730	6710	3100	7120	2110	6960	3080	1220	1070	2750
27	2560	6860	3700	6710	2820	6910	1880	5530	3330	1190	1060	2580
28	2710	6890	2930	6240	2470	6150	1870	4950	3790	1180	1270	2210
29	2650	6530	3370	5340	2360	5310	1870	4150	3710	1160	1480	2400
30	2790	6280	7940	3780	---	4170	2010	6040	3230	1180	1470	2410
31	3150	---	8690	3480	---	3370	---	5680	---	1160	1580	---
TOTAL	82300	176960	192770	173470	113700	146630	95560	163060	150870	49900	35550	79790
MEAN	2655	5899	6218	5596	3921	4730	3185	5260	5029	1610	1147	2660
MAX	3150	9760	12000	9780	12900	8620	5440	6960	9670	2950	1580	3290
MIN	2480	3080	2930	2160	1530	2110	1870	3230	2670	1160	1060	1460
AC-FT	163200	351000	382400	344100	225500	290800	189500	323400	299300	98980	70510	158300

CAL YR 1983 TOTAL 1494670 MEAN 4095 MAX 16600 MIN 1190 AC-FT 2965000
WTR YR 1984 TOTAL 1460560 MEAN 3991 MAX 12900 MIN 1060 AC-FT 2897000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2450	3820	5010	2990	1360	2050	4330	3120	3230	1300	1270	1130
2	2560	10100	6300	2790	1330	2040	4300	3470	3110	1280	1250	1140
3	2460	9600	6350	2500	1320	1860	3810	4150	3090	1260	1180	1140
4	2630	7020	6000	2220	1280	1940	3210	4340	2710	1250	1160	1120
5	2570	9250	5850	2320	1300	1640	2790	4260	2650	1250	1150	1140
6	2560	12900	5750	2090	1290	1760	2770	4070	5500	1240	1160	1370
7	2600	12800	3920	2200	1520	1700	3010	4140	10400	1240	1140	1310
8	2600	12500	2520	2100	1510	1640	2880	3820	8020	1220	1220	1220
9	2640	12100	2800	1940	1500	1600	2830	3430	6200	1220	1230	1590
10	2610	9490	5390	1790	1480	1610	2950	3130	6030	1550	1220	2230
11	2570	6950	4810	1600	2130	1620	2710	2690	5850	1190	1210	2420
12	2840	9350	4770	1630	4090	1610	2920	2410	5570	1200	1230	2570
13	3970	7790	4540	1590	2700	1600	3660	2390	4290	1200	1180	2940
14	3760	12900	4260	1630	2450	1580	4080	2350	3770	1180	1150	2890
15	3570	12600	4500	1760	3470	1600	4360	2370	3130	1180	1140	2960
16	2990	11900	4090	1710	2840	1650	4400	2760	2810	1190	1130	2870
17	2820	11500	3870	1940	2430	1730	3730	3420	2890	1180	1130	3120
18	2860	11600	3050	2140	2180	1740	3060	3970	2450	1190	1120	3610
19	3140	9940	2320	2040	2140	1760	2880	4080	2290	1180	1130	3340
20	3850	6970	2220	1940	2230	1780	2630	4090	2170	1190	1130	3180
21	3620	6420	2210	1910	2160	1920	2710	3870	1940	1240	1140	3080
22	3210	6020	2700	1730	2400	1860	2920	4750	1900	1250	1150	3040
23	3000	6220	3590	1940	2460	2840	3540	4890	1850	1240	1140	3020
24	2970	6450	3630	1660	2440	3370	3110	4890	1730	1270	1130	3020
25	3080	6240	3280	1550	2450	2680	3030	4110	1750	1230	1120	2890
26	5340	6070	3350	1490	2300	2500	2790	3420	1700	1220	1120	2860
27	5280	7510	3180	1450	2140	2480	2630	3410	1650	1210	1110	2920
28	5730	9610	2850	1400	1990	2300	3070	3140	1380	1200	1120	2690
29	4840	7640	2810	1390	---	2220	2900	2950	1310	1210	1120	2570
30	4250	6700	3380	1410	---	2610	2830	3310	1320	1240	1120	2610
31	4160	---	3400	1350	---	3970	---	3230	---	1250	1110	---
TOTAL	103530	269960	122700	58200	58890	63460	96840	110430	102690	38250	35910	71990
MEAN	3340	8999	3958	1877	2103	2047	3228	3562	3423	1234	1158	2400
MAX	5730	12900	6350	2990	4090	3970	4400	4890	10400	1550	1270	3610
MIN	2450	3820	2210	1350	1280	1580	2630	2350	1310	1180	1110	1120
AC-FT	205400	535500	243400	115400	116800	125900	192100	219000	203700	75870	71230	142800

CAL YR 1984 TOTAL 1504720 MEAN 4111 MAX 12900 MIN 1060 AC-FT 2985000
WTR YR 1985 TOTAL 1132850 MEAN 3104 MAX 12900 MIN 1110 AC-FT 2247000

Table 9.--Records of water discharge for North Santiam River at Mehama (14183000) 1966, 1977, and 1983-86--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2340	4050	3320	3550	4550	14600	1650	2180	2320	1140	1040	1020
2	2350	4300	1630	3980	4390	14000	1620	2310	2230	1140	1040	1050
3	2380	4350	2740	4780	4260	13800	1570	2470	2160	1120	1040	1020
4	2340	4230	3990	4150	3780	12000	1530	2250	2150	1220	1030	1090
5	2290	4320	3420	4520	3360	6020	1500	2490	2180	1160	1030	1200
6	2330	5260	4880	4950	2920	5210	1460	2410	1710	1130	1020	1320
7	2350	10800	7130	4470	2260	5940	1470	2140	1410	1130	1040	1330
8	2360	9860	6090	4460	2000	6340	1510	2380	1360	1260	1050	1480
9	2230	8650	5120	4660	1880	7970	1490	2440	1380	1580	1040	1610
10	2210	7310	4560	4600	1780	6980	1440	2880	1300	1230	1040	1730
11	2720	6580	3770	4500	1710	6000	1430	3060	1310	1170	1030	1720
12	3110	6160	2850	4280	1910	6100	1530	3050	1260	1150	1030	1690
13	3240	5930	2590	4180	2200	4870	1590	3900	1270	1130	1030	1700
14	3220	5820	2500	4070	2440	4390	1650	3840	1280	1120	1020	1690
15	3220	6020	2400	4060	3240	4320	1640	3520	1340	1140	1020	1710
16	3230	8340	2110	4650	8670	4110	1730	3240	1310	1160	1020	1720
17	3240	6300	1800	5960	10000	3430	2300	2570	1630	1160	1020	1750
18	3090	5510	1960	7710	7020	2380	2230	2390	1850	1110	1010	1790
19	3130	6620	2120	8310	6140	1960	2020	2310	1560	1100	1010	1720
20	3480	6500	2140	7890	7330	1830	2020	2570	1300	1080	1030	1890
21	3440	6270	1920	7190	7440	1820	2050	2560	1210	1070	1030	1880
22	4580	6140	1900	7570	18100	1770	1890	2850	1180	1060	1030	1830
23	8010	6010	1930	9500	23200	1860	1760	2740	1170	1040	1020	1880
24	6380	5990	2230	7250	14100	2960	1640	2650	1150	1050	1020	3090
25	8250	5240	2800	5400	17000	2470	1670	2690	1140	1060	1020	2920
26	6210	3810	2900	4780	16900	2190	1780	2440	1130	1050	1020	3950
27	4380	3750	2720	4750	15800	2080	2890	2320	1130	1050	1010	3720
28	4920	3530	2590	4700	15200	1930	3320	2050	1140	1060	1000	3390
29	4390	3480	2590	4640	---	1820	2720	1500	1140	1030	1030	3080
30	4130	3510	2570	5080	---	1750	2370	2120	1130	1040	1040	3570
31	4130	---	2510	4940	---	1680	---	2300	---	1040	1020	---
TOTAL	113680	174640	93780	165530	209580	154580	55470	80620	43830	34980	31830	59540
MEAN	3667	5821	3025	5340	7485	4986	1849	2601	1461	1128	1027	1985
MAX	8250	10800	7130	9500	23200	14600	3320	3900	2320	1580	1050	3950
MIN	2210	3480	1630	3550	1710	1680	1430	1500	1130	1030	1000	1020
AC-FT	225500	346400	186000	328300	415700	306600	110000	159900	86940	69380	63130	118100

CAL YR 1985 TOTAL 1018760 MEAN 2791 MAX 10800 MIN 1110 AC-FT 2021000
WTR YR 1986 TOTAL 1218060 MEAN 3337 MAX 23200 MIN 1000 AC-FT 2416000

Table 10.--Records of water discharge for South Santiam River near Foster (14187200) 1977 and 1983-86

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1400	1960	1200	980	595	856	1840	1370	2620	931	750	922
2	1400	2770	1110	980	595	758	1700	1970	2370	922	750	912
3	1400	2770	1090	990	587	884	1460	2980	1920	922	732	912
4	1400	1920	1200	847	580	793	1420	3900	3420	922	912	912
5	1400	1690	1130	724	572	724	1690	4900	3170	922	912	903
6	1390	1650	1160	724	565	716	1960	4230	2340	941	912	912
7	1420	1520	1170	716	572	1060	2250	4060	1920	941	912	912
8	1420	1520	1240	716	565	1700	2760	3780	2020	941	793	922
9	1430	1450	1390	707	572	2740	2070	3080	1820	931	856	912
10	1430	1550	1300	716	572	2130	1690	3800	1760	931	875	912
11	1430	1650	1200	724	580	1550	1420	3570	1600	931	912	912
12	1430	1540	1230	724	580	1730	1320	3130	1440	931	912	912
13	1420	1570	1240	793	595	1430	1460	1950	1130	922	912	912
14	1400	1640	1240	802	587	1160	1290	1510	1030	922	912	903
15	1400	1610	1220	776	580	893	1200	1740	1020	922	922	893
16	1420	1740	1180	750	580	793	1250	2920	1010	922	912	893
17	1420	2180	1110	741	572	784	1110	6020	1000	922	912	893
18	1860	2330	1210	732	557	884	1020	5360	990	922	912	903
19	2400	2310	1230	724	557	980	960	4660	990	931	903	903
20	2430	2100	1180	716	557	1170	866	4350	980	931	903	922
21	2480	1970	1130	716	572	1010	838	3420	980	922	903	922
22	2510	2070	1130	707	565	990	866	3130	970	912	903	1020
23	1800	2190	990	707	543	1320	990	3220	960	912	903	1180
24	1800	2190	990	707	550	1330	1170	2980	970	903	951	1610
25	1970	1310	980	650	550	1170	1350	1930	960	903	931	1560
26	2060	1250	1120	587	572	1030	1290	2450	951	912	931	1490
27	1960	1210	1120	587	587	1820	1090	2920	951	903	931	1920
28	1840	1220	1010	587	960	1850	1050	3190	941	903	922	2160
29	1930	1220	1000	587	---	1590	1010	3100	941	912	941	2180
30	2150	1210	990	595	---	1370	1130	2740	931	903	941	2500
31	1740	---	980	595	---	1200	---	2690	---	893	931	---
TOTAL	52940	53310	35470	22607	16419	38415	41520	101050	44105	28538	27704	34719
MEAN	1708	1777	1144	729	586	1239	1384	3260	1470	921	894	1157
MAX	2510	2770	1390	990	960	2740	2760	6020	3420	941	951	2500
MIN	1390	1210	980	587	543	716	838	1370	931	893	732	893
AC-FT	105000	105700	70350	44840	32570	76200	82350	200400	87480	56610	54950	68870

CAL YR 1976 TOTAL 856345 MEAN 2340 MAX 15000 MIN 471 AC-FT 1699000
WTR YR 1977 TOTAL 496797 MEAN 1361 MAX 6020 MIN 543 AC-FT 985400