SURFACE-WATER-QUALITY ASSESSMENT OF THE YAKIMA RIVER BASIN, WASHINGTON: ANALYSIS OF AVAILABLE WATER-QUALITY DATA THROUGH 1985 WATER YEAR

By J.F. Rinella, S.W. McKenzie, and G.J. Fuhrer

With sections on:

Water-resource development,
By Onni J. Perala, U.S. Bureau of Reclamation;

Major metals and trace elements--bed sediment,
By T.L. Fries and J.L. Ryder, U.S. Geological Survey;

Fish and other aquatic biological communities,
By S.S. Embrey, U.S. Geological Survey and
B.D. Watson, Yakima Indian Nation

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Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
10615 S.E. Cherry Blossom Drive
Portland, Oregon 97216

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FOREWORD

One of the great challenges faced by the Nation's water-resources scientists is providing reliable information to guide the management and protection of our water resources. That challenge is being addressed by Federal, State, Tribal, and local water-resources agencies and by academic institutions. Many of these organizations are collecting water-quality data for a host of purposes including: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, and water-supply facilities; and research to advance our understanding of water-quality processes. In fact, during the past two decades, tens of billions of dollars have been spent on water-quality data-collection programs. Unfortunately, the utility of these data for present and future regional and national assessments is limited by such factors as the areal extent of the sampling network, the frequency of sample collection, the varied collection and analytical procedures, and the types of water-quality characteristics determined. Therefore, despite these expenditures, only a small part of the data collected can be used to assess the status, trends, and causes of water-quality conditions at regional and national scales.

In order to address this deficiency, the Congress appropriated funds for the U.S. Geological Survey to begin testing and refining concepts in 1986 for a National Water-Quality Assessment (NAWQA) Program that, if fully implemented, would:

1. provide a nationally consistent description of water-quality conditions for a large part of the Nation's water resources;

2. define long-term trends (or lack of trends) in water quality; and

3. identify, describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends.

As presently envisioned, a full-scale NAWQA Program would be accomplished through investigations of a large set of major river basins and aquifer systems distributed throughout the Nation, which in aggregate, would account for a large percentage of the Nation's population and freshwater use. Each investigation would be conducted by a small team of individuals familiar with hydrologic system(s). Thus, the investigations would take full advantage of the region-specific knowledge of individuals in the areas under study. At present, four surface-water projects and three ground-water projects are being conducted as part of the pilot program to test and refine assessment methods and to help determine the need for and the feasibility of a full-scale program.

The final interpretive results of the pilot NAWQA Program will be presented in a series of U.S. Geological Survey Water-Supply Papers. Each of the seven pilot projects will be described in a Water-Supply Paper with separate chapters assigned to key elements of each investigation. Chapter A will be reserved for a summary report. Chapter B will be an analysis of available water-quality data for each project. Additional chapters will be written on specific topics appropriate for individual projects.

The pilot projects have depended heavily on cooperation and information from many Federal, State, Tribal, and local agencies. The assistance and suggestions of all are gratefully acknowledged.

Philip Cohen
Chief Hydrologist

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[Plate is in pocket]

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
acre-feet (acre-ft)	1233.	cubic meter
ton, short (T)	0.9072	megagram
gallon per minute (gal/min)	0.06309	liter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	0.4536	kilogram
gallon (gal)	3.785	liter

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

$$°F = (°C/0.555)+32$$

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.

The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

SURFACE-WATER-QUALITY ASSESSMENT OF THE YAKIMA RIVER BASIN, WASHINGTON: ANALYSIS OF AVAILABLE WATER-QUALITY DATA THROUGH 1985 WATER YEAR

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EXECUTIVE SUMMARY

In 1986, the U.S. Geological Survey (USGS) began testing and refining concepts for the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the program are to (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends in water quality; and (3) identify, describe, and explain, as possible, the major factors that affect water-quality conditions and trends.

At present (1990), the assessment program is in a pilot phase in seven project areas (four surface-water and three ground-water project areas) throughout the country that represent diverse hydrologic environments and water-quality conditions. One of the surface-water project areas is the Yakima River basin in Washington.

The first major activity undertaken in the Yakima pilot project was to compile, screen, and interpret available water-quality data. **The purpose of this report is to describe: (1) historical water-quality conditions in the basin, (2) long-term trends in water quality, and (3) relations of historical conditions and trends with natural and human factors.**

The Yakima River Basin

The Yakima River basin drains 6,155 square miles in south-central Washington and contains a diversity of landforms, including high peaks and deep valleys of the Cascade Range, broad river valleys, and lowlands of the Columbia Plateau. Even though areas covered with irrigated agriculture (approximately 1,000 square miles) and urbanization (50 square miles) are smaller than those areas covered with timber harvesting (2,200 square miles) or grazing (2,900 square miles), the intensity of the activities makes agriculture and urbanization of primary importance with respect to effects on water quality.

The Yakima River basin is one of the most intensively irrigated areas in the United States. The basin has 6 large storage reservoirs, 14 major diversions on the main stem, more than 1,900 miles of canals and laterals, 3 hydroelectric plants, 6 major irrigation projects, and numerous small irrigation systems. Surface-water diversions for irrigation are large and equivalent to about 60 percent of the water use and 81 percent of the annual streamflow from the basin. **The quality of the agricultural-return flow determines the quality of water in the lower Yakima River (downstream from the City of Yakima), because return flows account for as much as 80 percent of the lower main-stem flow during irrigation season.**

Surface-water-quality Conditions

Surface-water quality in the Yakima River basin is suitable for many designated uses. **Water quality in headwater streams is classified by the State of Washington (Washington State Administrative Code, 1988) as extraordinary (class AA--should exceed requirements for all beneficial uses)** and is controlled by the chemical properties of the precipitation, the mineralogy of the soils and geology, residence time in the ground-water system and storage reservoirs, forest management practices, and the nature and intensity of storm events. More than 70 percent of the irrigated land, 90 percent of the point-source nutrient loads, and more than 80 percent of the population are located in the lower basin downstream from Kittitas Valley. These point and nonpoint sources of contaminants affect water quality with measurable changes generally occurring downstream from Wilson Creek (Yakima RM [river mile] 147), which receives agricultural-return flow from Kittitas Valley. **Water quality downstream from the headwater reaches is classified by the State of Washington (Washington State Administrative Code, 1988) as good (class B for Sulphur Creek--should meet or exceed requirements for most beneficial uses) or excellent (class A--should meet or exceed requirements for all beneficial uses).**

To describe water-quality conditions in the Yakima River basin, and to facilitate intersite comparison, selected monthly data collected from 1974-81 and in 1975 water year are summarized in tables A and B, respectively. **Most water-quality constituent concentrations in the main stem increased in a downstream direction and were largest in tributaries that contained agricultural-return flow and point-source discharges.** These values indicate that current (1990) State standards were not met for stream temperature, pH, fecal-coliform bacteria, and dissolved oxygen. In addition, turbidity and phosphorus concentrations were detected at levels of concern relative to effects on aquatic life and eutrophication, respectively.

Observed trends in constituent concentrations at 43 locations in the Yakima River basin from 1974-81 water year indicate changes in stream quality (table C). **Increases in stream temperature, specific conductance, and concentrations of orthophosphate (soluble-reactive phosphorus), ammonia, and nitrite plus nitrate were widespread in the basin from 1974-81 water years.** Flow-adjusted-trend results indicate that about 50 percent of the increasing specific conductance trends probably were associated with the decreasing streamflows. **General increases in ammonia, nitrite-plus-nitrate, and orthophosphate concentrations may be due to the increasing use of nitrogen and phosphorus fertilizers in the basin and to increasing populations of livestock. General decreases in turbidity levels, and concentrations of suspended sediment and suspended phosphorus may be due to changes in crop types from row crops to less erosive permanent crops (for example, orchards) and to efforts to control erosion (for example, sediment-detention ponds, and sprinkler- and drip-irrigation methods).**

pH and Major Cations and Anions

Most (98 percent) of the pH measurements and alkalinity concentrations in the streams range from 6.4 to 8.6 pH units and 14 to 182 mg/L [milligrams per liter] (as calcium carbonate), respectively. **In general, these concentrations are typical of natural river water not influenced by contamination** (natural river water ranges from 6.5 to 8.5 pH units with alkalinities less than 165 mg/L; Hem, 1985). Alkalinity and pH values

Table A.--Summary of monthly streamflow and physical-property measurements and nutrient concentrations at selected sites in the Yakima River basin, Washington, 1974-81 water years

[90-percentile value indicates that 90 percent of the values were less than or equal to the listed value; 50-percentile value indicates that 50 percent of the values were less than or equal to the listed value; 10-percentile value indicates that 10 percent of the values were less than or equal to the listed value; concentrations are expressed in milligrams per liter except as follows: streamflow (cubic feet per second), temperature (degrees Celsius), turbidity (NTU--nephelometric turbidity units), specific conductance (microsiemens per centimeter at 25 degrees Celsius), pH (standard units), "--" = no data or no Washington State standard; all sites listed are Washington State class A streams, except Sulphur Creek, which is class B; 1/ = Not to exceed 5 NTU above background levels; 2/ = Washington State standard varies with temperature and pH (U.S. Environmental Protection Agency, 1986; Washington State Administrative Code, 1988)]

	Yakima River at (river mile in parenthesis)							Selected agricultural drain		Washington State standard--
Property or constituents	Cle Elum (183.1)	Ellensburg (148.0)	Umtanum (140.4)	Terrace Heights Bridge (113.2)	Granger (82.7)	Mabton (59.8)	Kiona (29.9)	Wilson Creek at Thrall Road	Sulphur Creek at McGee Road	class A streams
90-percentile values										
Streamflow	3,560	3,910	4,430	5,790	6,710	6,140	8,470	197	360	--
Stream temperature	16.0	15.5	15.5	16.0	18.9	21.0	22.0	15.5	19.0	21.0
Turbidity	8	13	14	16	16	17	22	12	54	1/ plus 5
Suspended sediment	16	20	32	32	60	59	113	38	285	--
Specific conductance	87	114	155	156	318	323	350	248	712	--
Dissolved oxygen	12.6	12.4	13.3	13.1	12.2	11.8	13.4	13.4	11.0	8.0
Chemical oxygen demand	9	16	14	14	16	16	--	21	32	--
pH	7.7	7.7	7.8	7.8	7.9	8.0	8.6	7.9	8.1	6.5-8.5
Ammonia, total as N	.02	.06	.05	.04	.18	.11	.17	.07	.47	2/
Nitrite + nitrate as N	.07	.18	.36	.26	1.3	1.4	1.5	.48	6.1	10
Phosphorus, total as P	.06	.12	.13	.12	.24	.22	.21	.24	.68	--
Orthophosphate, dissolved as P	.01	.03	.05	.03	.13	.10	.11	.10	.25	--
50-percentile values										
Streamflow	1,200	1,830	2,260	2,850	1,550	2,200	2,405	85.0	182	--
Stream temperature	8.8	8.7	8.2	9.0	11.0	12.8	11.6	9.8	12.7	21.0
Turbidity	1	1	2	3	6	6	7	4	13	1/ plus 5
Suspended sediment	4	6	8	10	22	23	26	12	45	--
Specific conductance	62	89	114	100	182	244	265	210	377	--
Dissolved oxygen	10.9	10.7	11.1	10.7	9.7	9.5	10.8	11.4	9.3	8.0
Chemical oxygen demand	4	6	7	7	10	10	--	13	16	--
pH	7.5	7.5	7.6	7.5	7.6	7.7	7.9	7.7	7.8	6.5-8.5
Ammonia, total as N	.01	.02	.01	.01	.05	.04	.07	.02	.16	2/
Nitrite + nitrate as N	.03	.06	.13	.06	.54	1.0	.89	.25	2.7	10
Phosphorus, total as P	.02	.03	.04	.04	.11	.12	.13	.12	.29	--
Orthophosphate, dissolved as P	<.01	.01	.01	.01	.05	.06	.08	.06	.16	--
10-percentile values										
Streamflow	235	424	709	1,050	415	840	1,040	40.0	57.7	--
Stream temperature	3.6	2.5	1.7	2.1	3.0	4.0	3.4	3.0	7.0	21.0
Turbidity	1	1	1	1	2	2	3	1	3	1/ plus 5
Suspended sediment	1	1	2	3	8	6	7	5	14	--
Specific conductance	42	65	86	75	107	142	149	155	262	--
Dissolved oxygen	9.1	9.1	9.2	8.7	7.5	8.1	8.7	9.3	7.7	8.0
Chemical oxygen demand	2	3	3	4	6	6	--	8.0	11	--
pH	7.2	7.3	7.4	7.3	7.4	7.5	7.6	7.5	7.6	6.5-8.5
Ammonia, total as N	<.01	<.01	<.01	<.01	.01	.01	<.01	<.01	.03	2/
Nitrite + nitrate as N	.01	.02	.02	.02	.14	.33	.37	.08	1.4	10
Phosphorus, total as P	.01	.01	.02	.02	.07	.08	.08	.07	.17	--
Orthophosphate, dissolved as P	<.01	<.01	<.01	<.01	.02	.03	.04	.03	.09	--

Table B.--Summary of monthly bacteria and major-ion concentrations in the Yakima River, Washington, 1975 water year

[90-percentile value indicates that 90 percent of the values were less than or equal to the listed value; 50-percentile value indicates that 50 percent of the values were less than or equal to the listed value; 10-percentile value indicates that 10 percent of the values were less than or equal to the listed value; concentrations are expressed in milligrams per liter except fecal-coliform bacteria (colonies per 100 milliliters); "--" = no data or no standard; all sites listed are Washington State class A streams, except Yakima River mile 191 which is class AA; 1/ = Geometric mean shall not exceed 100 organisms per 100 milliliters; 2/ = Shall not be less than 20 nor greater than 300 milligrams per liter, except under natural conditions]

	Yakima River (river mile in parenthesis)						Washington State standard--class A streams
Constituents	Near Cle Elum (191.1)	Thorp Highway Bridge (165.4)	Terrace Heights Bridge (113.2)	Near Toppenish (93.0)	Mabton (59.8)	Kiona (29.9)	
			90-percentile values				
Fecal-coliform bacteria	11	17	132	330	804	400	1/ 100
Calcium	12	12	18	20	29	32	--
Magnesium	2.0	3.9	5.8	6.8	11	11	--
Sodium	4.2	3.4	8.0	10	18	20	--
Potassium	1.6	.6	5.0	2.6	3.4	3.7	--
Chloride	4.6	2.7	3.3	4.4	6.7	7.8	250
Sulfate	3.4	2.2	5.6	6.9	17	20	250
Alkalinity as calcium carbonate	30	43	67	78	117	137	2/ 20-300
			50-percentile values				
Fecal-coliform bacteria	2	2	17	22	230	135	1/ 100
Calcium	8.2	7.6	11	12	22	21	--
Magnesium	1.4	2.5	3.4	4.4	7.7	7.7	--
Sodium	2.6	2.2	4.8	6.6	12	12	--
Potassium	.7	.4	1.2	1.4	2.8	2.4	--
Chloride	2.8	1.6	2.2	3.0	4.6	5.1	250
Sulfate	2.2	1.4	3.1	4.4	12	10	250
Alkalinity as calcium carbonate	24	31	43	53	88	88	2/ 20-300
			10-percentile values				
Fecal-coliform bacteria	1	1	<1	1	80	62	1/ 100
Calcium	6.4	4.6	8.8	9.2	12	12	--
Magnesium	.6	1.6	2.6	2.6	3.4	4.1	--
Sodium	2.2	1.4	3.1	3.5	6.8	6.7	--
Potassium	.4	.2	.6	.8	1.4	1.5	--
Chloride	1.3	.8	.8	1.4	2.1	2.2	250
Sulfate	1.2	1.0	1.8	2.3	4.3	5.6	250
Alkalinity as calcium carbonate	16	20	32	36	51	53	2/ 20-300

throughout most of the basin are indicative of water from noncalcareous (lacking calcium carbonate) igneous terrane along the eastern slopes of the Cascade Range. Increases in alkalinity and pH values down the main stem of the Yakima River probably result from agricultural-return flow and point-source effluent effects (including evapotranspiration and nutrient enrichment that causes eutrophication). **Most of the pH and alkalinity values meet State standards for the protection of freshwater aquatic life.** Many of the pH values that do not meet standards occurred during the summer months and probably were the result of increased photosynthetic activity from aquatic plants. Exceedance of the alkalinity guidelines for food canning (less than 1 percent of the values exceeded 300 mg/L as calcium carbonate) only occurred at two locations, both of which receive agricultural-return flow: South Drain near Satus and Yakima River at Kiona.

Table C.--Summary of temporal trends for streamflow and selected water-quality properties and constituents at sites having 4 to 8 years of monthly data, Yakima River basin, Washington, 1974-81 water years

["NA" indicates not applicable]

Property or constituent	Number of sites with 4 to 8 years of data	Non-flow-adjusted trends: Number of sites with upward trends	Non-flow-adjusted trends: Number of sites with downward trends	Flow-adjusted trends: Number of sites with upward trends	Flow-adjusted trends: Number of sites with downward trends
Streamflow	43	0	19	NA	NA
Stream temperature	43	12	0	8	2
Specific conductance	43	14	3	8	7
Total phosphorus	43	2	9	4	10
Dissolved ortho-phosphate	43	13	2	10	4
Suspended phosphorus	43	0	13	0	12
Total ammonia nitrogen	43	24	3	18	4
Dissolved nitrite plus nitrate	43	23	0	16	2
Turbidity	43	0	18	1	15
Suspended sediment	43	3	8	9	6

Headwater streams in the basin are poorly buffered and are susceptible to precipitation-induced acidification. **The pH and strong-acid-ion concentrations (sulfate and nitrate) of precipitation in the headwater streams in the Yakima River basin are similar to mean background levels in remote areas of the world; this similarity indicates that man's influences on the quality of precipitation in the upper basin might be small, when compared with levels in large population centers in the United States.**

Median major-ion concentrations of calcium, magnesium, sodium, potassium, chloride, sulfate, and total dissolved solids (13, 4.9, 7.1, 1.6, 2.5, 4.4, and 120 mg/L, respectively) **in the Yakima River basin are similar to or smaller than the mean concentrations observed in river water of the world** (14, 3.7, 5.7, 1.8, 6.8, 9.6, and 81 mg/L, respectively; Hem, 1985). The predominant major ions in surface water in the Yakima River basin are calcium and bicarbonate. The water generally has high calcium:sodium ratios and small fluoride concentrations (most less than 0.3 mg/L), which are typical of water from the basalt terrane located throughout much of the basin (White and others, 1963). Major-ion concentrations and specific conductance increase down the main stem of the Yakima River, but their relative ion composition is remarkably similar. Two mechanisms that could account for the observed increases in concentration are (1) evapotranspiration that equally concentrates all ions, and (2) uniform dissolution of ions from geologically similar rock and soil types. **Generally, major-ion concentrations do not pose a major alkali or salinity hazard nor should they affect soil properties through ion-exchange effects.** Few sulfate (less than 1 percent) and total-dissolved-solids concentrations (3 percent) exceeded State standards and U.S. Environmental Protection Agency guidelines for domestic water supplies and irrigation, respectively.

Suspended Sediment and Turbidity

Background levels of suspended sediment and turbidity in the Yakima River upstream from the Yakima River at Terrace Heights Bridge (Yakima RM 113.2) were small with median values less than 10 mg/L and 3 NTU, respectively. **These levels approximately doubled downstream from the Terrace Heights Bridge, primarily because of sediment contributed by turbid agricultural-return flows during irrigation season. The largest suspended-sediment concentrations in the Yakima River basin occurred in the Sunnyside subbasin, which has steep slopes that contribute to increased erosion.** In the main stem, the largest suspended-sediment concentrations generally occurred from April to June during high flows due to snowmelt; in the agricultural-return flows, large concentrations generally occurred during storm runoff, periods of peak irrigation, and at the start of irrigation season when soils were freshly tilled and irrigation ditches were layered with sediment from recent mechanical cleaning and windblown sources. **During the 1980 water year (a median flow year), the major loadings of suspended sediment in the Yakima River basin were from nonpoint sources.**

Nutrients

The Yakima River has small background concentrations of total phosphorus, dissolved orthophosphate, total ammonia, and dissolved nitrite plus nitrate (median values less than or equal to 0.04, 0.01, 0.02, and 0.13 mg/L, respectively) **from Cle Elum (RM 183.1) downstream to Terrace Heights Bridge (RM 113.2).** Total-phosphorus and nitrite-plus-nitrate concentrations upstream from Terrace Heights Bridge are about one-half of the median values for many rivers in the United States (Smith and others, 1987). The diluting effect of the Naches River at RM 116.3 reduces nutrient concentrations in the main stem. Farther downstream **in the vicinity of Parker (RM 104.6), however, median concentrations increase by about a factor of two or more,** and except for ammonia, which decreases downstream from Parker, **the nutrient concentrations continue to increase downstream to Kiona** (RM 29.9) [table A]. **These median nutrient concentrations downstream from Parker are equal to or greater than those for many rivers in the United States (Smith and others, 1987).** The increased concentrations at Parker might be attributed to nutrient loadings from a sewage treatment plant at RM 111.0, Wide Hollow Creek at RM 107.4, Moxee Drain at RM 107.3, and Ahtanum Creek at RM 106.9.

Downstream from two large canal diversions (Wapato and Sunnyside Canals) near Parker, the streamflow in the Yakima River is low during most of the irrigation season (April through October). Consequently, **point and nonpoint discharges (including agricultural-return flows) downstream from Parker cause substantial increases in median nutrient concentrations.**

Nutrient enrichment during the warm summer months results in some scattered patches of dense attached and rooted plant growth in the sluggish-moving reaches of Yakima River downstream from its confluence with Satus Creek (RM 69.6). However, the temporal and spatial coverages of historical nutrient data are insufficient to define whether causes of eutrophication are from point or nonpoint sources.

Increased stream turbidity in the lower Yakima River might be limiting aquatic plant growth and other effects of eutrophication by decreasing sunlight penetration that is needed for photosynthesis. Major increases in turbidity in streams in the lower basin result from soil erosion in irrigated agricultural areas; if soil erosion was reduced without also reducing dissolved nutrient concentrations in the Yakima River, conditions could become more eutrophic.

On the basis of the evaluation of 6,475 and 7,900 determinations of total ammonia and dissolved nitrite plus nitrate, respectively, **about 2 percent of the ammonia determinations (mostly in agricultural-return flows and downstream from sewage treatment plants) exceeded the EPA (U.S. Environmental Protection Agency, 1989) chronic-toxicity criteria for the protection of salmonids or other sensitive coldwater fish species,** and one site (Satus Drain 302) had nitrite-plus-nitrate concentrations larger than EPA's National Primary Drinking-Water Regulation (10 mg/L as N). Streams having the largest nitrite-plus-nitrate concentrations generally were in the Sunnyside subbasin, where a large number of dairies might be contributing to the enrichment.

Largest total-phosphorus concentrations occurred during snowmelt and irrigation seasons when suspended-sediment concentrations also were large. Largest nitrite-plus-nitrate, ammonia, and orthophosphate concentrations occurred from October through March when much of the nutrient loading could be attributed to ground-water and point-source contributions. In addition, reduced primary productivity (consumption of nutrients by stream biota) during the cold fall and winter seasons, also would contribute to the increased nutrient concentrations.

Estimates of major point-source loads of total phosphorus and total nitrogen in the Yakima River basin for 1980 indicate that: (1) the annual, total phosphorus, point-source, load was larger than the annual, total-phosphorus load in the Yakima River at Kiona near the terminus of the basin, and (2) the annual, total-nitrogen, point-source, load was about 13 percent of the annual, total-nitrogen, load at Kiona. **Even though the point-source phosphorus load appears large, it is about 25 percent of the estimated annual amount of phosphorus fertilizer applied in the basin; the point-source, total-nitrogen, load is about than 5 percent of the annual amount of nitrogen fertilizer applied.**

Stream Temperature

The upper Yakima River originates from precipitation, snowmelt, and ground-water seepage from the high Cascade Mountains. Consequently, the initial river temperature is cold, and the water becomes warmer as it flows to the lower basin.

Analysis of 12,500 instantaneous stream-temperature measurements from about 400 sites from 1959-85 water years indicates that **7 percent of the temperature measurements at the class AA streams in the basin** (headwater sites in the national forest) **were above the 16 °C** (degrees Celsius) **State standard, 5 percent at the class A streams** (sites downstream from the national forest) **were above the 21 °C standard, and 2 percent at the class B stream** (Sulphur Creek Wasteway) **were above the 21 °C standard.** As expected, most of the exceedances occurred during the warm July-August period.

Increased stream temperatures in the main stem during the summer result from the dominant influence of air temperature in the lower basin in conjunction with: (1) low flows downstream from the Wapato and Sunnyside Canal diversions (Yakima RM 106.7 and 103.8, respectively), (2) slow velocities due to a small stream gradient between Yakima RM 69.6 and 47.1, and (3) low flows between Prosser Dam (Yakima RM 47.1) and Chandler Pumping Plant (Yakima RM 35.8).

A calibrated model was used to estimate water temperatures for natural conditions in the main stem for August 1981, based on the assumptions of no reservoir storage and no diversions. The model simulation indicated that the mean stream temperatures would exceed the class A temperature standard of 21 °C from Umtanum (Yakima RM 140.4) to Kiona (Yakima RM 29.9) by as much as 1 °C.

Dissolved Oxygen

On the basis of 6,165 measurements of DO (dissolved oxygen) from 185 sites in the Yakima River basin, **DO concentrations in the basin are similar to those in many rivers in the United States** (Smith and others, 1987; median DO for rivers in the United States is 9.8 mg/L compared to the median DO of 10.2 mg/L for the Yakima River basin). Most of the data from the Yakima River basin were collected during daylight periods; the concentrations should be near maximum, if the controlling effect on daytime concentrations was photosynthesis. In streams containing abundant aquatic plant and animal (bacteria, invertebrates, and fish) growth, nighttime DO concentrations would be smaller as a result of respiration and the absence of photosynthesis.

More than 50 percent of sites had one or more DO concentrations that did not meet State standards. Twenty-five percent of the DO concentrations at class AA streams were less than the 9.5 mg/L standard. The class AA standard might be naturally unattainable for some headwater streams during the summer months because of altitude and temperature effects on DO saturation. **Ten and 1 percent of the DO concentrations at the class A and B streams were less than the State standards of 8.0 and 6.5 mg/L, respectively.** Many of the smaller DO concentrations occurred during the warm summer months at streams that receive relatively large nutrient and organic-carbon loads from point and nonpoint sources. Potential causes for the smaller concentrations include increased water temperatures that decrease DO concentrations at saturation, and increased rates of respiration (plants and animals) and biochemical oxygen demand.

Organic Carbon and Related Measures

On the basis of 193 samples from 26 sites in the basin, **total organic carbon concentrations range from 0.1 to 17 mg/L with a median concentration of 4.4. These concentrations are similar to average concentrations in (1) many rivers in the United States, (2) snow in North America** (dissolved organic carbon ranging from 0.1 to 6 mg/L), **and (3) tree-canopy drip** (dissolved organic carbon ranging from 5 to 10 mg/L; tree-canopy drip is precipitation that contacts tree branches and leaves as it falls to the ground; Thurman, 1985). Main-stem data from the Yakima River basin indicate that (1) dissolved organic carbon constitutes more than 80 percent of the total organic carbon, which is typical of many rivers in the United States (Thurman, 1985), and (2) median monthly concentrations of total organic carbon are relatively constant throughout the year.

COD (chemical oxygen demand) concentrations increase downstream in the main stem, from a median of 4 mg/L at Cle Elum (RM 183.1) to a median of 10 mg/L at Mabton (RM 59.8), as a result of increasing organic contributions from domestic, industrial, and agricultural sources. Sites in the basin having the largest COD concentrations are agricultural-return flows that also receive point-source discharges and runoff from dairies and livestock. **Many of the agricultural-return flows have the largest COD concentrations and the smallest DO concentrations in the Yakima River basin, reflecting the bacterial consumption of dissolved oxygen and organic matter as a food source.**

Major Metals and Trace Elements

In the Yakima River basin, concentrations of suspended and dissolved elements in streams depend on (1) man's influences, including transportation, urbanization, industrialization, and pesticide application; (2) the natural weathering and erosion of rocks and soils; and (3) ash fallout from the volcanic eruption of Mount St. Helens. Estimates of iron and selected trace-element (arsenic, cadmium, chromium, copper, lead, mercury, and zinc) sources indicate that point sources (mostly sewage treatment plants) are contributing less than 10 percent of the annual element loads to surface water in the basin. However, most trace element data in the basin are spatially and temporally limited, and are inadequate for accurately defining water-quality conditions and source loads.

Generally, concentrations of major metals and trace elements in water and sediment samples from the Yakima River basin are not enriched above natural concentrations. The range of dissolved concentrations in the basin is similar to the range of concentrations observed in other rivers in the United States, and the median dissolved concentrations are similar to background concentrations that have been minimally affected by man's activities. For example, median dissolved concentrations of arsenic, cadmium, copper, lead, mercury, and zinc in the Yakima River basin are <5, <1, 3, 4, <0.1, and 11 mg/L compared with 2, 0.07, 1.8, 0.2, 0.01, and 10 mg/L, respectively, for inland water that is minimally affected by man's activities (Forstner and Wittman, 1979). Median concentrations of these elements in bed-sediment samples from the upstream mountainous regions of the basin fall within the expected 95-percentile confidence range for uncontaminated soils in the Western

United States (R.C. Severson, U.S. Geological Survey, written commun., 1987, based on data in Shacklette and Boerngen, 1984). Because few water samples were collected from these mountainous regions, dissolved- or suspended-element concentrations could not be related directly to element concentrations in the bed sediment. **Except for arsenic, lead, and zinc, trace-element concentrations in 6-12 whole-fish samples from the Yakima River were similar to national baseline concentrations collected in U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program.** Eighty-fifth-percentile concentrations of arsenic, lead, and zinc in whole-fish samples from the Yakima River basin are 460, 1,260, and 77,900 compared with 230, 320, and 46,300 micrograms per kilogram (wet weight) for 85-percentile concentrations in whole-fish samples collected in the National Contaminant Biomonitoring Program (1978-79). A potential source of arsenic may be acid-lead-arsenate sprays used for controlling codling moths in apple orchards prior to 1947. High application rates of phosphate fertilizer increase the dissolution of arsenic from the soils and result in arsenic contamination in the shallow aquifers that feed drains in agricultural areas. A source of lead might be automotive exhaust from the combustion of leaded gasoline.

From 1953-85 water years, the dissolved elements that most often exceeded U.S. Environmental Protection Agency National Primary or Secondary Drinking-Water Regulations were iron (7 percent of the iron determinations), manganese (2 percent) and lead (2 percent). **Similarly, dissolved elements that most often exceeded State chronic-toxicity standards for aquatic life were lead (56 percent), mercury (43 percent), copper (23 percent), cadmium (12 percent), and zinc (3 percent).** The order of exceedances for total recoverable elements was similar to the order of exceedances for the dissolved elements, listed above, except that the frequencies of exceedances were larger.

In the Yakima River at Kiona (RM 29.9) near the terminus of the basin, dissolved lead and copper exhibited decreasing concentrations from the 1960s to 1985. Possible explanations for these decreases include the large decline in leaded-gasoline combustion during the 1970s, and a decreasing use of copper sulfate for eradicating nuisance aquatic plant growths in canals.

Radionuclides

The absence of baseline data prohibits any evaluation of radionuclides relative to spatial and temporal variability and to water-quality standards. The basin is near the Hanford Nuclear Facility (operated by the U.S. Department of Energy), and the collection of baseline radionuclide data would identify any need for concern.

Pesticides and Other Trace Organic Compounds

Even though the application of synthetic organic compounds is extensive on agricultural land in the Yakima River basin, relatively few samples have been collected to determine the spatial and seasonal distributions of these compounds in the aquatic environment. Data have been collected from about 30 sites in the basin, and about 50 percent of the samples have been collected from the Yakima River at Kiona near the terminus of the basin. **About 85 percent of the trace-organic-compound**

concentrations from 1968-83 water years were reported below the minimum analytical reporting levels (note that historical reporting levels are generally 1 to 2 orders of magnitude larger than those that are currently--1990--available.)

Concentrations of several trace organic compounds in water exceeded State water standards for chronic toxicity of freshwater aquatic life, including aldrin/dieldrin, endosulfan, dichlorodiphenyltrichloroethane (DDT) and its metabolites, endrin, parathion, and polychlorinated biphenyls (PCB). None of these concentrations exceeded standards for acute toxicity. Most of the exceedances occurred in the Yakima River at Kiona, partly because of the relatively large number of samples collected from the site.

The largest concentrations of the hydrophobic organic compounds (DDT and its metabolites, dieldrin, and others) in water occurred during irrigation season in agricultural-return flows that also contained the largest suspended-sediment concentrations. This pesticide-sediment relation indicates that concentrations of **hydrophobic contaminants could be reduced in streams by controlling sediment erosion of contaminated soils.** From 1968-82, **decreases in concentrations of DDT and its metabolites, and dieldrin in water and whole-fish tissues coincide with EPA's decision in December 1972 to ban further use of DDT due to health and environmental-hazard considerations and in 1974 to prohibit the manufacture of dieldrin in the United States.**

Routine fish monitoring by WDOE (Washington State Department of Ecology) from 1979 to 1984 showed that the largest concentrations of DDT plus metabolites in Washington State occurred in fish from the Yakima River basin. In 1985, concentrations of DDT plus metabolites in edible resident fish were below the Food and Drug Administration action level (5,000 μg/kg--micrograms per kilogram, wet weight), but they exceeded the maximum recommended concentration of 1,000 μg/kg (wet weight) established by the National Academy of Science for the protection of fish predators (such as fish-eating birds; Johnson and others, 1986).

Assuming an average fish consumption of 6.5 grams per day, the average lifetime (70 years) cancer risks (U.S. Environmental Protection Agency health assessment methodology; Johnson and others, 1986) for consumption of fish by humans from the lower Yakima River are $3x10^{-5}$, $8x10^{-5}$, $9x10^{-7}$, $2x10^{-6}$, and $1x10^{-5}$ for PCB, dieldrin, DDD, DDT, and DDE, respectively (a risk of $3x10^{-5}$ is 1 person per 300,000 people).

Fecal-coliform Bacteria

The presence of fecal-coliform bacteria indicates a potential health hazard from the transmission of pathogenic microorganisms in water from fecal contamination. Fecal-coliform-bacteria data are limited in both spatial and temporal coverage, so that the occurrence, temporal trends, and sources could not be quantitatively defined throughout the basin. **An evaluation of 2,235 fecal-coliform bacteria determinations at 200 sites from 1968-85 water years indicates that 49 percent of the determinations at 128 sites exceeded State standards.** About 32 percent of the determinations were made on main-stem samples and about 40 percent of these determinations exceeded standards. Most of the exceedances in the main stem occurred downstream from Granger (Yakima RM 82.7). **The largest percentage of exceedances occurred at the class B sites [Sulphur Creek] (93 percent of the class B determinations) and at the class A sites (54 percent),** whereas the class AA sites had 14 percent. Class AA sites are affected minimally by man's activities and exhibited the smallest bacteria concentrations. Prior to the 1970's, a source of fecal-coliform bacteria in the Yakima River basin was untreated and (or) improperly treated effluent from STPs (sewage treatment plants; Sylvester and others, 1951); since then, most of the STP discharges in the basin have been treated with chlorine, substantially reducing the bacteria concentrations in the effluent (Jim Milton, Washington Department of Ecology, oral commun., August 24, 1989). **Data collected since 1970 indicate that nonpoint sources are controlling the bacterial quality of streams.** Areas with concentrations greater than 200 colonies per 100 mL (milliliters) of water (class A standard is 100 colonies per 100 mL, and class B standard is 200 colonies per 100 mL) include sites at most agricultural-return flows, on the main stem downstream from major agricultural-return flows, and in subbasins with large densities of dairies and livestock, such as Granger, Sunnyside, and Kittitas subbasins.

Fecal-coliform concentrations were increasing from 1977-85 water years in the Yakima River at Parker (RM 104.6) and Kiona (RM 29.9) by about 6 and 14 percent per year, respectively. These increasing concentrations were not associated with increasing streamflows and could be attributed to increases in the number of livestock in the basin.

Fish and Other Aquatic Biological Communities

Because of the commercial and recreational value of anadromous fish in the Yakima River basin, the emphasis of biological investigations has been on the description, quantification, protection, and enhancement of salmon and trout populations. Prior to 1880, anadromous fish runs were estimated to be more than one-half million fish (Davidson, 1965). By 1900, all summer streamflow in the Yakima River basin had been appropriated and diverted by private interests for irrigation. A serious water shortage had developed, leaving the lower Yakima River with increasing temperatures in stagnant pools. By 1905, the construction of large storage reservoirs and other water-resource developments for irrigation had seriously affected fish migrations in the Yakima River; the number of anadromous fish annually returning to the Yakima system declined to about 60,000 (Davidson, 1965). By 1920, anadromous fish runs further declined to 12,000 and have remained at approximately this level for 70 years.

Major habitat and water-sediment factors that currently (1990) are suspected of affecting fishery in the Yakima River basin are (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990): (1) fish passage problems associated with irrigation diversions in the tributaries, (2) passage and rearing habitat restrictions resulting from low streamflows in both the main stem and the tributaries, (3) adverse effects to spawning and rearing habitat associated with rapid daily-flow fluctuations downstream from large storage reservoirs, (4) erosion of agricultural soils and subsequent deposition of fine-grained sediment on fall chinook spawning beds in the lower river, (5) false-attraction flows associated with agricultural-return flows, (6) degraded rearing habitat, including the lack of large organic debris, caused by prolonged, excessively high-flow augmentation for irrigation, (7) stream temperatures higher than 24 °C in the lower river, which constitute a partial thermal block for fish passage and decrease available habitat for native, cold-water species, (8) pesticide concentrations above safe, chronic-exposure levels for fish in the main stem and in the agricultural-return flows, and (9) degradation of riparian cover caused by grazing and agricultural activities. The relative importance of each of these factors has not been quantified.

The fewest resident fish are found in the Yakima River from Prosser (RM 47.4) to Mabton (RM 59.8). Within this reach, the current is slow, the water is warm and turbid from agricultural-return flow, and the streambed is composed of silt and clay.

A limited number (both temporally and spatially) of benthic invertebrate and phytoplankton samples indicate changes in habitat and water-quality conditions along the main stem of Yakima River. Benthic invertebrate communities reflect downstream increases in fine-grained-sediment deposition, stream turbidity, temperature, and organic-carbon concentrations from point and nonpoint sources. Phytoplankton samples indicate that algal blooms occurred annually in the Yakima River at Kiona from 1975-81 water years. The codominant algal genera are tolerant of pollution, commonly being associated with nutrient-enriched water.

Needs for Future Data Collection and Analysis

Future data-collection activities in the basin require close scrutiny of sampling, preservation, and analytical techniques to ensure that the data are representative of actual stream conditions. In addition, analytical procedures need to provide constituent reporting levels that are less than water-quality criteria and standards.

Water-quality issues that need to be addressed in future data-collection programs include: eutrophication (nutrients), erosion and deposition (suspended sediment and turbidity), sanitary quality (fecal indicator bacteria), toxic compounds (trace-organic compounds, trace elements, and radionuclides), habitat and contaminant effects on biological communities, high-water temperatures, and small dissolved-oxygen concentrations. Additional data are needed to describe spatial and temporal distributions as well as the sources of these contaminants in the aquatic environment.

INTRODUCTION

Background

Beginning in 1986, Congress appropriated funds for the U.S. Geological Survey (USGS) to test and refine concepts for the National Water-Quality Assessment (NAWQA) Program. The NAWQA Program is designed to address a wide range of water-quality issues that include chemical contamination, acidification, eutrophication, salinity, sedimentation, and sanitary quality. The long-term goals of the program are to:

1. provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources;

2. define long-term trends (or lack of trends) in water quality; and

3. identify, describe, and explain, as possible, the major factors that affect current conditions and trends in water quality.

This information will be provided to regulators, water managers, policy makers, and the public resulting in an improved scientific basis for evaluating the effectiveness of water-quality management programs and for predicting the likely effects of contemplated changes in land- and water-management practices.

The NAWQA Program is organized into study units on the basis of known hydrologic systems. For ground water, the study units are large parts of aquifers or aquifer systems, and for surface water the study units are major river basins. The study units are large, involving areas of a few thousand to several thousand square miles.

At present (1990), the assessment program is in a pilot phase. Seven study units--representing a diversity of hydrologic environments and water-quality conditions--were selected for the pilot program. The seven pilot project areas include four that focus primarily on surface water and three that focus primarily on ground water. The surface-water pilot project areas are the Yakima River basin in Washington; the lower Kansas River basin in Kansas and Nebraska; the Upper Illinois River basin in Illinois, Indiana, and Wisconsin; and the Kentucky River basin in Kentucky. The ground-water pilot project areas are the Carson Basin in western Nevada and eastern California; the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.

Purpose and Scope

A large amount of water-quality data have been collected in the United States by a diverse group of organizations for widely different purposes. One of the first activities to be undertaken in each pilot NAWQA project was to compile, screen, and interpret available water-quality data.

This report provides an initial assessment of water quality in the Yakima River basin, Washington (fig. 1). More specifically, the purpose of this report is to describe, to the extent possible:

(1) historical water-quality conditions in the Yakima River basin,

(2) long-term trends in water quality that have occurred over recent decades, and

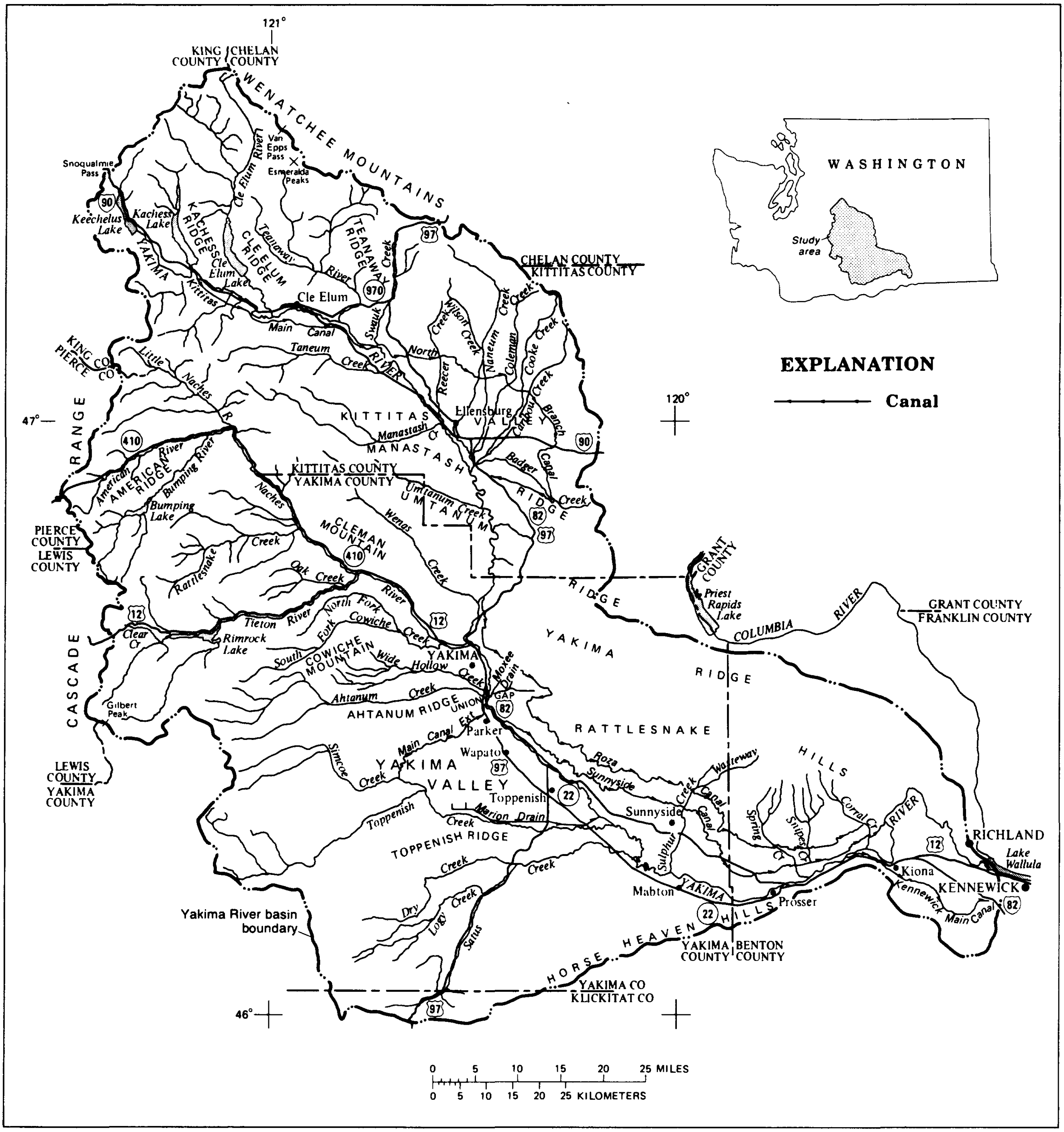

Figure 1.--Drainage and topographic features in the Yakima River basin in south-central Washington.

(3) relations of historical conditions and trends in water quality to natural and human factors.

The scope of this report includes (1) compilation of available water-quality data, (2) an assessment of water-quality conditions and trends, (3) a discussion of the utility of available water-quality data for assessment, and (4) needs for future-data collection and analysis.

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DESCRIPTION OF THE YAKIMA RIVER BASIN

The Yakima River basin is located in south-central Washington and encompasses all of Yakima and Kittitas Counties, except those northeast areas where small streams drain directly to the Columbia River, and the northern half of Benton County exclusive of the area that drains directly to the Columbia River (fig. 1). The Yakima River is more than 214 miles in length and has a total drainage area of 6,155 square miles (Columbia Basin Inter-agency Committee, 1964).

Physiography, Geology, and Topography

The Yakima River basin contains a diversity of landforms, including the high, glaciated peaks and deep valleys of the Cascade Range to the west, the broad river valleys to the south and east, and the lowlands of the Columbia Plateau to the east. The altitude of the basin ranges from 8,184 feet in the Cascade Range to about 340 feet at the Columbia River.

From the great north-south axis of the Cascade uplift, subordinate anticlines extend eastward. These anticlines form ridges that rise from 1,000 to 3,000 feet above the intervening valleys, the floors of which are not much more than 1,000 feet above sea level (fig. 1). In general, the ridges have undulating crests with smooth sides. The streams are located at low elevation in young valleys that are covered with bunch grass and sagebrush.

The basin is underlain by a great variety of consolidated rocks. Metamorphic, sedimentary, and intrusive- and extrusive-igneous rocks directly underlie the headwater areas in the Cascade Range. Basalt-lava flows and some interbedded and weakly consolidated sediment are predominant in the central and eastern parts of the basin. Unconsolidated valley-fill materials, composed of lacustrine deposits and alluvium, underlie the basin lowlands, and some eolian deposits occur locally along lower valley sides. Lava flows of Quaternary age occur in the headwater areas of the Toppenish Creek and Satus Creek subbasins (Swanson and others, 1979a; Molenaar, 1985; Pearson, 1985).

The basalt-lava flows and the valley-fill deposits are important aquifers in the study area. Individual lava flows range from a few feet to more than 100 feet thick. The total thickness of the basalt series is probably greater than 10,000 feet in the central part of the Plateau (Swanson and others, 1979b). Deformation of the basalt and the Ellensburg Formation has resulted in several structural features that are reflected in the landforms, particularly those in the lower part of the basin. Compressional folding of the upper basalt layers has formed the Kittitas Valley and several northwest-to-southeast trending anticlinal ridges (Pearson, 1985).

Glaciation caused deep erosion in the mountains and deposition of the disaggregated rock material in the lower valleys of the study area. Cutting by alpine glaciers produced sharp peaks and ridges with steep-walled cirques and valleys along the Cascade crest. The eroded material then was carried by valley glaciers and deposited in valley bottoms (Pearson, 1985).

Present-day geologic changes in the area include the slow but continuing erosion of the mountains by streams and small glaciers with associated deposition of the eroded materials along stream channels and in the flood plains and lowland lakes. The 1980 eruption of the Mount St. Helens volcano, in the Cascade Range to the west, deposited ash over large parts of the study area (Molenaar, 1985). This deposition provides a source of easily erodible material.

In the valley bottoms of the central-western part of the basin, soils have developed principally from unconsolidated, glacially deposited material (Pearson, 1985). Types and characteristics of the soils in Kittitas County are described by Sibley and Krashevski (1957); similar studies were made in Yakima County by Maytin and Starr (1960) and in Benton County by Rasmussen (1971). Moen (1978) has given locations of rock types in the basin, showing andesites, basalts, and metamorphic rocks such as greenschist, phyllite, and slate in the Cle Elum and Teanaway River basins and in Swauk Creek basin near Cle Elum; and andesites and basalts in the American, Bumping, and Tieton River basins. Trace-element enrichments identified within the Yakima Basin in the Cascade Range prior to the 1980 eruption of Mount St. Helens include chromium, copper, gold, iron, lead, mercury, molybdenum, nickel, silver, and zinc.

There are about 1,900 miles of perennial streams in the Yakima River basin mapped at the 1:250,000 scale by the USGS. The Yakima River begins from the eastern slope of the Cascade Range at Keechelus Lake in the Upper Kittitas Valley and flows southeasterly through the lower plateau and river-bottom lands to the Columbia River. Keechelus Lake at Yakima river mile (RM) 214.5 is a glaciated lake that was enlarged and is operated as a reservoir. The headwaters of the lake and other tributaries flow from glaciers and snowfields near the 5,000- to 7,000-foot crest of the Cascade Range. The Yakima River also receives flow augmentation during irrigation season from Kachess and Cle Elum Lakes, which are operated as reservoirs and flow into the Yakima River at RM 203.5 and 185.6, respectively.

After the Yakima River flows from Kittitas Valley through 25 miles of canyon, it flows into an area that receives drainage from streams in (downstream order) the Wenas Valley and Selah area, Naches Valley, Moxee area, and Ahtanum Valley (pl. 1 and fig. 1). The Naches River, a major tributary with 1,106 mi^2 (square miles) of drainage area, flows into the Yakima River at RM 116.3. The Naches River receives flow augmentation during the summer from Rimrock Lake and Bumping Lake. The river flows through a gap in the basalt ridges at Union Gap. The lower Yakima River receives flow from several streams and drains that often are augmented with agricultural-return flow (Sylvester and Seabloom, 1962; CH2M Hill, 1977; Molenaar, 1985; and Pearson, 1985).

Land Use and Population

Major land-use activities in the basin include growing and harvesting timber, dryland pasture grazing, intense farming and irrigated agriculture, and urbanization.

In the headwater streams, timber harvesting may be affecting water quality, because removal of trees along streams might be increasing peak runoff and resulting in (1) destabilization of stream channels, (2) increased sediment erosion and sedimentation, and (3) modification of available fish habitat (Greg Watson, Washington State Department of Fisheries, written commun., November 1989). Even though the areas covered by irrigated agriculture (approximately 1,000 mi^2) and urbanization (50 mi^2) are smaller than areas of forest (2,200 mi^2) or grazing (2,900 mi^2), the intensity of the activities makes agriculture and urbanization of primary importance with respect to water-quality effects. Dominant crops (making up 76 percent of the irrigated area) are irrigated pasture, apples, wheat, alfalfa, hops, dry corn, grapes, and hay (table 1).

Table 1.--Acreage of crops in selected irrigation projects in the Yakima River basin, Washington, 1984

[Data source is Bureau of Reclamation, written commun., 1986]

	Kittitas District	Roza District	Yakima-Tieton District	Wapato District	Sunny-side District	Kenne-wick District	Special and Warren Act contracts	Total
Barley	1,190	451	15	2,254	229	50	100	4,289
Corn, dry	53	4,065	--	14,804	1,908	60	205	21,095
Oats	1,171	--	--	97	40	65	140	1,513
Wheat	5,620	3,847	10	20,592	3,431	1,260	3,080	37,840
Other	8	161	0	0	0	0	28	197
Total cereals	8,042	8,524	25	37,747	5,608	1,435	3,553	64,934
Alfalfa	6,354	3,866	888	9,632	7,343	2,390	4,160	34,633
Other hay	11,628	75	0	2,411	180	260	4,049	18,603
Irrigated pasture	24,637	3,874	2,096	14,258	16,597	1,220	8,823	71,505
Silage	232	3,207	0	1,800	5,304	22	280	10,845
Other	95	0	0	0	0	0	100	195
Total forage	42,946	11,022	2,984	28,101	29,424	3,892	17,412	135,781
Beans	0	664	0	1,637	134	0	0	2,435
Hops	0	6,583	0	8,167	5,936	0	2,464	23,150
Peppermint	0	1,366	0	8,215	71	0	0	9,652
Spearmint	0	2,610	0	2,300	2,292	0	0	7,202
Total field crops	0	11,223	0	20,319	8,433	0	2,464	42,439
Asparagus	0	2,341	0	4,206	5,871	93	0	12,511
Sweet corn	500	784	0	7,954	432	0	1,620	11,290
Melons	0	0	0	242	16	0	0	258
Peas	0	0	0	0	72	0	0	72
Potatoes	500	1,280	0	1,157	57	0	0	2,994
Squash	0	0	0	320	106	0	0	426
Tomatoes	0	22	0	372	10	0	0	404
Other vegetables	0	225	0	226	181	0	0	632
Total vegetables	1,000	4,652	0	14,477	6,745	93	1,620	28,587
Apples	400	13,836	18,306	7,387	2,997	980	7,844	51,750
Apricots	0	163	0	67	158	17	77	482
Cherries	0	2,571	230	518	2,602	580	895	7,396
Grapes	0	8,525	0	2,966	8,477	45	324	20,337
Peaches	0	457	0	803	238	150	590	2,238
Pears	150	1,828	1,761	1,160	1,287	82	2,692	8,960
Prunes & plums	0	450	0	364	718	230	125	1,887
Other	0	152	0	765	43	30	30	1,020
Total fruits	550	27,982	20,297	14,030	16,520	2,114	12,577	94,070
Seeds	85	100	0	72	0	5	0	262
Nursery	0	783	0	65	143	25	62	1,078
Family gardens	20	43	0	336	179	560	744	1,882
Total seeds, nursery, and gardening	105	926	0	473	322	590	806	3,222
TOTAL CROPS	52,643	64,329	23,306	115,147	67,052	8,124	38,432	369,033

Over the last century, the population in the Yakima River basin has increased from fewer than 100,000 people in 1910 to more than 300,000 in 1980 (Onni Perala, U.S. Bureau of Reclamation, Yakima, Washington, written commun., April 1990). The Washington Office of Financial Management (1984) lists the 1983 populations of each county--incorporated (urban) and unincorporated (rural)--as follows: Kittitas--15,730 and 9,170; Yakima--88,800 and 88,200; and Benton--77,600 and 31,100. The 1983 and 1989 populations of the larger towns in the Yakima River basin are listed in table 2.

Table 2.--Population estimates for selected towns in the Yakima River basin, Washington, 1983 and 1989

[Data collected by the Washington State Office of Financial Management and Forecasting Division]

Town	Population 1983	Population 1989
Yakima	48,500	50,610
Kennewick	35,700	36,880
Richland	32,000	29,970
Ellensburg	11,550	11,730
Sunnyside	9,450	9,730
Toppenish	6,575	6,600
Grandview	6,300	6,350
Selah	4,520	4,980
Prosser	4,150	4,010
West Richland	3,864	3,650
Wapato	3,310	3,370
Union Gap	3,120	3,230
Benton City	1,880	1,815
Granger	1,810	1,825
Cle Elum	1,775	1,760
Zillah	1,685	1,835
Mabton	1,234	1,245

Agricultural practices have changed and continue to change slowly from row crops to hay in the Kittitas Valley and from row crops to permanent crops (such as grapes, apples, and pears) in the lower Yakima Valley. These changes have affected the quantity of water needed for irrigation, the methods of applying irrigation water, and the quality of the water draining from fields and returning to the Yakima River (Ron Van Gundy, Manager, Roza Irrigation District, oral commun., July 1986). Cultivation and irrigation practices associated with permanent crops and hay result in less soil erosion than those practices associated with row crops.

Industrial activities related to agriculture include the packing and processing of fruits, vegetables, hops, meat, and other farm products. About 23,000 dairy cattle in 70 dairies near Sunnyside and Granger and 50,000 beef cattle in eight feedlots between Ellensburg and Prosser are important to the Yakima Valley economy (Washington Department of Ecology, written commun., 1988).

Climate

The climate of the Yakima River basin ranges from maritime along the crest of the Cascade Range to arid in the lower valleys. The mountainous western and northern parts of the basin receive precipitation principally as snow during the period November to March and as rain during the remainder of the year. Much of the snowfall in the mountains is retained through the winter; some is retained for longer periods in the perennial snowfields and glaciers at higher altitudes (Pearson, 1985). Chinook winds (warm air descending the eastern slopes of the Cascade Range) and rain-on-snow events occasionally cause rapid melting of the snowpack. At times, these events result in severe erosion of soils and flooding along lowland stream channels.

Precipitation varies considerably across the basin throughout the year. Mean-annual precipitation ranges from about 140 inches in the higher mountains of the northwestern part of the basin to less than 10 inches in the Kennewick area (U.S. Weather Bureau, 1965). Mean-monthly precipitation data at four sites in the basin for 1951-80 (30 years) are shown in figure 2. The amount of precipitation that occurs during the October-to-March period, in both the arid and maritime parts of the basin, ranges from 61 to 81 percent of the annual precipitation. The variation in annual precipitation can be large (fig. 3). The geographic variability in mean-annual precipitation for the Yakima River basin, 1951-80 is shown in figure 4.

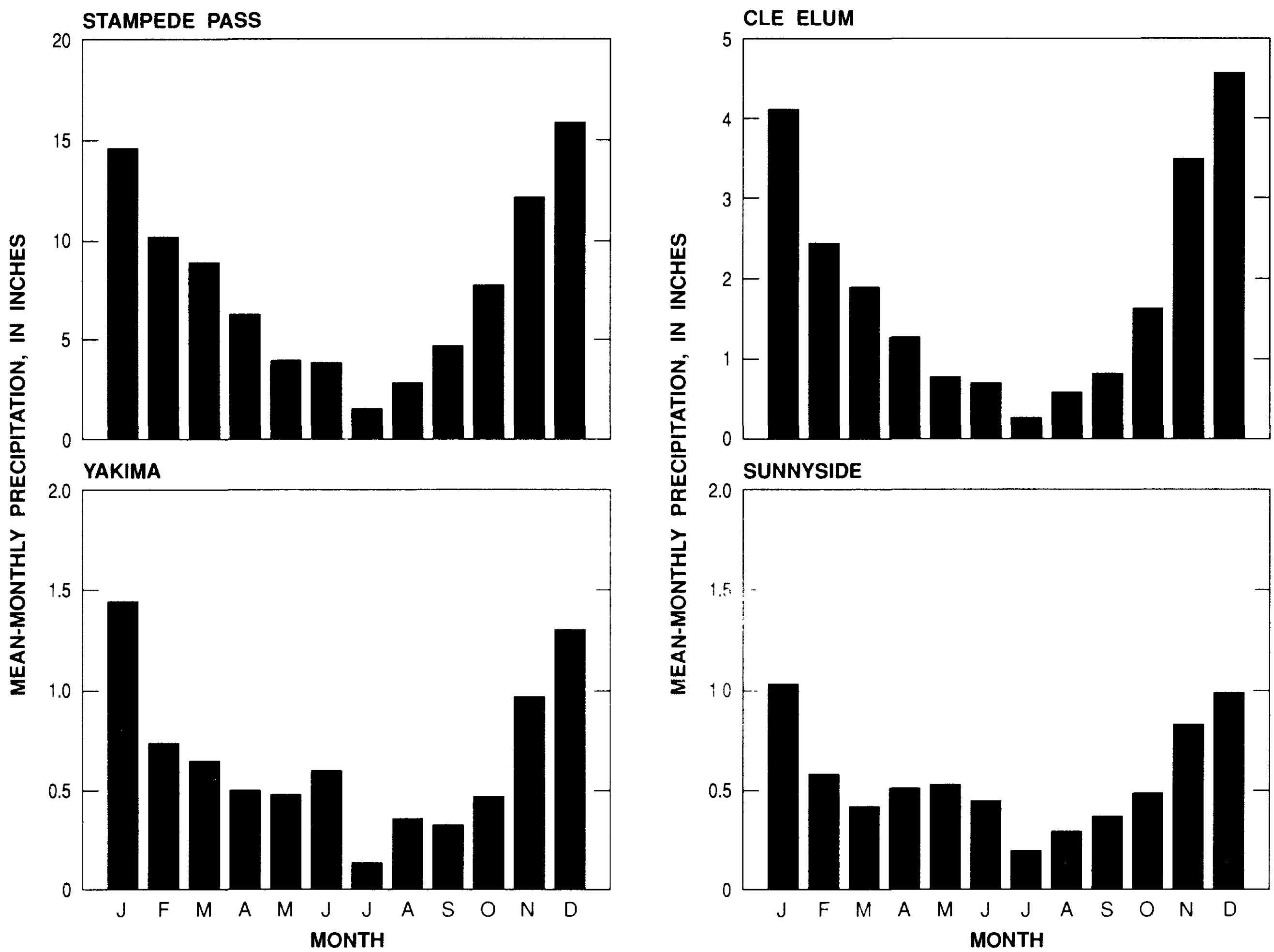


Figure 2.--Mean-monthly precipitation at Stampede Pass, Cle Elum, Yakima, and Sunnyside in the Yakima River basin, Washington, 1951-80 (National Oceanic and Atmospheric Administration, 1982).

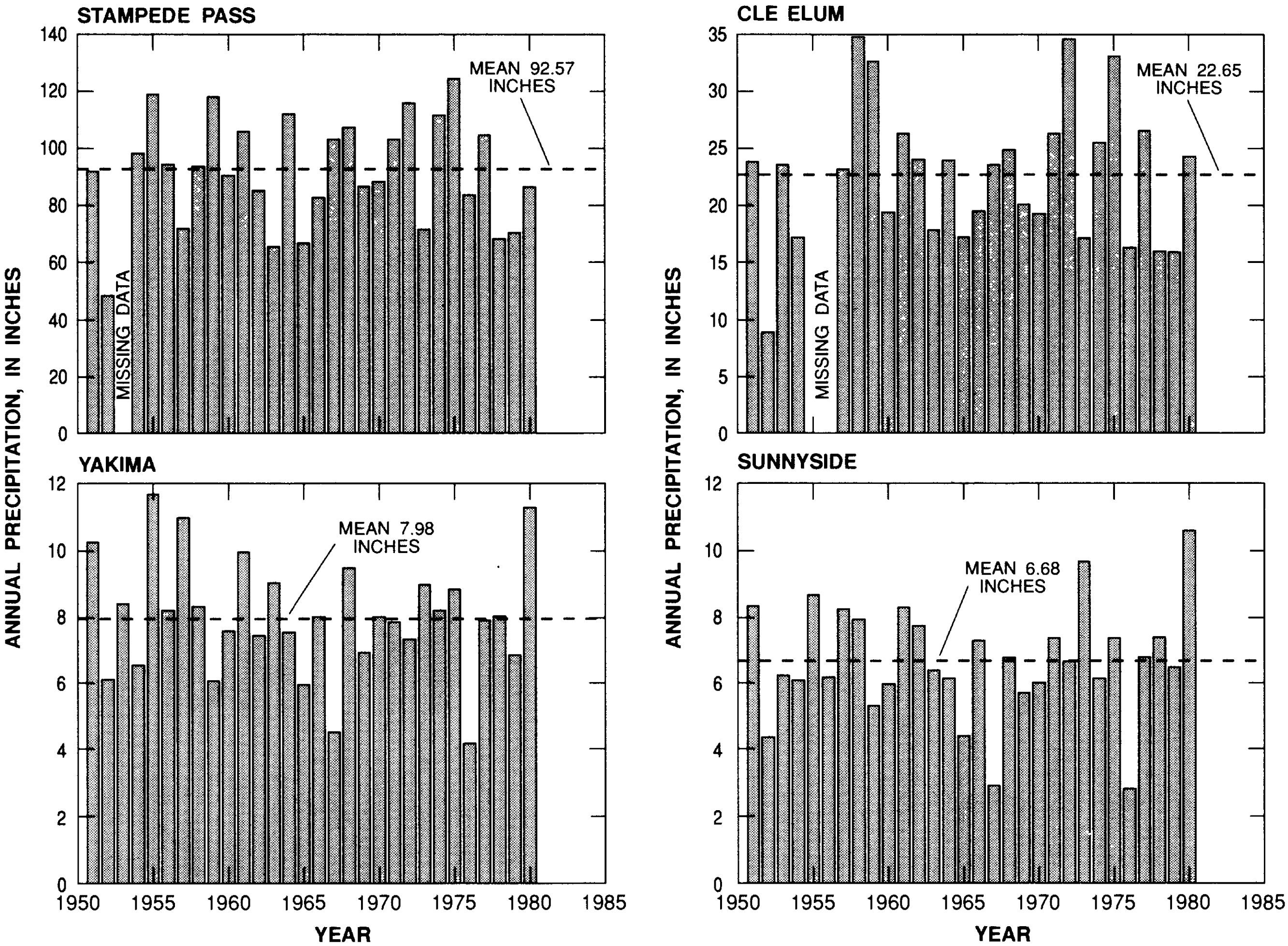


Figure 3.--Annual and mean-annual precipitation at Stampede Pass, Cle Elum, Yakima, and Sunnyside in the Yakima River basin, Washington, 1951-80 (National Oceanic and Atmospheric Administration, 1982).

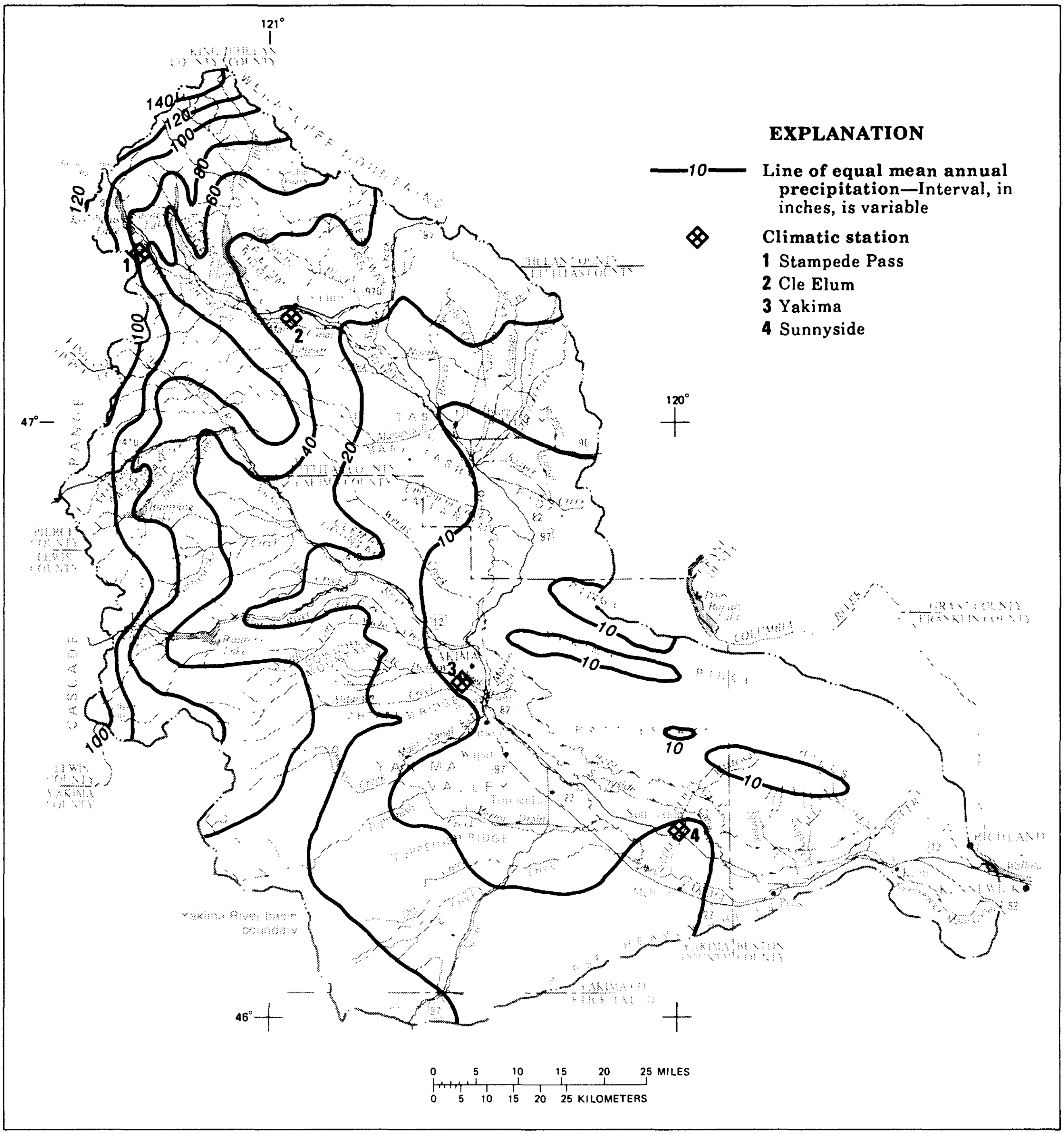


Figure 4.--Mean-annual precipitation in the Yakima River basin, Washington, 1951-80 (National Oceanic and Atmospheric Administration, 1982).

Air temperatures in the basin generally are inversely related to altitude. Maximum and minimum mean-monthly temperatures occur in July and in January, respectively. Mean-monthly temperatures ranged from 24 to 63 degrees Fahrenheit at Lake Kachess (about 2,300 feet in altitude) and 31 to 77 at Kennewick (about 350 feet in altitude; McKenzie and Rinella, 1987).

Surface-water Hydrology

The Yakima River and its major tributary, the Naches River, have perennial streamflow as a result of ground-water inflow, and summertime melting of snowfields and glaciers in the Cascade Range. The relative positions of selected streams, canals, and return flows in the Yakima River basin are shown in figure 5. Several snow courses in the basin are measured annually for water content of the snowpack to predict annual runoff (U.S. Department of Agriculture, 1986). Annual runoff ranges from 100 inches per year in the Cascade Range to less than 0.2 inches per year on the valley floor downstream from the City of Yakima (fig. 6).

The discharge of streams fed by snowmelt declines during the November-January period, when air temperatures are low and melting is minimal. As temperatures increase from February through June, the snowmelt gradually increases stream discharges. Peak snowmelt and runoff of streams draining the eastern slope of the Cascade Range generally occur concurrently in May and June. By July, most of the snow has melted and rainfall has decreased; a subsequent decrease in streamflow occurs through September.

Reservoirs are used to (1) augment summer flows for irrigation, (2) augment fall and winter flows for instream habitat (to maintain flow over spawning areas), and (3) reduce flooding during winter storms and spring snowmelt. Reservoir releases provide most of the water used for irrigation during the July-October period, when natural streamflows are minimal and irrigation of agricultural crops cause maximum demand for water.

Mean-annual flows and mean-monthly flows from 1951-80 at four gaging sites in the Yakima River basin are shown in figures 7 and 8. Mean-annual flows in the Yakima River at Cle Elum (RM 183.1) and in the American River near Nile (RM 0.5) are less variable than flows in the Yakima River near Parker (RM 103.7). This difference in streamflow variability results from the operation of the large canal diversions for irrigation just upstream from Parker. Seasonal variability at these sites is quite different. Runoff at the American River site near Nile is high from snowmelt in May and June; the seasonal variation in runoff at this site occurs because the streamflow is not reservoir controlled. The streamflow in the Yakima River at Cle Elum is affected by three, large, upstream reservoirs and Kittitas canal at Yakima RM 202.5. These upstream effects include minimal flows from October to March due to maximum reservoir storage and large flows from April to September due to the reservoir releases for irrigation. Streamflows for the Yakima River near Parker (RM 103.7) and at Kiona (RM 29.9) are similar, with low flows occurring July to September after snowmelt and during the irrigation season; the streamflows also are high from December through March at both sites because of rainfall runoff at the lower altitudes in the basin.

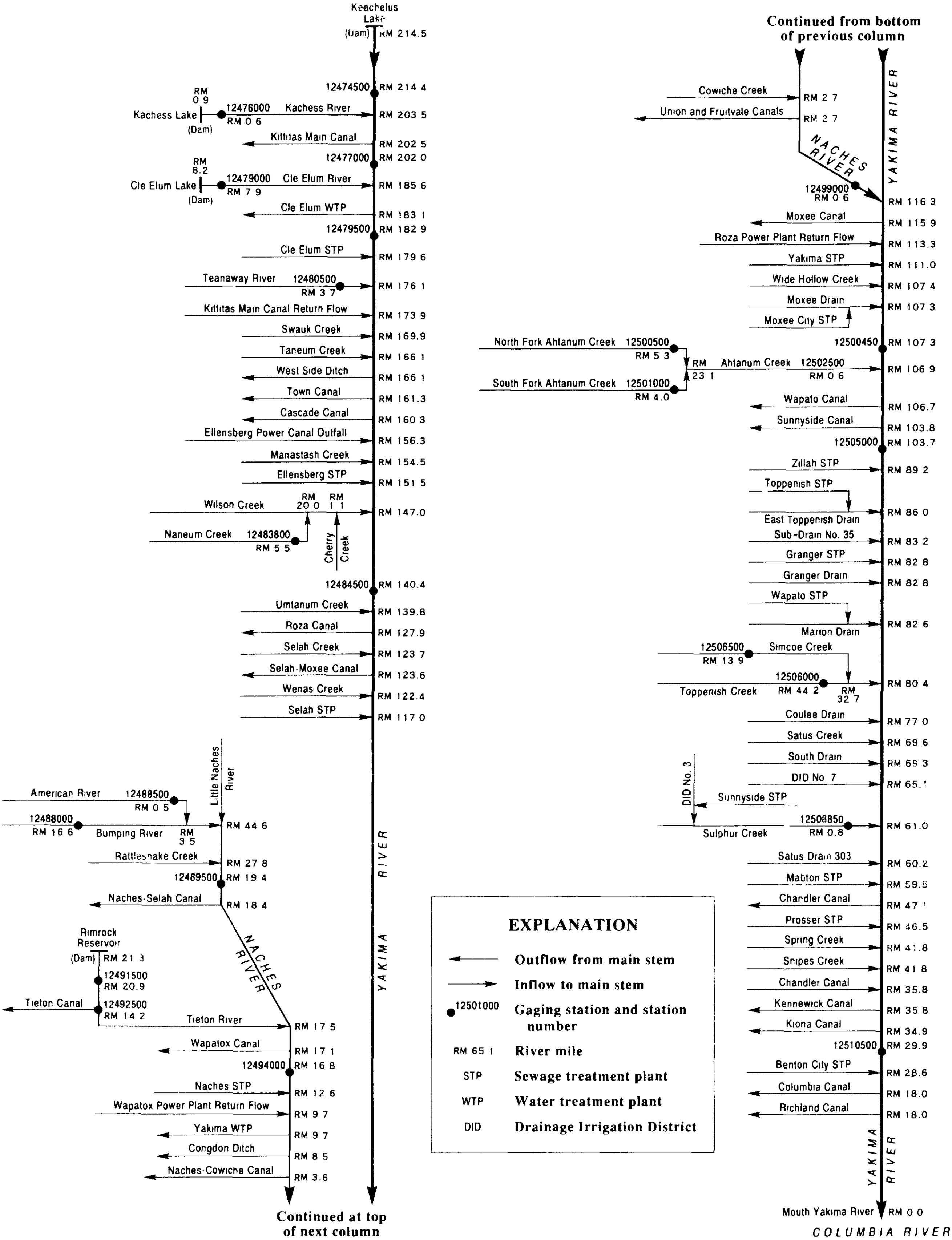


Figure 5.--Schematic diagram showing relative positions of selected tributaries, diversion canals, return flows, and stream-gaging stations in the Yakima River basin, Washington (see table 3 for names and streamflow characteristics of selected gaging stations).

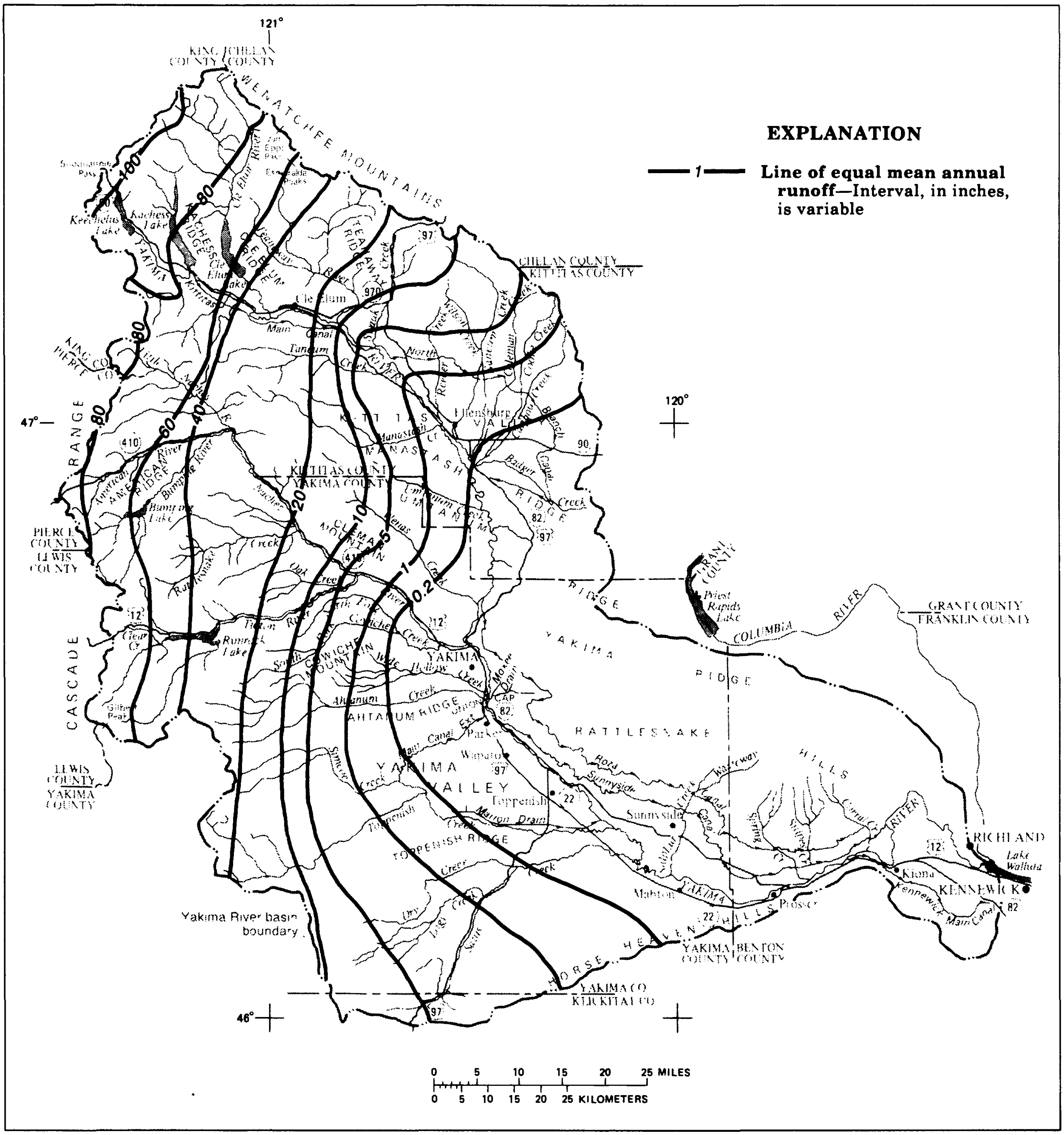


Figure 6.--Mean-annual runoff in the Yakima River basin, Washington, 1951-80 water years (Gebert and others, 1987).

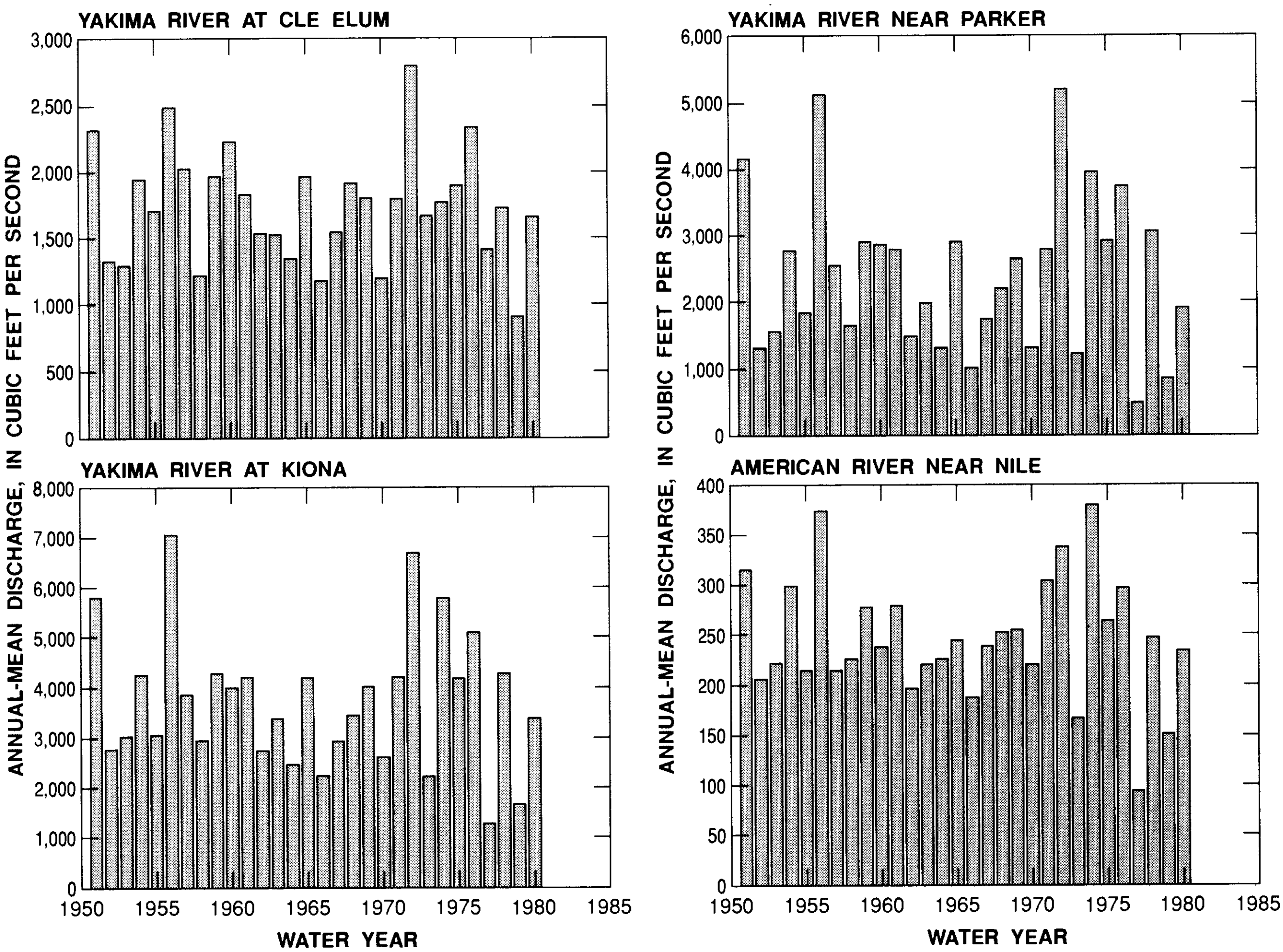


Figure 7.--Annual-mean discharge in the Yakima River at Cle Elum, near Parker, at Kiona, and American River near Nile in the Yakima River basin, Washington, 1951-80 water years.

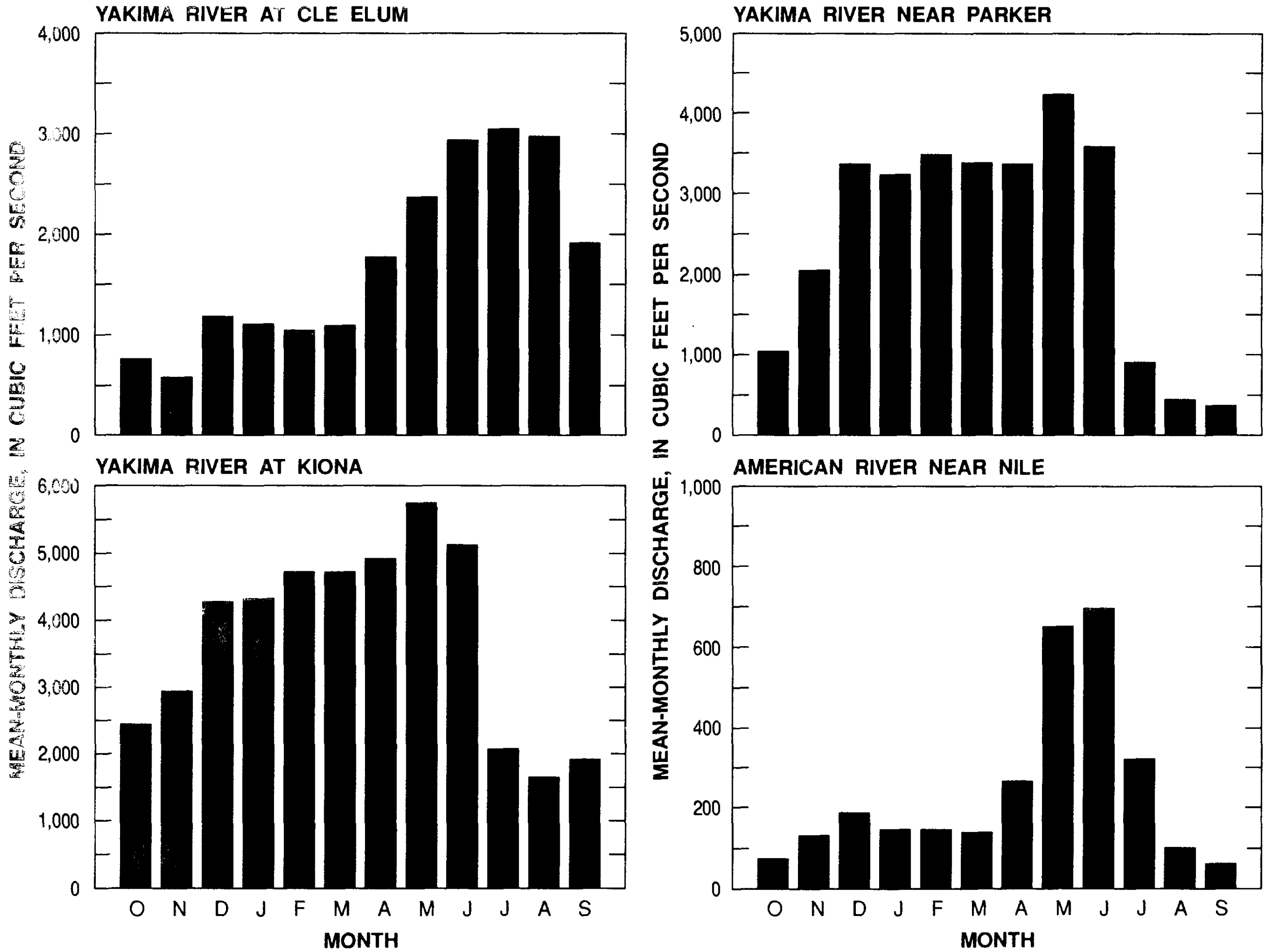


Figure 8.--Mean-monthly discharge in the Yakima River at Cle Elum, near Parker, at Kiona, and American River near Nile in the Yakima River basin, Washington, 1951-80 water years.

Streamflow statistics for selected gaging sites with at least 10 years of record through the 1979 water year (WY) are presented in table 3 (Williams and Pearson, 1985). Most of the extreme low flows were measured early in the period of record, before all the reservoirs were operational and before State regulations were established to provide minimum flows for fish.

The index of variability is the ratio of the difference of the 10- and 90-percent exceedance frequencies (daily mean discharge) to the streamflow at the 50-percent exceedance frequency (table 3). This index provides a measure of the stream variability that occurs 80 percent of the time. Smaller index values indicate less variability in annual streamflow. Differences in streamflow variability are related to (1) subbasin altitude, (2) precipitation patterns, (3) snowmelt patterns, and (4) the large use of water for irrigation. The effect of irrigation diversions is shown clearly by examination of the indices for the Yakima River above Ahtanum Creek at Union Gap (at RM 107.2 where the index equals 2.20) and near Parker (at RM 103.7 where the index equals 4.22).

Table 3.--Streamflow characteristics at selected gaging sites in the Yakima River basin, Washington, 1899-1979 water years

[Exceedance frequency is the percentage of time that indicated streamflow is equaled or exceeded; index of variability is the ratio of the difference of streamflows at the 10- and 90-percent exceedance frequencies to the streamflow at the 50-percent exceedance frequency; "--" indicates no data; locations shown in figure 5]

Site number	Site name (abbrev.)	Period of record	Drainage area, in square miles	Mean annual flow, in cubic feet per second	7-day, 10-year low flow, in cubic feet per second	Streamflow, in cubic feet per second Exceedance frequency for daily mean discharge, in percent: 90	50 (median)	10	Index of variability
12474500	Yakima River near Martin	1904-78	54.7	336	0.6	2.5	190	890	4.67
12476000	Kachess River near Easton	1904-78	63.6	292	.5	.9	140	840	5.99
12477000	Yakima River near Easton	1910-15 1941-55	188	592	28	95	440	1,300	2.74
12479000	Cle Elum River near Rosyln	1904-78	203	933	1.5	26	540	2,500	4.58
12479500	Yakima River at Cle Elum	1907-78	495	1,780	104	300	1,400	3,600	2.36
12480500	Teanaway River near Cle Elum	1909-14 1947-52	200	377	3.5	17	160	1,100	6.77
12483800	Naneum Creek near Ellensburg	1957-78	69.5	57	8.2	15	27	153	5 11
12484500	Yakima River at Umtanum	1909-79	1,594	2,470	325	600	2,100	4,800	2.00
12488000	Bumping River near Nile	1909-78	70.7	295	2.2	41	210	660	2.95
12488500	American River near Nile	1940-79	78.9	240	30.6	51	120	610	4.66
12489500	Naches River at Oak Flat near Nile	1905-17	641	1,172	164	260	640	2,900	4.13
12491500	Tieton River at Tieton Dam near Naches	1925-78	187	509	2.4	8.4	330	1,300	3.91
12492500	Tieton River at Canal Headworks near Naches	1926-78	239	473	4.3	27	290	1,000	3.36
12494000	Naches River below Tieton River near Naches	1909-13 1915-79	941	1,260	9.6	84	750	3,200	4.15
12499000	Naches River near North Yakima	1899-1913	1,106	822	75.4	250	1,000	4,300	4.05
12500450	Yakima River above Ahtanum Creek at Union Gap	1968-79	3,479	2,290	553	1,200	3,000	7,800	2.20
12500500	North Fork Ahtanum Creek near Tampico	1910-78	68.9	70	8.1	15	34	180	4.85
12501000	South Fork Ahtanum Creek near Tampico	1915 1917-24 1931-78	24.8	20	3.6	5.5	11	48	3.86
12502500	Ahtanum Creek at Union Gap	1904-05 1912-14 1951-53 1960-79	173	82	7.3	15	44	200	4.20
12505000	Yakima River near Parker	1908-78	3,660	2,530	8.3	170	1,500	6,500	4.22
12506000	Toppenish Creek near Fort Simcoe	1909-23	122	98	4.1	13	35	280	7.63
12506500	Simcoe Creek below Spring Creek near Fort Simcoe	1909-23	81.5	29	.1	.6	6.1	84	13.7
12510500	Yakima River at Kiona	1906-15 1933-79	5,615	3,660	441	1,300	2,500	7,900	2.64

Between these two sites, Wapato and Sunnyside Canals divert large volumes of streamflow during irrigation season. These diversions result in extremely small flows in the Yakima River near Parker as evidenced by the 7-day, 10-year flows decreasing from 553 ft^3/s (cubic feet per second) at Union Gap to 8.3 ft^3/s near Parker (note that part of this difference is due to the comparison of site statistics during different time periods). The extreme low flow in the Yakima River near Parker makes this downstream reach vulnerable to contaminant enrichment from small point- and nonpoint source loadings. The 7-day, 10-year flow at Kiona (RM 29.9) increases to 441 ft^3/s partially as a result of contributions from agricultural runoff.

To further examine the impacts of irrigation on streamflow in the main stem of the Yakima River, observed and simulated mean-daily streamflows are shown in table 4 for July, August, and September 1981. Estimates for the simulated flows assume no reservoir storage and no diversions--representing natural conditions. Because of flow augmentation for irrigation diversions, the observed mean-daily streamflows upstream from Union Gap in the main stem are 171 to 446 percent of the simulated flows. However, near Parker (RM 103.7) and near Prosser (RM 46.3), the observed flows are only 15 to 40 percent of the simulated flows because of large upstream irrigation diversions.

Table 4.--Observed and simulated mean-daily streamflows for selected months during 1981 irrigation season for the Yakima River, Washington (Vacarro, 1986)

[Streamflows in cubic feet per second, RM - river mile]

Yakima River Site	Observed monthly streamflows			Simulated streamflows 1/		
	July	August	September	July	August	September
Umtanum (RM 140.4)	4,273	4,207	1,877	1,533	943	1,100
Union Gap (RM 2/ 106)	3,347	3,226	2,952	1,948	838	1,410
Near Parker (RM 103.7)	475	357	406	2,068	888	1,450
Near Prosser (RM 46.3)	370	297	634	2,406	1,288	1,990
Kiona (RM 29.9)	1,488	1,391	1,894	2,556	1,345	2,060

1/ Assuming no reservoir storage and no diversions--natural conditions.
2/ Yakima River at Union Gap downstream from Ahtanum Creek.

Water Use

Water-Resource Development

By Onni J. Perala, U.S. Bureau of Reclamation

Water-resources development in the Yakima River basin grew from local uses in the mid-1800's to its current status of national prominence. The timeline, shown in table 5, documents major administrative decisions, institutional influences, and water-development measures that affect the management and regulation of water resources (quantity and quality) in the basin. The types and quantities of water use in the Yakima River basin have changed since the mid-1850's when events were first recorded. Presently (1990), primary water uses are for hydroelectric power, irrigation, public water supply, and maintaining minimum flows for fishery.

The beginning: 1850-1900

At the time of the Lewis and Clark expedition, the Yakima Valley was inhabited by isolated Indian tribes. The Indians were food gatherers and fisherman, primarily consuming fish, roots, and berries. Many of the names given to geographic features (rivers, lakes, and specific locations) in the basin are derived from the early Indian culture; for instance, Naches means "plenty of water"; Selah, "smooth water"; Cle Elum, "swift water"; Tieton, "roaring water"; Ahtanum, "stream by long mountain"; and Kennewick, "grassy place."

White settlement began in the 1850's when Ben Snipes arrived in the valley. He found grass "tall enough to reach the belly of his horse," and he selected the area for raising cattle.

Table 5.--Timeline listing major administrative influences and water-resource developments in the Yakima River basin, Washington, 1855-1985

Administrative influences	Calendar year	Water-resource development
United States Treaty with Yakima Nation	1855	
Irrigation at Ahtanum Mission	1864	
	1872	Start of Ellensburg Water Company, Snipes and Allen Ditch, and Manastash Ditch Company
	1878	Start of Konewock Ditch Company
Washington becomes a State	1879	
	1880	Start of Fowler Ditch Company, Union Gap Irrigation District, Naches Cowiche Canal Company, Piety Flat Ditch Company, and Taneum Canal Company
	1884	Northern Pacific Railroad service to Yakima Valley
	1885	Start of Selah, Moxee, and Terrace Heights Irrigation Districts
	1888	First train through Stampede Pass Tunnel
	1889	Start of Naches-Selah and Westside Irrigation Districts and Gleed and Moxee Ditch Companies
	1891	Sunnyside Division Dam completed
	1894	Start of Yakima Valley Canal Company
Reclamation Act	1902	
	1903	Log crib dam at Kachess Lake
	1904	Start of Cascade Canal Company
United States filing for water project	1905	Prosser Diversion Dam completed
Limiting agreements signed	1906	Tieton Diversion Dam and Distribution System, and log crib dam st Cle Elum Lake constructed
	1910	Bumping Lake Dam constructed
	1912	Kachess Dam constructed
	1914	Clear Creek Dam constructed
Washington State adopts water code	1917	Keechelus Dam constructed
	1925	Tieton Dam constructed
	1929	Easton Diversion Dam constructed, and start of fish ladders and screens on major diversions
	1930	First water to Kittitas Reclamation District
	1933	Cle Elum Dam constructed
	1939	Roza Diversion Dam constructed
	1941	First water to Roza Division
Consent Decree--Civil Act. #21	1945	
Washington State Groundwater Code	1948	Vanport Flood Disaster--start of Columbia River System forecasts and flood control
	1956	Kennewick Irrigation District construction, and Chandler Power/Pump Plant
	1959	Roza Power Plant on line and first water to Kennewick Irrigation District
National Environmental Policy Act	1969	
Clean Water Act; Boldt I Decision	1974	
State starts Yakima River Adjudication	1977	
Boldt II Decision Yakima River basin	1978	
Enhancement Act	1979	
Northwest Power Planning and Conservation Act (NWPPC); Quakenbush Decision	1980	
Start flip-flop operation--water from Yakima reservoirs for early irrigation and from Naches reservoirs for late season	1981	
NWPPC Fish/Wildlife Program	1982	
	1984	Phase I Ladders and Screens Projects
	1985	Start screening and laddering construction period, 1984-89

One of the earliest events that shaped this basin's history was a treaty between the Yakima Indian Nation (14 confederated bands) and the United States in 1855, which established the Yakima Indian Reservation, more than 1 million acres of land in the southwest part of the basin.

In the 1860's, Catholic priests at the Ahtanum Mission in the central part of the basin started small-scale irrigation to grow their own food supply. Twenty years later, irrigation development began in earnest in the Yakima River basin; July, August, and September of each year were periods of limited water supplies. The first canals were built primarily alongside the river systems. In 1891, the Washington Irrigation Company--the largest development for that time--started diverting at Sunnyside Diversion Dam (Yakima RM 103.8).

Organized development: 1900-20

In 1902, when the Reclamation Act was passed, an agency called the Reclamation Service began developing water resources in the West. Early Yakima Valley settlers recognized that winter and spring runoff could be stored and used for irrigation development. They petitioned the Secretary of Interior to direct the Reclamation Service to initiate studies in the Yakima River basin to develop storage.

By 1902, about 121,000 acres were under irrigation in the Yakima River basin, about 25 percent of the present (1990) irrigation development. This acreage was served from natural flows in the Yakima River and tributaries, with none of the present large storage reservoirs yet in existence. However, natural runoff was inadequate to insure a dependable water supply for development, even at the turn of the century (CH2M Hill, 1977).

In the meantime, the irrigation districts understood the advantages of storage. The Cascade Irrigation District built a small log-crib dam to raise the outlet of Kachess Lake, and the Union Gap Irrigation District built a small log-crib dam to raise the outlet of Cle Elum Lake. Both dams were constructed a long distance upstream from their respective points of diversion, which was an ambitious effort for this time period. These small dams resulted in a relatively large quantity of storage, because both Kachess and Cle Elum Lakes were old glacial lakes with large surface areas.

In 1905, the United States filed for withdrawal of the unclaimed water in the basin. In order for the Federal government to develop water projects in the basin, they needed to adhere to State laws and honor all existing water rights. Consequently, the need for quantification of existing water diversions of natural runoff by private irrigation developments led to the limiting agreements of 1906. The Federal government decided that if the developers would agree to limit their maximum diversion to the quantity of water diverted in August 1905, the Government would use the remaining water to develop storage and open new land for irrigation.

Following the limiting agreements of 1906, the Sunnyside and the Tieton were two of the earliest irrigation-development divisions. The Sunnyside Division was an enlargement of the development started by the Washington Irrigation Company. Also, at that time, Bumping Lake was the first reservoir constructed. Bumping Lake was built, so that prior users diverting water from the Naches River would have assurance of a water supply and would suffer no diminution with the development of the Yakima-Tieton Irrigation District. Kachess Dam was built in 1912, Clear Lake in 1914, and Keechelus in 1917.

Largest and latest storage developed: 1920-40

After Keechelus Lake was built, water development became of secondary importance because the United States was involved in World War I. Immediately after the war, construction restarted; and Tieton Dam, which forms Rimrock Lake, was finished in 1925. Shortly after that, the Easton Diversion Dam was completed, along with the main canal and the distribution system for the Kittitas Reclamation District. The first water was delivered in the Kittitas Reclamation District in 1930. About this time, problems with fishery passage were noted at the Easton diversion facilities. Thus, the first efforts of fish-protective facilities began by constructing ladders and screens on the diversion dams. Sunnyside and Wapato Diversion Dams were laddered in 1929 and 1930. In 1933, Cle Elum Lake, the largest reservoir in the system, was completed. It was the last major storage reservoir built in the basin (as of 1990).

The Roza Division started with construction of Roza Diversion Dam in 1939, and the Roza Canal distribution system (located on the uphill side of the Sunnyside Division). The Roza Power Plant, located in Terrace Heights east of the City of Yakima, provides power to the 18 plants that pump water to the high side of Roza Canal. Residual power is provided to the Bonneville Power Administration network. Lands receiving the pumped water account for three-eighths of the irrigable land in the division.

In addition to Reclamation-irrigation projects, the Wapato Irrigation Project was developed and constructed by the Bureau of Indian Affairs from 1896 to 1930. This irrigation district is the largest in the basin, accounting for about one-third of the valley's irrigated land and one-third of the valley's water use.

Multiple-use management: 1940-70

The last irrigation project development occurred in the late 1950's when the Reclamation Service built the Kennewick Division and the pumping plant and powerplant at Chandler. The powerplant generates 12,000 kw (kilowatts) and the pumping plant transports water to the Kennewick Division. As water use developed, competition for managed water arose among the irrigation divisions in the basin, and a need developed to establish priority rights for the available water supply. Water distribution had been based on water rights and limiting agreements. Early users had agreed to operate within each year's designated water supply in a manner that would avoid disputes. Disputes arose, however, and led to legal filings that firmly quantified water rights.

In 1945, the District Court of Eastern Washington issued a decree under Civil Action 21, called the 1945 Consent Decree. The Consent Decree established the rules under which the Bureau of Reclamation should operate the Yakima system to meet the needs of the irrigation districts that predated the Reclamation storage project, as well as divisions that the Reclamation Service had developed.

In 1948, the Columbia River system experienced the Vanport flood that set the stage for multipurpose operations. Vanport was a small shipbuilding town located along the banks of the Columbia River between Vancouver, Washington and Portland, Oregon. In May, heavy rains fell on a heavy snowpack in the Columbia River basin. As a result, the Columbia River and all of its tributaries were at flood stage on Memorial Day weekend of 1948. The flood was so great in the Yakima River that only a 1-foot ripple was observed at Sunnyside Dam (an 8-foot-high concrete weir) with flows measuring 37,700 ft^3/s (compared to mean monthly flow of 5,000 ft^3/s, 1909-79).

After the flood in which Vanport was destroyed, Portland officials approached the U.S. Army Corps of Engineers and water-resource agencies to develop plans to avert such disasters in the future. From 1948-55, water forecast stations were established in the Columbia River and its tributaries including the Yakima River. Formal flood-control operations also began.

From 1946-72, after the the reservoir system was built, the water supply in the basin was adequate for irrigation, and the Yakima project was in a flood-control operation nearly every spring. This time period of adequate supply is one of the primary reasons why additional storage has not been developed in the basin since 1933. After 1972, water shortages occurred, and renewed efforts for water-resource planning and storage development ensued.

Increased needs and preservation: 1970-90

In 1969, Congress passed the National Environmental Policy Act, which required that an impact statement be prepared to identify environmental concerns resulting from a project's actions.

In 1974 and 1978, Judge George Boldt (Senior District Court Judge for the Western District of Washington) issued a two-phase decision that shaped fishery resources in the Northwest. The Boldt-I decision decreed that half the salmon catch would be for Indian use at off-reservation locations and half for non-Indians. The Boldt-II decision provided for hatchery-bred fishery for Indian use and for protecting salmon habitat in the basin.

After experiencing the lowest streamflows ever recorded in the basin in 1977, the Yakima River Basin Water Enhancement Act of 1979 directed the U.S. Department of Interior to study potential conservation savings, new storage, and improved regulation of water resources in the basin. The objectives of the enhancement act were to (1) provide water to increase instream flows for protection and enhancement of anadromous fish, (2) provide water to supplement irrigation supplies on some presently irrigated lands having a proratable water supply during dry water years, (3) provide water for new irrigation development on the Yakima Indian Reservation, and (4) develop a comprehensive water management plan for the basin to improve efficiency in utilization of available water supplies.

Beginning in 1977, a formal adjudication of the entire Yakima River system began in Superior Court in Yakima. During this adjudication, all water claims are being prioritized (based on date) to establish firm water rights, which will simplify operation by establishing priority of water delivery in the system.

In 1980, the Northwest Power Planning and Conservation Act directed Bonneville Power Administration, in cooperation with Federal, State, Tribal, and local agencies, to improve anadromous fish runs in the Pacific Northwest by authorizing mitigation in Columbia-River tributaries for impacts from Columbia River hydroelectric development. In the fall of 1980, redds were discovered in a stretch of the Yakima River between the mouth of the Cle Elum River (Yakima RM 185.6) and the mouth of Teanaway River (Yakima RM 176.1). As a result of finding redds, Judge Justin Quackenbush (Federal District Court for Eastern Washington) mandated (Quackenbush Decision) that water be released, whether storage water or storable inflows, to sustain adequate water levels to keep the eggs alive during winter incubation. Since 1981 and each year following, reservoir releases have been manipulated to provide preestablished flows for spawning and incubation. Spawning-flow quantities are negotiated and Yakima reservoirs are operated to maintain these low flows. Storage from Yakima reservoirs is used presently (1990) to meet June, July, and August irrigation demands, and Naches reservoir storage is used to meet September and October requirements.

In 1984, Phase I of the Yakima River Basin Water Enhancement Project began with construction of fish passage and protective facilities. About $56 million of facilities were built to improve fish passage from Horn Rapids Dam (Yakima RM 18) to Easton Diversion Dam (Yakima RM 202.5). This construction involved two types of structures: ladders on diversion dams to allow adult spring chinook salmon to head upstream to spawning grounds, and screens on the entrances to canals to prevent juvenile fish from becoming trapped in the distribution systems. These facilities allow fish to pass safely upstream or downstream in the Yakima River system.

Today (1990), the Yakima River basin is one of the most intensively irrigated areas in the United States. The basin has six storage reservoirs, 14 major diversions on the main stem, more than 1,900 miles of canals and laterals, three hydroelectric plants, six major irrigation projects, and numerous small irrigation systems.

Presently, the irrigation project consists of seven government constructed divisions: the Sunnyside, Tieton, Roza, Kittitas, Wapato, Kennewick, and Storage. In 1988, the "Fruit Bowl of the Nation" (Yakima River basin) produced a gross irrigated-crop value of more than $500 million. In addition to natural-flow diversions, project reservoirs store over 1 million acre-feet of water for irrigation and flood control. The Yakima reservoirs also have grown into prime outdoor recreation sites.

The magnitude of surface water used in 1961-85 water years for hydroelectric power, irrigation, public supply, and other uses is shown in figure 9. The primary uses include irrigation and hydroelectric power generation. Two government-operated powerplants generate about 160 million kilowatt hours of power each year. The mean annual

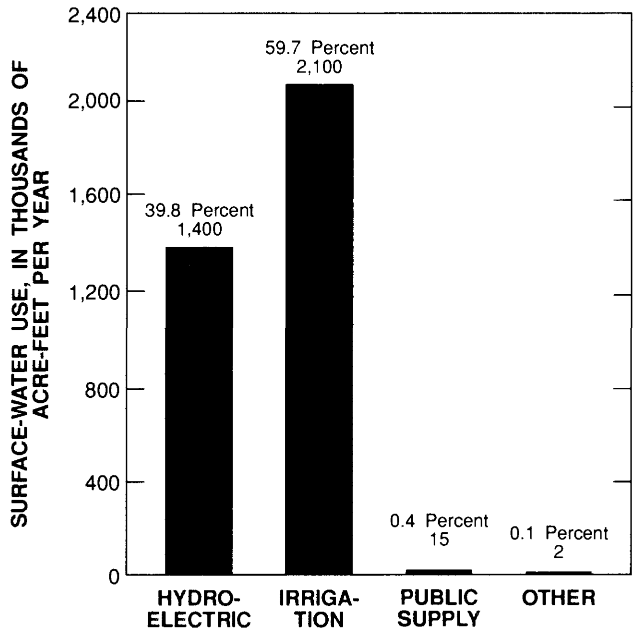


Figure 9.--Major uses of surface water in the Yakima River basin, Washington, 1961-85 water years.

streamflow from 1961-85 in the Yakima River at Kiona (RM 29.9) was 2,594,000 acre-feet per year. Comparison of this mean-annual streamflow with the mean-annual water used from 1961-85 indicates that 54 and 81 percent of the Kiona flow was used for hydroelectric power and irrigation diversion, respectively. Considering that this water use primarily occurred during irrigation season indicates that water is used multiple times in the basin.

Irrigation districts in the Yakima River basin, the acreages receiving irrigation water, and the annual diversion from surface water are listed in table 6. The largest users include the Kittitas Reclamation District in the upper basin and the Roza, Wapato, and Sunnyside Valley Irrigation Districts that provide water to the lower basin. An undefined amount of water also is pumped from wells, the number of which increased significantly after the 1977 drought.

The irrigation season usually extends from early April into mid-October. The monthly rates of water application to the six principal irrigation project areas--the Kittitas, Yakima-Tieton, Roza, Sunnyside-Valley, Wapato, and Kennewick Districts--for 1984 are shown in table 7. Most of the irrigation water is from May through August, primarily by the ridge and furrow method, although a significant and increasing quantity is applied by sprinklers.

The difference between quantities of water diverted and delivered to farms (shown in table 7) is attributed to controlled spillage back to the Yakima River and to losses through evapotranspiration and seepage. During the 1984 calendar year, 390,140 acre-feet of water were diverted to the Roza Canal for power generation and was returned to the Yakima River at Terrace Heights (RM 113.3). About one-half of the total water delivered by the Kennewick District goes to urban areas for irrigation of lawns and gardens. The Sunnyside-Valley District receives an unmeasured quantity of agricultural-return flow and spillage from the Roza system, which explains the apparently high percentage of water that the Sunnyside-Valley District delivered to farms. The Wapato District uses water diverted directly from the Yakima River, supplemented with diversions from small drainages, such as Toppenish Creek, and drainage water pumped into canals for a second-time use as irrigation water.

Upcoming water-resource developments in the basin include Phase II of the Yakima River Basin's Enhancement Project which involves construction of fish passage and protective facilities on some of the smaller diversion structures. Through the Yakima River Basin Water Enhancement Project in 1990, USBR continues to evaluate and compare alternative plans for developing additional water supplies and improving present use of the water in the Yakima River basin. Another phase under consideration is a fish hatcheries program, which would augment the supply of fish and provide a salmon and steelhead sports fishery in this basin.

Table 6.--Major irrigation districts and diversions in Yakima River basin, Washington, 1984

[Data provided by U.S. Bureau of Reclamation, 1986]

Name of irrigation unit	Irrigated area (acres)	Annual diversion from surface water (acre-feet)
Kittitas Reclamation District	52,900	322,000
Cascade Irrigation District	12,700	28,000
Ellensburg Town Canal	19,530	46,000
West Side Irrigation Company	7,000	24,000
Roza Irrigation District	66,600	360,000
Yakima-Tieton Irrigation District	25,600	91,000
Naches-Selah Irrigation District	9,800	38,000
Selah-Moxee Irrigation District	4,500	23,000
Moxee Sub "A"	300	2,000
Terrace Heights Irrigation District	400	2,000
Union Gap Irrigation District	3,100	12,000
Yakima Valley Canal Company	3,200	17,000
Broadway Irrigation District	200	1,000
Special and Warren Act Contractors	38,500	21,000
Wapato Irrigation District	111,000	632,000
Sunnyside Valley Irrigation District	95,500	491,000
Kennewick Irrigation District	1/15,900	92,000

1/ Includes irrigated cropland plus urban and suburban lands receiving irrigation water.

Table 7.--Irrigation water diverted from streams and delivered to farms, Yakima River basin, Washington, 1984

[Source of data is U.S. Bureau of Reclamation, written communication, 1986; acre-ft = acre-feet; "--" indicates no data available]

Month	Kittitas Reclamation District		Yakima-Tieton Irrigation District		Roza Irrigation District		Sunnyside Valley Irrigation District	
	Diverted, acre-ft/ acre	Delivered, acre-ft/ acre	Diverted, acre-ft/ acre	Delivered, acre-ft/ acre	Diverted, acre-ft/ acre	Delivered, acre-ft/ acre	Diverted, acre-ft/ acre	Delivered, acre-ft/ acre
April	0.12	0.04	0.13	0.01	0.48	0.10	0.52	0.20
May	.80	.53	.46	.27	.76	.38	.81	.57
June	.95	.65	.69	.49	.94	.56	.94	.74
July	1.32	.95	.76	.61	1.09	.78	1.06	.91
August	1.46	1.05	.80	.63	1.09	.75	1.08	.89
September	1.11	.64	.71	.54	.73	.40	.90	.70
October	.32	.17	--	--	.31	.12	.39	.28
Total, April-October	6.08	4.03	3.55	2.56	5.40	3.09	5.70	4.29

Month	Wapato Irrigation District			Kennewick Irrigation District		
	Diverted, acre-ft/ acre	Other sources, acre-ft/ acre 1/	Delivered, acre-ft/ acre	Diverted, acre-ft/ acre 2/	Estimated delivery to urban area, acre-ft/acre 3/	Delivered, acre-ft/ acre
March	0.08	--	0.02	--	--	--
April	.41	0.23	.36	0.55	0.36	0.36
May	.94	.66	1.01	.90	.55	.55
June	.94	.70	1.08	.89	.61	.62
July	.96	.60	.99	1.12	.84	.85
August	.90	.63	.94	1.11	.84	.85
September	.73	.51	.79	.86	.51	.52
October	.18	.17	.22	.36	.23	.23
Total, March-October	5.14	3.56	5.44	5.79	3.94	3.98

1/ Water diverted from Toppenish and Simcoe Creeks and drainage water pumped into canals for additional use as irrigation water.
2/ Water diverted for cropland plus urban area divided by cropland plus urban acreage.
3/ Urban area receives about 46 percent of the delivered water (Gary Wetherley, Kennewick Irrigation District, oral commun., 1986), expressed as water delivered to urban area divided by 7,338 acres, the total urban plus suburban acreage.

Fishery

Prior to major irrigation development in the Yakima River valley in the 1900's, the Yakima River was one of the most important anadromous fish producers in the Columbia River basin. Much of the decrease in fish population has been attributed to fish-passage problems and habitat restrictions associated with irrigation development; overfishing in the ocean, Columbia River, and Yakima River; and Columbia River hydropower development. In the past few years, State and Federal agencies--most recently the Northwest Power Planning Council--and the Yakima Indian Nation have been working to improve conditions for spawning, rearing, and the downstream migration of juvenile fish and upstream migration of adults. Since 1980, notable improvements have occurred and even greater future improvement is anticipated (John Easterbrook, Washington

Department of Fisheries, oral commun., March 4, 1986). Fish are discussed more thoroughly in the section on fish and other aquatic biological communities.

Point-source Loads

In this report, point sources are defined as pipe or outfall discharges from municipalities and industries. These sources may flow directly into the main stem of the Yakima River or may enter the main stem from tributaries. Nonpoint sources include diffuse sources such as overland runoff and ground-water discharge. Both point and nonpoint sources may degrade water quality; however, point-source loads are usually more easily identified and controlled. Water-quality constituent loads for 1974 (high streamflow year), 1977 (low streamflow year), and 1980 (near median streamflow year) were estimated for this study to evaluate point-source effects over a range of streamflows.

Permit levels for point-source discharges are available from National Pollutant Discharge Elimination System (NPDES). These levels represent maximum effluent quantities that should not be exceeded and do not necessarily represent actual discharges. NPDES discharges are shown in figure 10 for 1974, 1977, and 1980. The largest single source of effluent volume is the Yakima sewage treatment plant (STP), which serves the largest population in the basin.

Annual point-source loads for selected nutrients, biochemical oxygen demand, suspended solids, and fecal-coliform bacteria were estimated using records provided by the Washington Department of Ecology (table 8). Data for potentially toxic trace elements and organic compounds generally were not available. Daily, weekly, or monthly discharge measurements were available for most point sources from 1974-80. Except for weekly, monthly, or seasonal data on concentrations of ammonia, biochemical oxygen demand, and suspended solids, few constituent-concentration data were available, because permit levels have not been established for many constituents.

Nutrient loads were estimated to help evaluate potential effects of point-source discharges. Because of the paucity of seasonal data, the nutrient loads are only estimates; however, they are expected to be within an order of magnitude of the actual loads. The "Total estimated load" in table 8 represents the point-source load for the basin and includes estimates of point sources with missing data. For example, if a secondary sewage-treatment plant was missing total phosphorus concentrations, an average value from other secondary sewage-treatment plants in the basin was substituted.

Stream Classification and Associated Water-quality Standards

Washington State streams are classified according to general beneficial water uses. An antidegradation policy is being used to protect existing water-quality conditions (Washington State Administrative Code, 1988). In the Yakima River basin, streams are rated either class AA (extraordinary), class A (excellent), or class B (good). Class AA streams must markedly and uniformly exceed water-quality standards for all, or substantially all, designated water uses;

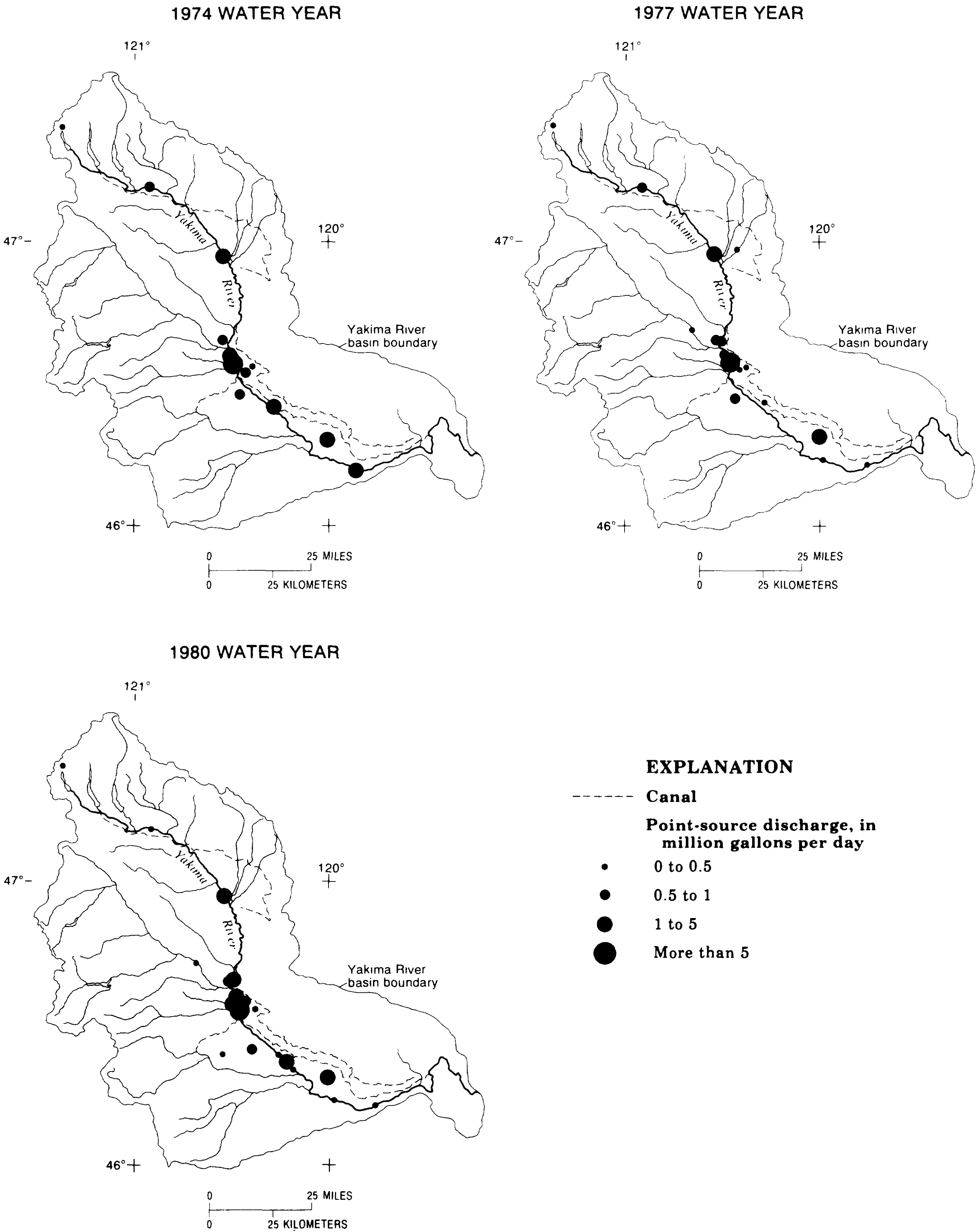


Figure 10.--Point-source discharges based on National Pollutant Discharge Elimination System permit levels for the Yakima River basin, Washington, 1974, 1977, and 1980 water years.

Table 8.--Estimated point-source loads in the Yakima River basin, Washington, 1974, 1977, and 1980 water years

[Loads expressed in units of 1,000 pounds per year, except where indicated; "--" indicates no data; N = nitrogen; P = phosphorus; BOD_5 = 5-day biochemical oxygen demand; "Total estimated load" represents the point-source load for the basin and includes estimated loads for point sources with missing data; STP = sewage treatment plant; Cr = Creek]

			Constituent loads							
Effluent source	Receiving water	Annual mean flow in cubic feet per second	Dissolved nitrite plus nitrate as N	Total ammonia as N	Total ammonia plus organic nitrogen as N	Dissolved orthophosphate as P	Total phosphorus as P	Biochemical oxygen demand, BOD_5	Suspended solids	Fecal coliform bacteria (billion colonies per year)
					1974					
Snoqualmie Pass Sewer	Coal Creek	0.114	0.058	3.1	3.6	0.2	0.29	4.5	5	--
Cle Elum STP	Yakima River	1.11	.88	7.2	9.9	1.2	5.2	44	77	--
Ellensburg STP	Yakima River	7.28	17	88	130	6	66	150	175	--
Selah STP	Yakima River	1.1	.32	.65	--	14	19	580	260	--
Snokist Growers	Yakima River	1.728	--	10	37	4.2	29	36	350	--
Yakima STP	Yakima River	14.58	1.4	250	280	160	530	430	5,500	--
Union Gap STP	Wide Hollow Cr	.8	--	--	--	--	--	--	--	--
Moxee STP	Moxee Drain	.084	--	--	--	--	--	--	--	--
U&I Sugar Company	Yakima River	6.42	--	114	--	--	--	180	--	--
Wapato STP	Yakima River	.853	--	--	--	--	--	--	--	--
Sunnyside STP	Sulphur Creek	1.842	--	--	--	--	--	150	420	--
Grandview STP	Yakima River	2	.25	11	--	14	18	100	210	--
Total estimated load1/:		59	110	860	1,500	260	840	6,800	12,000	70,000
					1977					
Snoqualmie Pass Sewer	Coal Creek	0.164	0.084	4.4	5.2	0.29	0.42	2	7.3	--
Cle Elum STP	Yakima River	1.11	.88	7.2	9.9	1.2	5.2	84	61	--
Ellensburg STP	Yakima River	4.97	7.5	16	2.0	20	24	60	44	--
Kittitas STP	Cook Creek	.492	.077	4.5	5.9	1.3	2.9	21	15	--
Selah STP	Yakima River	.901	.26	.53	--	12	16	240	260	--
Naches STP	Naches River	.102	--	--	--	--	--	7	5.4	--
Yakima Cement Products	Yakima River	1.16	--	--	--	--	--	--	--	--
Snokist Growers	Yakima River	1.241	--	--	--	--	--	390	480	--
Yakima STP	Yakima River	16.04	1.6	280	310	180	590	1,000	820	--
Union Gap STP	Wide Hollow Cr	.7	--	--	--	--	--	290	290	--
Moxee STP	Moxee Drain	.074	--	--	--	--	--	1	4.7	--
Zillah STP	Yakima River	.189	1.6	.1	1.1	1.4	2.1	1.5	9.5	--
Wapato STP	Yakima River	.944	--	--	--	--	--	--	--	--
Sunnyside STP	Sulphur Creek	2.087	--	--	--	--	--	160	190	--
Mabton STP	Yakima River	.158	.009	8.7	10	2.2	2.7	5.9	7.3	--
Prosser STP-Domestic	Yakima River	.52	--	--	--	--	--	54	57	--
Prosser STP-Industrial	Yakima River	1.68	--	0	--	--	--	3,400	3,300	--
Total estimated load1/:		49	89	690	1,300	270	810	6,800	6,600	40,000
					1980					
Snoqualmie Pass Sewer	Coal Creek	0.139	0.071	3.8	4.4	0.25	0.36	3.2	2	--
Cle Elum STP	Yakima River	.712	.56	4.6	6.3	.76	3.3	12	11	32
Ellensburg STP	Yakima River	5.82	8.8	18	2.4	23	28	110	80	2,400
Selah STP	Yakima River	1.15	.34	0.68	--	15	20	93	480	41
Naches STP	Naches River	.088	--	--	--	--	--	1.8	3.2	--
Yakima Cement Products	Yakima River	1.78	--	--	--	--	--	--	--	--
Snokist Growers	Yakima River	1.036	--	--	6	--	13	24	90	--
Boise Cascade STP	Yakima River	2.38	--	--	--	--	--	--	--	--
Yakima STP	Yakima River	17.03	1.7	300	330	190	620	2,200	2,100	4,500
Boise Cascade STP	Yakima River	3.33	--	--	--	--	--	--	--	--
Moxee STP	Moxee Drain	.099	--	--	--	--	--	1.3	5.6	1
Zillah STP	Yakima River	.228	1.9	0.125	1.3	1.7	2.6	1.8	6.8	--
Toppenish STP	E Toppenish Drn	1.789	3.4	60	71	19	23	18	15	--
Granger STP	Yakima River	.226	--	--	--	--	--	7.1	9.2	--
Wapato STP	Yakima River	.872	--	--	--	--	--	22	14	--
Harrah STP	Harrah Drain	.063	--	--	--	--	--	2	2.2	--
Sunnyside STP	Sulphur Creek	2.514	--	--	--	--	--	160	190	1,500
Mabton STP	Yakima River	.187	.011	10	12	2.6	3	5.6	6.8	--
Prosser STP-Domestic	Yakima River	.591	--	--	--	--	--	50	60	320
Prosser STP-Industrial	Yakima River	.664	--	--	--	--	--	800	1,000	--
Total estimated load1/:		55	94	730	1,200	300	860	4,700	6,200	20,000

1/ Includes flows and loads for point sources that are not listed in the table.

class A streams must meet or exceed standards established for all, or substantially all, designated water uses; and class B streams must meet or exceed the requirements for most uses (except for domestic-water supplies, salmonid spawning, and primary-contact recreation) [table 9].

Three stream classifications in the Yakima River basin are shown in figure 11. Class AA streams include the Yakima River from its confluence with the Cle Elum River (RM 185.6) to its headwaters, the Cle Elum and Tieton Rivers, the Naches River from Snoqualmie National Forest boundary (RM 35.7) to the headwaters, tributaries to the class AA waters, and all streams lying within national parks, national forests, and (or) wilderness areas. Class A streams include all other streams in the basin except Sulphur Creek, a tributary to the Yakima River at RM 61, which is class B. Tributaries to Sulphur Creek are classified as class A. In this report, the quality of lakes and reservoirs were compared to the corresponding stream classification of the outflow,

Table 9.--Characteristic water uses for Washington State stream classifications in the Yakima River basin, Washington

Water use	Stream classifications AA	A	B
Water supply			
-Domestic	X	X	
-Industrial	X	X	X
-Agriculture	X	X	X
Stock watering	X	X	X
Fish			
Salmonid			
-Migration	X	X	X
-Rearing	X	X	X
-Spawning	X	X	
-Harvesting	X	X	X
Other Fish			
-Migration	X	X	X
-Rearing	X	X	X
-Spawning	X	X	X
-Harvesting	X	X	X
Wildlife habitat	X	X	X
Recreation			
-Primary contact[1]	X	X	
-Secondary contact[2]	X	X	X
-Sport fishing	X	X	X
-Aesthetic	X	X	X
Commerce and navigation	X	X	X

[1]Primary contact includes any activity in which the body is completely submerged in the water (such as, swimming, water skiing).

[2]Secondary contact includes any activity in which the body is partially, but not completely submerged (such as, wading).

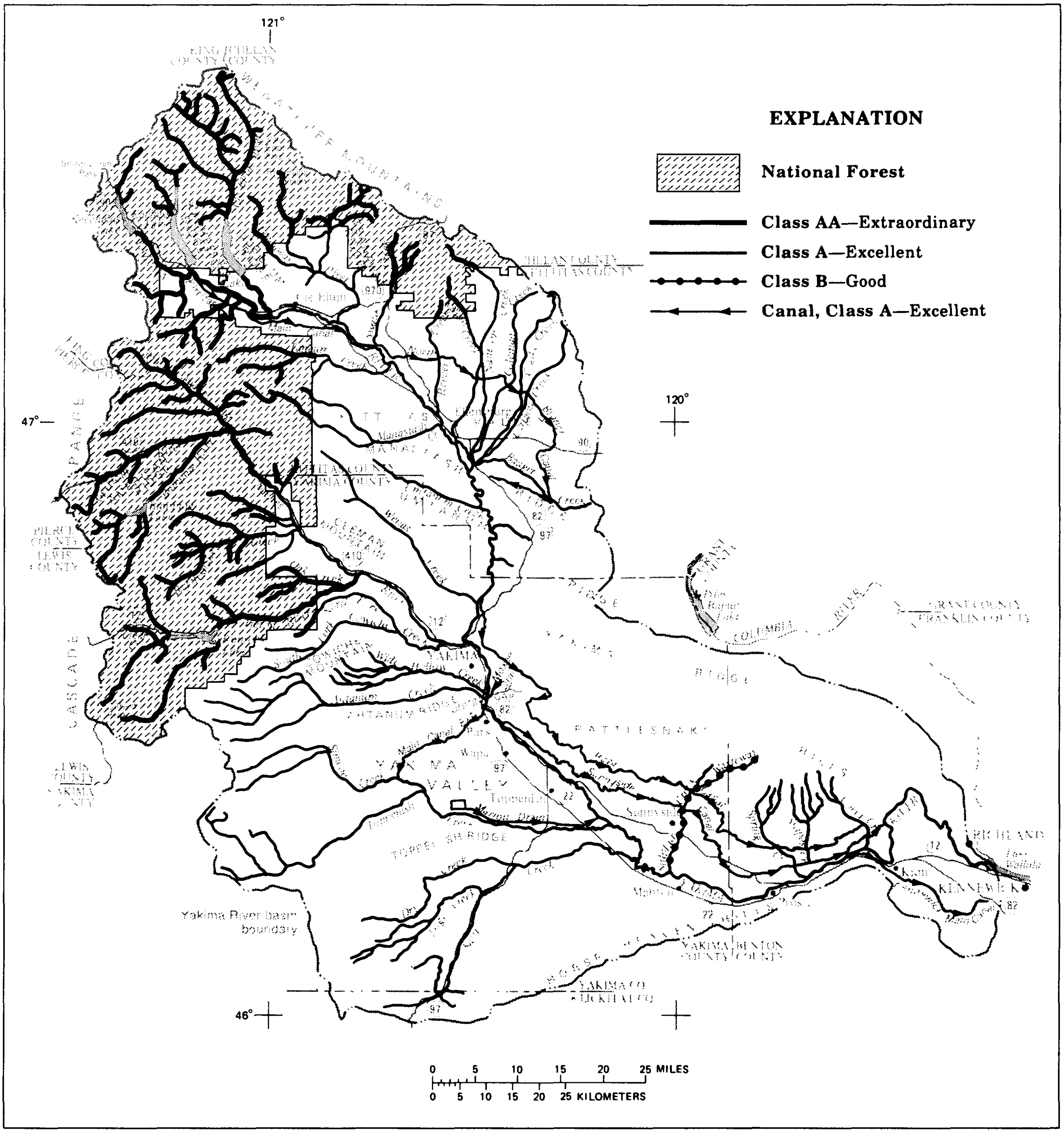


Figure 11.--Water-quality classification by Washington Department of Ecology for streams in the Yakima River basin, Washington.

because many of the State lake-class standards are based on "no measurable change from natural conditions," which is difficult to define. Special State standards have been established for some river reaches that cannot meet standards under natural conditions. For example, the class A standard for stream temperatures of 18.0 °C has been increased to 21.0 °C.

State water-quality standards have been established for various water uses and stream classifications mentioned above. To help evaluate the potential for water-quality problems in the basin, historical data from the Yakima River basin are compared to current (1) EPA National Primary (enforceable) and Secondary (not enforceable) Drinking-Water Regulations, (2) EPA water-quality criteria for the protection of aquatic life and human health (not enforceable), and (3) Washington State standards (enforceable). Washington State has adopted many of EPA's regulations and criteria as standards that are legally enforceable (State of Washington Administrative Code, 1988). Some State standards apply only to a particular stream classification and others apply to all classifications. For example, State standards for fecal-coliform bacteria, dissolved oxygen, and stream temperature vary with stream classification (table 10), whereas standards for trace elements and organic compounds apply to all stream classifications (table 11). State standards and selected EPA Primary and Secondary Drinking-Water Regulations are shown in table 11. Concentrations of concern for those constituents not listed in table 10 and 11 are identified in this report based on EPA water-quality criteria (U.S. Environmental Protection Agency, 1986).

Toxicity to aquatic life is expressed by EPA and State of Washington in terms of acute (short-term) or chronic (long-term) effects (U.S. Environmental Protection Agency, 1986). Acute toxicity is denoted as the lethal concentration for a specified percentage of individuals (U.S. Environmental Protection Agency, 1986), and generally is expressed in the State of Washington Code (1988) as an instantaneous concentration not to be exceeded at any time or a 1-hour average concentration not to be exceeded more than once every 3 years. Chronic toxicity is denoted as the concentration that affects biota over a lifetime or over a time span of more than one generation. A chronic effect generally occurs in a species population rather than in the individual organism, and is expressed in the State of Washington Code (1988) as a 24-hour average concentration not to be exceeded or a 96-hour average concentration not to be exceeded more than once every 3 years.

ASSESSMENT APPROACH

The first step in the assessment approach was to collate all available ambient surface-water-quality data. The next steps were: select the suite of constituents to be analyzed, evaluate and screen the data, and design methods for data analysis. A generalized schematic diagram for this approach is shown in figure 12.

Collation of Water-quality Data for the Yakima River Basin

Several agencies have collected and analyzed stream-quality data in the basin: Washington Department of Ecology, U.S. Geological Survey, U.S. Bureau of Reclamation, Yakima Indian Nation, U.S. Forest Service, U.S. Department of Agriculture, U.S. Environmental Protection Agency, and the U.S. Fish and Wildlife Service. In June 1986, all available data were obtained from USGS's National WATer Data STOrage and REtrieval (WATSTORE) Computer System and EPA's STOrage and RETrieval (STORET) Computer System.

Table 10.--Washington State standards for stream classifications in the Yakima River basin, Washington

[Watar-quality standards are from tha State of Washington Administrative Code (1988). > indicates greater than; < indicates less than; NTU = nephelometric turbidity units; T = temperature in degreas Celsius]

Water-quality classi-fication	Fecal coliform bacteria, in colonies per 100 milliliters: Geometric mean 1/	Fecal coliform bacteria, in colonies per 100 milliliters: 10-percent exceedence 2/	Dissolved oxygen, in milligrams per liter	Temperature, in degrees Celsius: Standards 3/	Temperature, in degrees Celsius: Maximum increases 4/	pH units: Standards 5/	pH units: Within-range variation 6/	Turbidity, permissible increases over background levels of: <50 NTU: NTU	Turbidity, permissible increases over background levels of: >50 NTU, Percent of background 7/
AA	50	100	9.5	16	$\frac{23}{T + 5}$	6.5-8.5	0.2	5	10
A	100	200	8.0	21	$\frac{34}{T + 9}$	6.5-8.5	.5	5	10
B	200	400	6.5	21	$\frac{34}{T + 9}$	6.5-8.5	.5	10	20

1/ Based on a minimum of five samples equally spaced over a 30-day period.
2/ Not more than 10 percant of the total samples taken over any 30-day period may exceed this value.
3/ When natural conditions exceed criteria, no temperature increases will be allowed which will raise the receiving water temperatura more than 0.3 degrees Celsius.
4/ Temperature increases shall not at any time exceed the given quotient where "T" represents the largest background ambient temperature near the point of discharge and unaffected by the discharge.
5/ Criteria are exceeded when values fall outside of range.
6/ A man-caused variation should not exceed listed value within the specified range.
7/ When turbidity is greater than 50 NTU's, listed value indicates permitted increase in turbidity over background, in percent.

Table 11.--Washington State standards and selected U.S. Environmental Protection Agency National Primary and Secondary Drinking-Water Regulations for stream quality in the Yakima River basin, Washington

[Water-quality standards are from the State of Washington Administrative Code (1988). All units are in micrograms per liter, DDT = dichlorodiphenyltrichloroethane, PCB = polychlorinated biphenyls, ln = natural logarithm, e = 2.718, EPA = U.S. Environmental Protection Agency, MCL = maximum contaminant level; hardness in milligrams per liter as calcium carbonate; "-" indicates no regulation]

Substance	Acute	Chronic	EPA drinking water MCL
Aldrin/dieldrin 1/	2/ 2.5	3/ 0.0019	-
Ammonia	4/,5/,7/	4/,6/,7/	-
Cadmium	5/ $\leq e^{(1.128[\ln(\text{hardness})] - 3.828)}$	6/ $\leq e^{(.7852[\ln(\text{hardnass})] - 3.490)}$	10
Chlordane	2/ 2.4	3/ 0.0043	8/ 2
Chlorine	5/ 19.0	6/ 11.0	-
Chlorpyrifos	5/ 0.083	6/ 0.041	-
Chromium (Hexavalent)	5/ 16.0	6/ 11.0	50
Chromium (Trivalent)	5/ $\leq e^{(0.8190[\ln(\text{hardness})] + 3.688)}$	6/ $\leq e^{(0.8190[\ln(\text{hardness})] + 1.561)}$	50
Copper	5/ $\leq e^{(0.9422[\ln(\text{hardness})] - 1.464)}$	6/ $\leq e^{(0.8545[\ln(\text{hardness})] - 1.465)}$	9/ 1,000
Cyanide	5/ 22.0	6/ 5.2	
DDT & metabolities	2/ 1.1	3/ 0.001	
Endosulfan	2/ 0.22	3/ 0.056	
Endrin	2/ 0.18	3/ 0.0023	.2
Heptachlor	2/ 0.52	3/ 0.0038	8/ .4
Hexachlorocyclo-hexane (Lindane)	2/ 2.0	3/ 0.08	4
Lead	5/ $\leq e^{(1.273[\ln(\text{hardness})] - 1.460)}$	6/ $\leq e^{(1.273[\ln(\text{hardness})] - 4.705)}$	50
Mercury	5/ 2.4	6/ 0.012	2
Nickel	5/ $\leq e^{(0.8460[\ln(\text{hardness})] + 3.3612)}$	6/ $\leq e^{(0.8460[\ln(\text{hardness})] + 1.1645)}$	-
Parathion	5/ 0.065	6/ 0.013	-
PCB	3/ 2.0	3/ 0.014	8/ .5
Pentachlorophenol	5/ $\leq e^{[1.005(pH) - 4.830]}$	6/ $\leq e^{[1.005(pH) - 5.290)]}$	8/ 200
Selenium	2/ 260.0	3/ 35.0	10
Silver	2/ $\leq e^{(1.72[\ln(\text{hardness})] - 6.52)}$	7/ 0.12	50
Toxaphene	5/ 0.73	6/ 0.0002	5
Zinc	5/ $\leq e^{(0.8473[\ln(\text{hardness})] + 0.8604)}$	6/ $\leq e^{(0.8473[\ln(\text{hardness})] + 0.7614)}$	

1/ Aldrin is metabolically converted to dieldrin. Therefore, the sum of the aldrin and dieldrin concentrations are compared with the dieldrin criterion.
2/ An instantaneous concentration not to be exceeded at any time.
3/ A 24-hour average not to be exceeded.
4/ Standards are based on stream pH and temperature.
5/ A 1-hour average concentration not to be exceeded more than once every 3 years.
6/ A 4-day average concentration not to be exceeded more than once every 3 years.
7/ U.S. Environmental Protection Agency (1986).
8/ Proposed maximum contaminant level.
9/ Secondary maximum contaminant level.

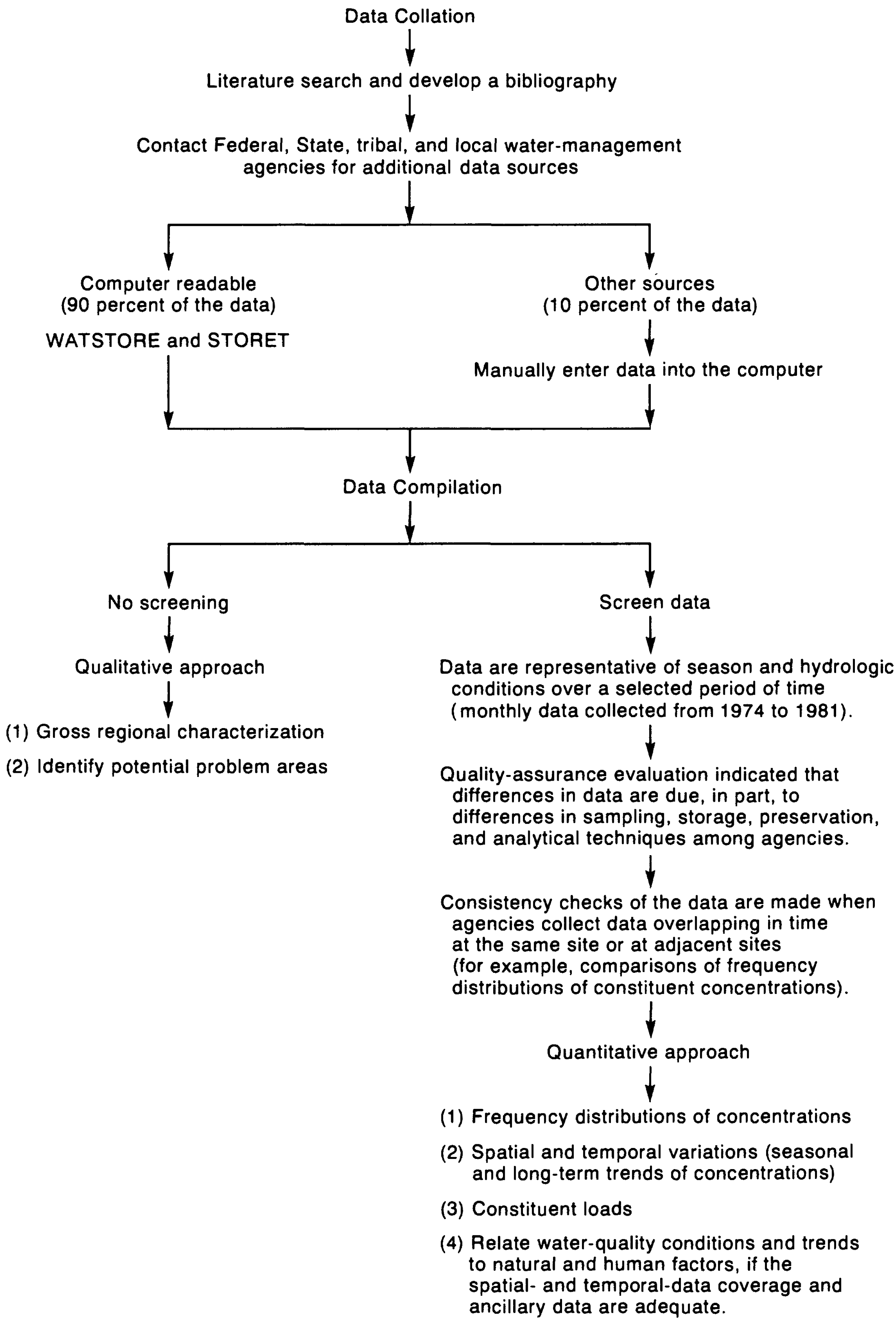


Figure 12.--The assessment approach used for interpreting historical water-quality data from the Yakima River basin, Washington. (WATSTORE = National Water Data Storage and Retrieval Computer System and STORET = Storage and Retrieval Computer System.)

A bibliography of water-quality reports was prepared and presented to interested scientists and water-management personnel (including the Yakima River NAWQA Liaison Committee) for review, suggestions, and identification of additional data sources. The reports that are listed in the bibliography were inventoried to determine whether the water-quality data had been retrieved from either WATSTORE or STORET. Those data that were not computer retrievable were manually entered into the USGS computer system in Portland, Oregon.

Collation of available water-quality data resulted in a historical data file consisting of more than 240,000 constituent determinations. These data were collected through 1985 WY and excluded USGS daily-values data (such as flow, temperature, specific conductance, and suspended sediment). Additional data collected through 1985 are continually being added to the historical file; for example, organic-compound data collected by the WDOE in 1985 were not in STORET at the time of the June 1986 retrieval.

Selection of Constituents and Properties for Analysis

Constituents included in this report are shown in table 12 along with their principal environmental effects and associated water-quality issues. For many of these constituents, EPA has established ambient water-quality criteria (U.S. Environmental Protection Agency, 1986).

Evaluation of Water-quality Data

Agencies tend to collect data for different purposes, creating inconsistencies in data records among agencies because of: differences in sampling approaches, sampling methods, sampling frequency, geographic coverage within the basin, constituents measured, length of record, quality assurance of sample handling, laboratory analysis, and data storage. Moreover, there is a lack of historical data on potentially toxic substances--trace elements and especially synthetic organic substances--and on biological data that could be used to assess stream health. These differences in data create a formidable challenge for defining historical water-quality conditions. Some difficulties in historical data interpretation have been overcome in this analysis by separating the interpretative approach into two broad categories: quantitative and qualitative.

Quantitative-analysis Approach

The water-quality data used in quantitative analysis were selected to be representative of the same temporal (seasonal and long-term period) and hydrologic conditions for as long a time period and at as many sites as possible. By using equivalent time periods and flow conditions (for example, low and (or) high streamflows), the water-quality data are normalized relative to seasonal and flow variations. This normalization is helpful for evaluating the effects of man's activities or other natural factors. Quantitative data are used for intersite and intrasite comparisons and for determining the seasonal and annual variability of concentrations. Additionally, time-trend results and loads are estimated to provide insights to water-quality conditions, sources of loads, and causes of changes over time. Only sites with a monthly sampling frequency during the same time period were selected for

Table 12.--Principal environmental effects and water-quality issues for selected constituents addressed in this report, Yakima River basin, Washington

["-" indicates no principal effect or not an issue; "X" indicates principal effect or that constituent affects the specified issue]

	Principal effects			Water-quality issues					
Constituent	Human health	Eco-systems	Agri-culture	Toxic contami-nation	Nutrient enrichment	Acidifi-cation	Soil erosion/ sedimen-tation	Salinity	General suit-ability
Major metals and trace elements									
Antimony	X	X	-	X	-	-	-	-	-
Arsenic	X	X	X	X	-	-	-	X	-
Barium	X	-	-	X	-	-	-	-	-
Beryllium	X	-	-	X	-	-	-	-	-
Boron	-	-	X	-	-	-	-	X	-
Cadmium	X	X	-	X	-	X	-	-	-
Chromium	X	X	-	X	-	X	-	-	-
Copper	-	X	X	X	-	X	-	-	-
Iron	-	-	-	-	-	-	-	-	X
Lead	X	X	-	X	-	X	-	-	-
Manganese	-	-	-	-	-	-	-	-	X
Mercury	X	X	X	X	-	X	-	-	-
Nickel	X	-	-	X	-	X	-	-	-
Selenium	X	X	X	X	-	-	-	X	-
Silver	-	X	-	X	-	-	-	-	-
Zinc	-	X	-	X	-	X	-	-	-
Nutrients									
Ammonium	-	X	-	X	X	-	-	-	-
Nitrate	X	X	X	X	X	X	-	-	-
Nitrite	X	X	X	X	X	-	-	-	-
Total nitrogen	-	X	-	-	X	-	-	-	-
Ortho-phosphate	-	X	-	-	X	-	-	-	-
Total phosphorus	-	X	-	-	X	-	-	-	-
Major constituents and solids									
Calcium	-	X	X	-	-	X	-	X	X
Magnesium	-	X	X	-	-	X	-	X	X
Sodium	X	X	X	-	-	X	-	X	X
Potassium	-	-	-	-	-	-	-	-	-
Sulfate	X	X	-	-	-	X	-	X	X
Chloride	-	X	X	-	-	X	-	X	X
Alkalinity	-	X	-	-	-	X	-	X	X
Acidity	-	X	-	-	-	X	-	-	-
Fluoride	X	-	-	X	-	-	-	-	-
Total dissolved solids	-	X	X	-	-	-	-	X	X
Suspended sediment	X	X	-	-	-	-	X	-	X
Field measurements									
pH	-	X	-	-	-	X	-	-	-
Specific conductance	-	-	-	-	-	-	-	X	-
Temperature	-	X	-	-	-	-	-	-	X
Dissolved oxygen	-	X	-	-	-	-	-	-	X
Radiochemical									
Gross alpha	X	-	-	X	-	-	-	-	-
Gross beta	X	-	-	X	-	-	-	-	-
Radon - 222	X	-	-	X	-	-	-	-	-
Pesticides									
Pesticides and other trace organic compounds	X	X	-	X	-	-	-	-	X
Sanitary quality									
Fecal coliform bacteria	X	X	-	X	-	-	-	-	X

analysis. To be representative of seasonal and hydrologic conditions, the frequency probably should be greater than monthly for certain hydrologic conditions (for example, storm samples); however, this greater sampling rate over several years does not exist in the Yakima data base.

The best spatial coverage was obtained by selecting data collected by the USBR and the USGS for the time period 1974 through 1981 WY. During this period, 26 sites usually were sampled monthly for the 8-year duration and 8 sites usually were sampled monthly for 6 years (generally, 1974-79). The sites with 8 years of record averaged about nine samples per year per site. The site with the fewest observations during the 8-year period averaged more than seven samples per year.

Quality assurance is an important consideration in the quantitative interpretation of water-quality data. For meaningful comparisons between data from USGS sites and USBR sites, the samples should be comparably collected, stored, preserved, and analyzed. The USGS obtained depth- and width-integrated samples that were collected isokinetically relative to river velocities. The USBR samples were generally grab samples collected just below the surface in flowing water. Grab samples may provide biased results if concentrations of dissolved and suspended constituents were not homogeneous in the cross section at the sampling site. Homogeneity is dependent on (1) channel characteristics, (2) vicinity and characteristics of upstream constituent sources, (3) characteristics of upstream mixing, and (4) suspended-sediment particle size and concentration. Evaluation of the procedures indicated that both agencies used laboratory protocols that generally were consistent with the EPA guidelines. Both agencies used similar quality-control techniques that included standards, blanks, replicates, and spikes; and both agencies have participated in quality-assurance programs. However, written documentation plans for both agencies are relatively recent--USGS in 1981 (Peart and Thomas, 1983; Friedman and Fishman, 1989) and USBR in 1987 (U.S. Bureau of Reclamation, 1987). An investigation of the consistency of the data collected by both agencies where they had overlapping data (mostly nutrient concentrations) at the same site or adjacent sites indicated that the data from the two agencies generally were comparable.

Qualitative-analysis Approach

Data were not screened for the qualitative analysis. All available ambient surface-water-quality data for a selected constituent are summarized for interpretation; consequently, geographic coverage is usually good for the relatively inexpensive field measurements (streamflow, temperature, pH, and specific conductance) and laboratory determinations of nutrients, suspended sediment, and turbidity. Qualitative analyses primarily are appropriate for supplementing analyses of quantitative data. Qualitative interpretations are limited to general regional comparisons and identification of areas with elevated concentrations. These limitations occur, because the data were collected with: (1) an unknown sampling objective, (2) unknown quality assurance, and (3) often poor temporal coverage. Overcoming data limitations described above becomes more difficult as the data become older, and fewer agency personnel are able to identify the degree to which these limitations are relevant. For several constituent groups, such as synthetic organic compounds and trace elements, the historical spatial coverage is poor.

Methods of Analysis

Methods of data analysis were dependent on data availability and the type of analytical approach (quantitative or qualitative). General procedures and statistical methods which were used for analysis are listed in the following sections.

Characterizing Spatial Water-quality Variability

Review of water-quality data for the qualitative analysis indicated that water quality was strongly related to the type of conveyance channel and associated water and land uses. As a result for selected constituents, the historical sampling sites were grouped into one of the following categories:

Tributary -- Natural stream minimally affected by man's activities;

Canal -- Manmade channel with water diverted for irrigation from rivers upstream from Parker, Washington (Yakima RM 103.7);

Drains plus other -- Natural or manmade channels with water quality affected by agricultural-return flow and point sources. This category includes canals that either contain water pumped from drains (such as Satus Canal) or water diverted from the Yakima River downstream from Parker (such as Chandler and Kennewick Canals); and

Main stem -- Sites on the Yakima River between Martin (RM 214.4) and the mouth.

Interpretation of geographic variation of water-quality conditions was accomplished by: (1) selecting all available data for a constituent, (2) separating the data into subbasins, (3) further separating the data according to conveyance-channel types, and (4) determining the 90th percentile values to represent extreme constituent concentrations (potential problem areas). The 90th-percentile values for each channel-conveyance type then were placed on a map to show variations in water quality for each subbasin. Variations in land use for each subbasin are shown in figure 13. From these maps, subbasins and conveyance-channel types with large constituent concentrations or no data were easily identified; in addition, variations in constituent concentrations were qualitatively related to land and water uses and point-source discharges.

Identifying Potential Problem Areas

Sites with elevated constituent concentrations also were identified in the qualitative analysis by determining the frequency distributions (percentile values) of constituent concentrations or values for each

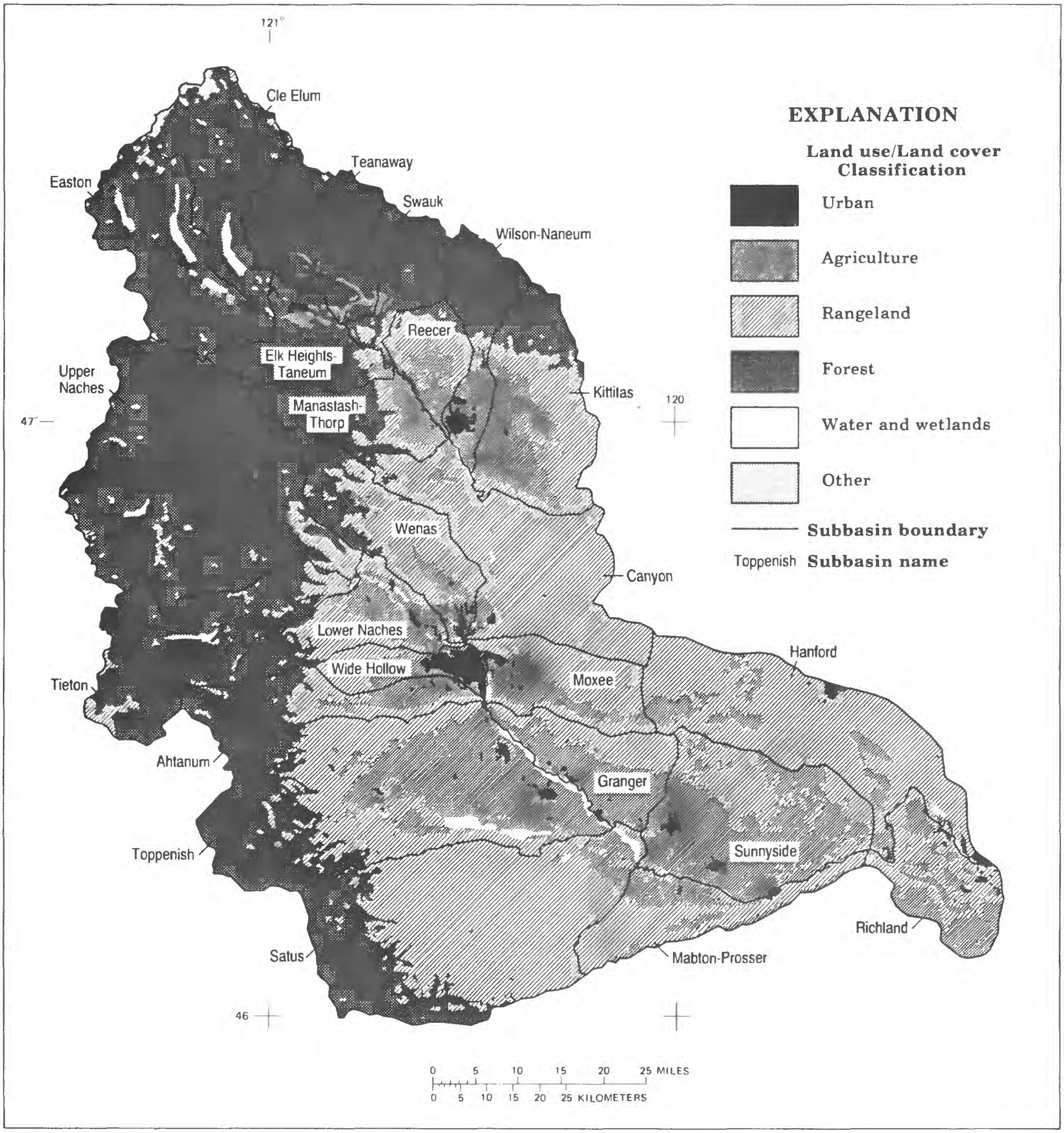


Figure 13.--Land use in the Yakima River basin, Washington, 1981 (Fegeas and others, 1983).

sampling site using available data through 1985 WY. The percentile distributions for each site were compared with EPA Primary and Secondary Drinking-Water Regulations, EPA criteria, and Washington State standards for each identified water use. Elevated constituent concentrations in this qualitative analysis have an unknown quality assurance, and do not necessarily indicate that an actual problem existed; but the data do indicate additional sampling is needed to determine if a problem exists.

Quantitative Comparisons of Water-quality Conditions

Intersite and intrasite comparisons of constituent concentrations were made by comparing the frequency distributions of monthly instantaneous data collected from 1974 through 1981. Later in this report, these distributions are shown graphically in boxplots (Tukey, 1977) and in table 49 at the back of report (table 49 shows the number of samples, the minimum and maximum concentrations, and the 10, 25, 50, 75, and 90 percentiles; PSTAT, Inc., 1989). The median value is the 50 percentile value, which indicates that 50 percent of the samples had a concentration less than or equal to that reported value. Boxplots of frequency distributions are shown in a downstream order for intersite comparisons of data from main-stem sites. Also, boxplots showing monthly distributions at a site are presented for seasonal intrasite comparisons.

Data that were reported below the analytical reporting level are referred to as censored data or less-than values. In this report, these data were included in the statistical summaries and are preceded with a "<" sign in the summary tables. For illustration, the less-than values are shown at levels equal to one-half the analytical reporting levels.

Loads

Constituent loads (in tons per year) and yields (in pounds or tons per day per square mile) were estimated using constituent transport models. These models were based on multiple regression analysis between constituent load and several independent variables including: time (to compensate for long-term trends), sine and cosine of time (to compensate for seasonal variations), and logarithm of discharge. Mallows' Cp (Draper and Smith, 1981) was used to select the best-fit model. Mallows Cp is an estimate of a model's total square error (overall variance error plus bias error), and the model with the smallest Cp was selected as the best-fit model. The regression equations for the transport models are shown in table 50 at the back of report. Equations that are based on the regression of transformed values (logarithms of loads and discharge) may result in underestimates of the constituent loads; consequently, a correction factor (smearing estimate; Duan, 1983) has been added to the load to correct for this negative bias.

The accuracy of the constituent transport models and estimated loads is dependent on collecting representative samples over those critical hydrologic conditions that control constituent transport. Consequently, the actual errors associated with the load estimates have not been defined. Some comparison checks with daily-value data, however, indicate that errors could exceed 50 percent of the reported estimates. Therefore, constituent-load estimates in this report should be used only to identify the potential major sources that will require further data collection for more accurate load quantification.

Separate annual-constituent loads were estimated using daily-mean flows for three different time periods: 1974, a high-flow year; 1977, a low-flow year; and 1980, a near-median-flow year. These three time periods were selected to show the variations in loads during differing flow regimes. Two sets of model-calibration data were used in this report. One set contained all of the constituent data available from 1970-85, and the other set contained all of the data available within plus or minus 3 months of the water year for which the load was being estimated. By selecting data collected within this 18-month time period, the calibration data set usually contained 12 constituent determinations. The resultant loads from these two calibration data sets are compared later in this report. The 16 years of data (1970-85) generally includes model-calibration data during periods of larger streamflows which tends to reduce load-estimate errors associated with extrapolated predictions. Some bias in the load estimate for any given water year is probable if changes in constituent transport occurred over the 16-year period. These changes could result from changes in land- and water-use activities. If changes occurred, the smaller data set (18-month period) might be more appropriate. Both data sets, however, tended to produce comparable results.

Trends Analysis

The seasonal Kendall test (Crawford and others, 1983) was used to determine monotonic time trends in constituent concentrations in the Yakima River basin. Results of this test are shown in table 51 at the back of report. This distribution-free test (based on ranking of data values) uses a modified form of Kendall's tau to determine trends.

The seasonal Kendall test involves hypothesis testing for trend detection. The null hypothesis is that the variable of interest (for example, constituent concentration) and its time of observation are independent, which indicates no trend (Smith and others, 1982). The chance of making an error by rejecting the null hypothesis when a trend actually does not exist is measured by probability level (ρ). For example, if $\rho = 0.10$, then there is a 10 percent chance of making an error when rejecting the null hypothesis. In this report, test results that yielded a ρ less than or equal to 0.10 were considered significant for indicating upward or downward trends in constituent concentrations.

Seasonal Kendall test unadjusted for streamflow

Seasonal patterns often are observed in water-quality data, and they may affect results from trend analyses. For example, in the calculation of long-term trends, data collected during an extreme high-flow winter storm should not be compared to data collected during a low-flow summer condition. To minimize erroneous conclusions that could result from these types of comparisons, data collected in the same month of different years are compared (such as comparison of values from January 1974 with those from January 1985). When the later constituent value (in time) is larger, a plus is scored, but when lower, a minus is scored (Smith and others, 1982). Equal numbers of pluses and minuses indicate the absence of a trend. When there are significantly more pluses than minuses, an upward trend in constituent concentration is likely. In this non-parametric test, censored data (less-than values) were divided by two and were included in the analysis.

Trends, unadjusted for streamflow, are important, because they represent changes in constituent concentrations that may affect water quality including the biota.

This trend analysis was made using monthly constituent concentrations from sites with 4 to 8 years of data collected from 1974 through 1981 WY. Only those trends for sites with concurrent data records should be used for intersite comparisons. Concurrent data are more likely to be representative of similar hydrologic conditions and corresponding time intervals for changes in land- and water-use activities. To minimize the effect of differences in sampling-time periods, trends from those sites with 5 or 6 years of data are compared among one another, while trends from sites with 7 or 8 years are compared among one another.

Seasonal Kendall slope estimator

To estimate the magnitude of the trend, a seasonal slope estimator is computed (Hirsch and others, 1982). The slope estimator is the median of the data set containing the differences between data values collected in the same month of different years divided by the number of years between the data. For example, assume that the total phosphorus concentration at a site was 0.2 mg/L (milligrams per liter) in January 1974 and 0.3 mg/L in January 1975. The difference between the values divided by the number of years between the data is 0.3-0.2/1975-1974 = 0.1 mg/L per year. After computing these differences for each of the months for all combinations of years, the slope is reported here as the median change in the constituent value per year. The slope also is reported in units of percent change per year and is calculated as follows:

(slope divided by median constituent value) x 100.

Seasonal Kendall flow-adjusted procedure

Trends in water quality are associated not only with fluctuations in climate and flow but also with man-caused changes in basin processes, including land-use practices, point-source loading rates, and agricultural and forestry practices. Flow-adjustment procedures (removing constituent-concentration fluctuations due to flow) were used to determine trends that are associated with changes in basin processes. This procedure involves testing for changes in the relation between flow and constituent concentration over the period of interest (Crawford and others, 1983). Flow-adjusted trend results are shown in table 51 at the back of this report. For flow-adjusted trends, the models used for determining relations between constituent concentration (dependent variable) and discharge (independent variable) are linear (equation 2 listed in table 51), log-linear (equation 3), hyperbolic (equation 4.1

to 4.8), inverse (equation 5), quadratic (equation 6), log-log (equation 7), and log-quadratic log (equation 8). These equations types correspond to the models recommended by Crawford and others (1983, p. 11-12).

SOURCES AND CHARACTERISTICS OF AVAILABLE SURFACE-WATER-QUALITY DATA

Sources of Water-quality Data

Water-quality data collected from streams in the Yakima River basin over a time span of about 50 years were collated for interpretation in this report. Most of the available surface-water-quality data for the Yakima River basin were collected by four Federal agencies and one State agency (listed below).

Water-quality data for more than 800 parameters have been collected from 502 sites (table 52 at the back of report; pl. 1). The sampling agencies have collected these data from the following numbers of sites through 1985 WY:

180 sites -- U.S. Geological Survey (some of these sites were sampled in cooperation with the Yakima Indian Nation and the Washington Department of Ecology),

114 sites -- U.S. Forest Service,

94 sites -- U.S. Bureau of Reclamation,

36 sites -- U.S. Environmental Protection Agency,

32 sites -- Washington Department of Ecology (does not include special sampling in 1985 for DDT (dichlorodiphenyldichloroethane) compounds and other contaminants; Johnson and others, 1986),

36 sites -- CH2M HILL (data-collection activities for the Washington Department of Ecology),

9 sites -- U.S. Department of Agriculture, Bureau of Plant Industry, Division of Irrigation Agriculture (early 1940 data), and

1 site -- U.S. Fish and Wildlife Service.

Several of these agencies collected data from the same sites; however, the sampling programs among agencies appeared to be coordinated, because most samples were not collected at the same time.

Using the number of determinations of specific conductance as an approximate measure for estimating sampling frequency, the following frequencies are observed:

Number of sites	Sampling frequency statistic
340	One or more samplings, 1940-85 WY.
46	Four or more consecutive years of data collected from 1974-81 WY.
26	Eight consecutive years of data collected from 1974-81 WY.
34	Forty-eight or more months with determinations and six or more consecutive years of data from 1974-81 WY.

The qualitative-analysis data set for specific conductance consists of all data from the 340 sites. The quantitative-analysis data set consists of data from the 34 sites that had 48 or more determinations from 1974-81. These 34 sites have monthly data with adequate seasonal and annual coverage to represent water-quality conditions at 9 locations in the main stem of the Yakima River and at 25 of the major tributaries and canals.

The number of sampling sites and corresponding sampling frequencies for specific conductance (listed above) are typical of the available data for stream temperature, pH, dissolved oxygen, turbidity, total phosphorus, dissolved orthophosphate, ammonia, nitrite plus nitrate, dissolved solids, and suspended sediment. Accordingly, these constituents were interpreted using the quantitative approach at the 34 sampling sites. Sampling frequencies for major and trace inorganic constituents, pesticides and other trace synthetic organic compounds, radiochemicals, fecal-indicator bacteria, and other biological determinations were generally low and sporadic throughout the basin. Therefore, these determinations generally were interpreted using the qualitative approach.

Types of Water-quality Determinations

Water-quality samples have been analyzed for a variety of physical, chemical, and biological constituents and properties. These determinations have been categorized into 10 groups: (1) PHYSICAL PROPERTIES and field measurements consisting of temperature, pH, turbidity, dissolved oxygen, and specific conductance; (2) MAJOR INORGANIC IONS; (3) TRACE ELEMENTS; (4) MAJOR METALS including iron, manganese, and aluminum; (5) NUTRIENTS, including those constituents containing nitrogen and phosphorus; (6) MAJOR ORGANIC COMPOUNDS including organic carbon, oil and grease, chemical-oxygen demand, and biochemical-oxygen demand; (7) TRACE ORGANIC COMPOUNDS AND PESTICIDES including priority organic pollutants as identified by the EPA; (8) RADIOCHEMICALS; (9) BIOTA such as bacteria, algae, invertebrates, and other organisms, and (10) SEDIMENT including suspended sediment in water. The number of samples for each of these groups are shown in figure 14 for the ambient surface-water monitoring sites.

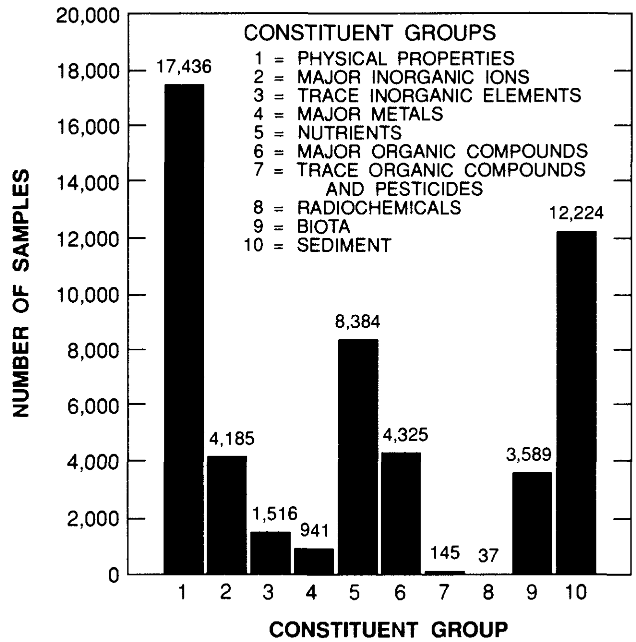


Figure 14.--Number of surface-water-quality samples by constituent group for samples collected in the Yakima River basin, Washington 1940-85 water years.

The physical-property, sediment, and nutrient groups had the largest number of samples, probably because the constituents (1) are the least costly to determine, (2) can provide a good preliminary indication of water-quality conditions, (3) are perceived as being associated with water-quality concerns in the basin, and (4) have analytical methods with small detection levels that have been available for the last couple of decades. In contrast, the potentially toxic constituent groups including the trace elements, pesticides and other trace organic compounds, and radiochemicals had the smallest number of samples for determining spatial and temporal variability. Most of the samples in the biota group represent measurements of fecal indicator bacteria.

Spatial Distribution of Sampling Sites

The locations of the historical sampling sites are shown in figure 15 for selected collection agencies. The agencies conducted different types of data-collection activities to meet various agency responsibilities that include water-quality surveillance monitoring, pollution control, future land-use or water-use planning, research, and resource assessment. These various agency responsibilities dictate the placement and number of sampling sites and can affect the applicability and availability of the data for broad-scale interpretation. As shown in figure 15, the U.S. Forest Service sites are located in the headwaters in the Wenatche National Forest; USBR and the WDOE sites are located along the main stem of the Yakima River and near the mouths of

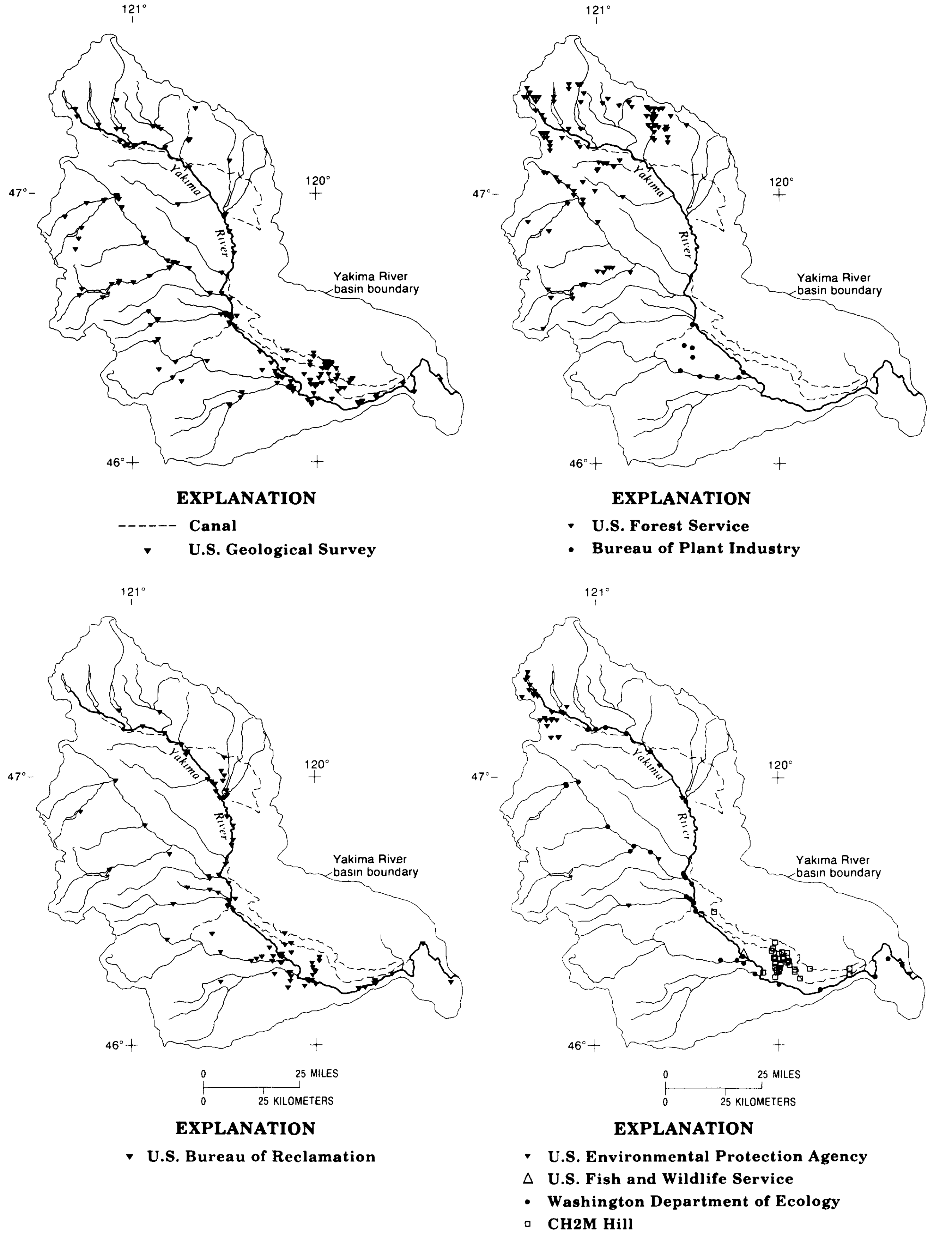


Figure 15.--Distribution of historical water-quality sites by collection agency in the Yakima River basin, Washington, 1940-85 water years.

major tributaries (including agricultural-return flows); EPA and CH2M Hill sites are located in small detached areas, probably established for evaluating specific questions or problems; and the USGS sites are spread more evenly throughout the basin, as a result of having cooperative studies with different agencies including the Yakima Indian Nation and WDOE.

Screening of the qualitative data (all available data) resulted in a quantitative data set that has been substantially reduced in spatial coverage. For example, the number of sampling sites for total phosphorus determinations decreased by a factor of five from 171 to 34 sites. Some of the qualitative sites only have one determination, and the quantitative sites have more than 48 determinations collected in 6- to 8-consecutive water years from 1974 through 1981.

Temporal and Hydrological Distribution of Samples Used in the Quantitative Data Analysis

Intersite comparisons of water-quality data necessitate that the data from the sampling sites be temporally and hydrologically comparable. For example, it would be inappropriate to compare data collected at one site during summer low flows with data collected at another site during winter high flows. To evaluate data representation at the 34 sites selected for the quantitative analysis, the annual and monthly distributions of data were compared among sites. In addition, the sampling coverage was evaluated against the flow-duration curve to ensure that the data were representative of the water-quality conditions that vary with streamflow. The quantitative data set consists of one USGS site (Yakima River at Kiona) and 33 USBR sites. At several of the USBR sites, the USGS also collected about two samples per month for a 1-year period in 1974 or 1975 WY.

Annual distributions of the number of samples collected at two sites for nitrite-plus-nitrate nitrogen and fecal-coliform bacteria are shown in figure 16. The Yakima River site at Cle Elum (RM 183.1) shows the distributions that are typical for a USBR site; the Yakima River at Kiona (RM 29.9) shows the distributions that are typical for the USGS site. At both sites, nitrite-plus-nitrate data were analyzed using the quantitative approach. Notice that nitrite-plus-nitrate data at each site consist of 6 or more consecutive years of data. The USGS site at Kiona averages 12 or more determinations per year, while the USBR site at Cle Elum averages about 10 determinations per year. The sampling frequency for fecal-coliform bacteria at Cle Elum is typical of the sporadic sampling frequency for data that were interpreted using the qualitative approach. In contrast, the Kiona site was the only site in the basin that met the data requirements for the quantitative analysis of fecal-coliform bacteria.

Monthly distributions of the number of samples collected at the Kiona and Cle Elum sites for nitrite plus nitrate and fecal-coliform bacteria are shown in figure 17. During the 8-year period from 1974-81, eight determinations for each month would be expected at both sites if the sampling frequencies were monthly. The sampling frequency, however, was greater than monthly at the Kiona site for most of the months. To eliminate the bias that results from having more than one determination

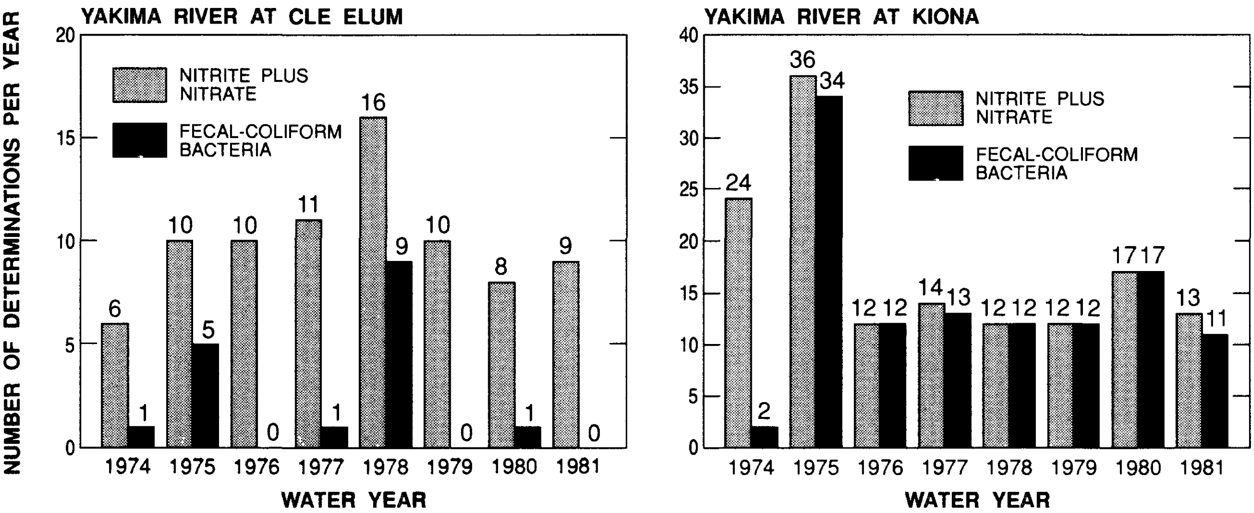


Figure 16.--Number of annual determinations of nitrite plus nitrate and fecal-coliform bacteria for the Yakima River at Cle Elum and Kiona, Washington, 1974-81 water years.

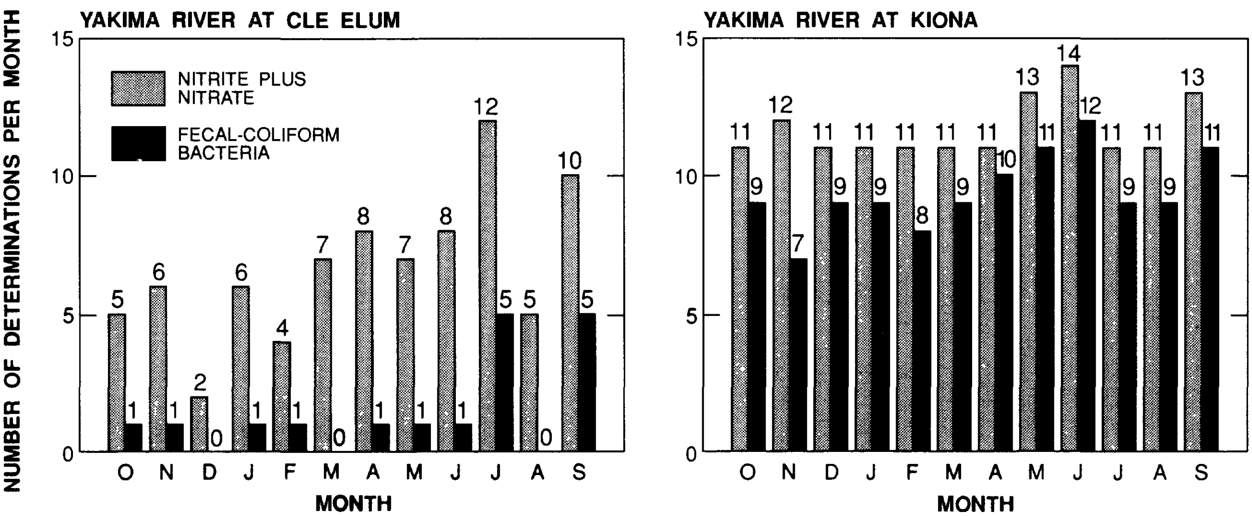


Figure 17.--Number of monthly determinations of nitrite plus nitrate and fecal-coliform bacteria for the Yakima River at Cle Elum and Kiona, Washington, 1974-81 water years.

per month per year, only one determination (the first determination) from each month for each year was used for intersite and intrasite comparisons of annual constituent distributions and trend results. The sampling frequencies for the quantitative interpretation of the nitrite-plus-nitrate data from the USBR sites were more sporadic, but approximately monthly. Ten of the 12 months had five or more determinations, February had four determinations, and December had only two determinations. Consequently, the annual distributions of constituent concentrations for the USBR site are slightly biased because of the lack of December and February data. The number of monthly fecal-coliform-bacteria determinations at the Kiona site should provide an adequate representation for each month. In contrast, the poor monthly coverage of fecal-coliform-bacteria determinations at Cle Elum (USBR site) indicates that annual, seasonal, and long-term variations cannot be adequately defined.

To ensure that monthly water-quality data can be used to accurately compute frequency distributions of constituent concentrations, data need to be collected over the range of daily streamflows. In addition, the frequency of water-quality-data collection should correspond to the frequency of streamflow occurrence (flow-duration percentages) of daily streamflows. For example, if streamflow in the Yakima River at Kiona exceeded 10,000 ft^3/s about 5 percent of the time for 1974-81 WY, then about 5 percent of constituent-concentration data ideally should have been collected when streamflows exceeded 10,000 ft^3/s. The collection of monthly samples at a site does not guarantee this data coverage over the range of flow-duration percentages. The numbers of nitrite-plus-nitrate determinations that correspond to the flow-duration intervals are shown in figure 18 for the Yakima River at Cle Elum and Kiona. In this figure, the percentage range that corresponds to the duration of daily mean flows was divided into 10-percent segments between 10 and 100 percent (near 100 percent corresponds to low flows) and 5-percent segments between 0 and 10 percent (near 0 percent corresponds to high flows). Ideally, the 10-percent segments should each contain 10 percent of the determinations and the 5-percent segments should contain 5

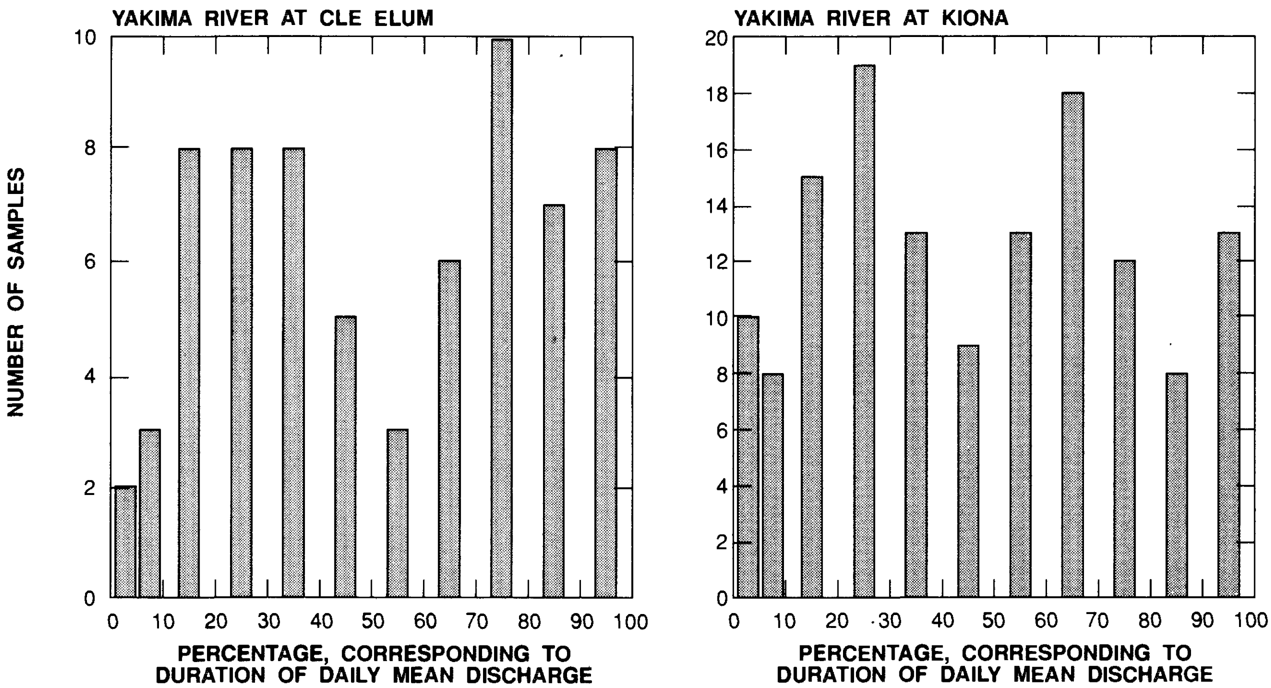


Figure 18.--Distribution of nitrite-plus-nitrate samples collected over the range of daily mean discharges for the Yakima River at Cle Elum and Kiona, Washington, 1974-81 water years.

percent of the determinations. On the basis of having 8 years of monthly data, there should be a total of 96 determinations (10 percent of 96 equals 9.6 determinations per 10-percent segment; 5 percent of 96 determinations equals 4.8 determinations per 5-percent segment). The data from the Kiona site appears to adequately cover the range of flow-duration intervals; the data coverage for the Cle Elum site appears to be slightly lacking in coverage at the high flows and even more so at the median flows. However, no segment of the duration is devoid of data. For this report, the availability of USBR data over the range of streamflows was assumed to be acceptable for statistically analyzing the data.

Other Relevant Data Bases

Ancillary data are used in this study to quantify relations between historical water-quality conditions and natural and human factors (table 13). For example, these data can be used to explain trends in water quality.

ANALYSIS OF AVAILABLE SURFACE-WATER-QUALITY DATA

Chemical concentrations in streams are related to many factors that are associated with land- and water-use activities. In addition, the volume of streamflow, which is extensively regulated by storage reservoirs in the Yakima River basin, is related directly to the dilution of dissolved chemicals and the rate of transport of suspended sediment and suspended chemicals derived from weathering processes and soil erosion.

Streamflow Conditions

Water-quality conditions during low flows generally coincide with larger concentrations of dissolved chemicals, and conditions during high flows generally coincide with larger concentrations of suspended chemicals. Quantitative interpretation of water-quality data for intersite and intrasite comparisons requires knowledge of short-term (1974-81 WY) and long-term streamflow conditions.

A ranking of annual streamflow data for the period of record (61 years, 1906 to 1986 WY, with some missing years of record) for the Yakima River at Kiona, indicates that the flow in 1974 WY ranks as the sixth largest flow; the 1977 flow ranks 61st which is the lowest flow; and the 1980 flow ranks 34th which is a near median flow for the period of record (fig. 19).

Relation of Hydrologic Conditions during 1974-81 Water Years to Long-term Hydrologic Conditions in the Yakima River Basin

Comparison of flow-duration curves for the period selected for quantitative interpretation (1974-81 WY) with the longer-time periods (1960-86 WY and 1906-86 WY) indicates similarity in hydrologic conditions (fig. 20). The streamflow site, Yakima River at Kiona (RM 29.9) was selected for this hydrologic comparison, because it represents the flow leaving the basin. The period, 1906-86 WY, represents the total period of streamflow record at Kiona; the period, 1960-86 WY,

Table 13.--Ancillary data used for interpreting historical water-quality data in the Yakima River basin, Washington

Data base	Description	Reference
Acid Deposition System Data Base	Chemical analyses of wet-atmospheric deposition samples from the National Atmospheric Deposition/ National Trends Network sites.	Watson and Olsen, 1984
Resources for the Future, Environmental Data Inventory	Constituent loads discharged to streams from industrial and municipal-waste-treatment plants and nonpoint sources.	Gianessi, 1986
Resources for the Future, Pesticide Usage Inventory	Inventory of pesticides used by crop type	Gianessi and Puffer, 1988 Sacha and others, 1987
U.S. Department of Agriculture	Fertilizer use by county	Alexander and Smith, 1990
U.S. Census of Population	Population by county and selected cities and towns	
U.S. Geological Survey National Digital Carto-graphic Data Base	Land use and land cover, hydrography, and basin boundary	Fegeas and others, 1983
U.S. Geological Survey Water-Use Information Program	12 categories of water use	
Washington Department of Ecology	Files of effluent discharges and constituent concentrations and loads	Washington Department of Ecology files. (manually collated by U.S. Geological Survey personnel, 1988)

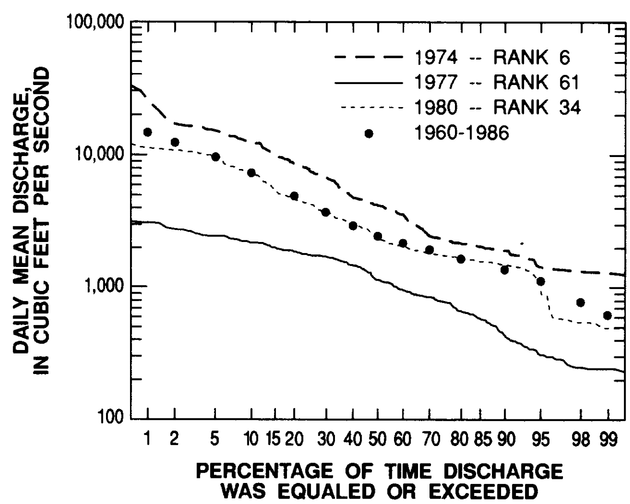


Figure 19.--Flow-duration curves for four selected periods for the Yakima River at Kiona, Washington, 1960-86, 1974, 1977, and 1980 water years. Rank 1 corresponds to the highest flow and rank 61 corresponds to the lowest flow year.

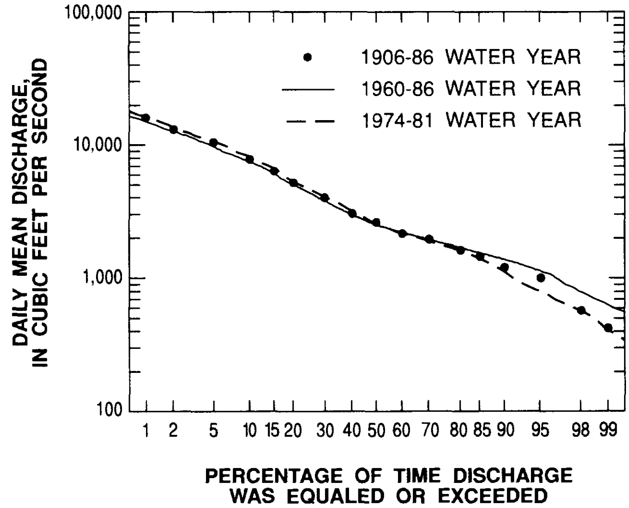


Figure 20.--Flow-duration curves for three selected time periods for the Yakima River at Kiona, Washington, 1906-86, 1960-86, 1974-81 water years.

represents a recent long-term period that was minimally impacted by major construction on the irrigation system. Generally, all of the flow-durati‹n curves appear to be similar. This similarity suggests that water-quality conditions from 1974-81 WY were not altered by atypical hydrologic conditions, when compared to long-term streamflow data.

Water-quality Constituent Loads during Low-, Median-, and High-streamflow Years

To evaluate the effect of hydrologic variations on constituent loads, annual constituent loads in this report are computed for a high-flow year (1974 WY), a low-flow year (1977 WY), and a median-flow year (1980 WY). Flow duration curves for these years are shown in figure 19.

Spatial and Seasonal Variations

Streamflow conditions in the Yakima River basin can vary widely, both spatially and seasonally. Both of these variations were examined in this report for the 1974-81 WY.

Distributions of monthly instantaneous streamflows for samples collected from 1974-81 WY along the main stem of the Yakima River are shown in figure 21. This general overview indicates a small increase in median streamflow from RM 183.1 to 140.4. The decrease in streamflow from RM 140.4 to RM 121.2 is due primarily to water diversion into Roza Canal at RM 127.9. The increase at RM 113.2 results from the Naches River inflow at Yakima RM 116.3 and the partial return of Roza Canal water that is used for power generation at RM 113.3. The decrease in median streamflow at RM 104.6 results from water diversion into Wapato Canal. Additional water is diverted into Sunnyside Canal at RM 103.8 (not shown in fig. 21). Downstream from this point, the median streamflow in the main stem gradually increases as a result of agricultural-return flow, canal-return flow, and contributions from small tributaries.

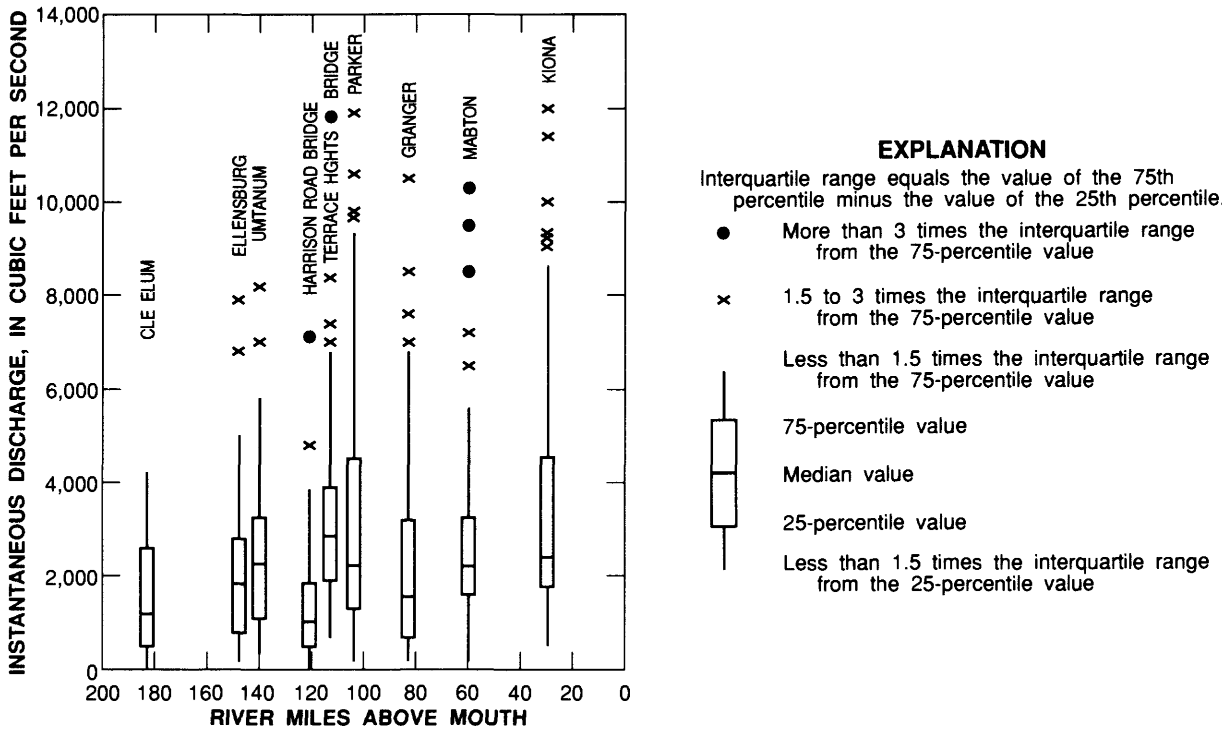


Figure 21.--Instantaneous discharge in the Yakima River, Washington, 1974-81 water years (some large values are not shown).

A more comprehensive characterization is shown in table 14 where annual streamflows are based on continuous streamflow data collected by the USGS from 1974-81 WY. A general understanding of the surface-water flow and components of the water budget in the Yakima River basin can be obtained by examining the annual water contributions.

The first major canal diversion, Kittitas Canal intake, is located a short distance downstream from Lake Easton Dam at RM 202.5. Kittitas Canal withdraws streamflow that is equivalent to 10 percent of the total annual flow in the Yakima River at Kiona at RM 29.9. The three reservoirs upstream from Yakima RM 185.6 account for about 80 percent of the total reservoir storage (1,070,700 acre-feet) in the basin. The measured annual flow at the Yakima River at Cle Elum (RM 183.1) is about 44 percent of the annual flow at Kiona (or 54 percent of the Kiona flow when the Kittitas Canal diversion is included) even though the subbasin above RM 183.1 contains only 9 percent of the drainage area. The relatively large contribution of water from upstream from RM 183.1 reflects larger contributions of precipitation from the eastern slopes of the Cascade Range. In addition, large water losses occur in the lower valley (downstream from Yakima RM 183.1) owing to evapotranspiration and (or) ground-water seepage.

At the Yakima River at Umtanum (RM 140.4), the flow is equivalent to 67 percent of the flow at Kiona while the drainage basin upstream from RM 140.4 accounts for only 28 percent of the total area. The flow contribution from upstream from Umtanum does not include evapotranspiration losses of irrigation water from more than 200 mi^2 of agricultural land in Kittitas Valley. The streamflow passing Yakima RM 107.2 at Union Gap is

Table 14.--Drainage areas and mean-annual streamflow for selected sites in the Yakima River basin, Washington, 1974-81 water years

[Values are reported as a percentage of the basin drainage area (5,615 square miles at Yakima River at Kiona) or mean-annual streamflow (3,764 cubic feet per second that includes flows in Kennewick and Kiona canals) at Yakima River mile 29.9. "NA" indicates not applicable; "--" indicates data not available; "Measured" indicates that streamflow was measured at gaging site or drainage area was measured to gaging site; RM = river mile]

Yakima river mile	Site name	Yakima river-mile confluence with tributary or canal	Percent of total drainage area at Yakima RM 29.9		Percent of mean-annual streamflow flowing at or diverted downstream of Yakima RM 29.9. Negative values indicate surface-water withdrawal.	
214.5	Keechelus Dam		<1		--	
	Kachess River	203.5	1		--	
	Kittitas Canal intake	202.5	NA		-10	
	Cle Elum River	185.6	4		--	
183.1			9	Measured subtotal	44	Measured
	Crystal Creek	183.1	--		--	
	Thornton Creek	177.5	--		--	
	Teanaway River	176.1	4		10	Estimated
	Kittitas Main Wasteway	173.9	--		--	
	Horseshoe Canyon Creek	173.1	--		--	
	Morrison Canyon Creek	172.1	--		--	
	Swauk Creek	169.9	2		--	
	Cascade Canal intake	168.9	--		--	
	Taneum Creek	166.1	1		--	
	Cascade Canal Wasteway	165.3	--		--	
	Town Canal intake (Ellensburg Water Co.)	161.3	--		--	
	Cascade Canal intake	160.0	--		--	
					--	
	Dry Creek	157.6	--		--	
155.9			18	Measured subtotal	--	
	Manastash Creek	154.5	1		--	
	Reecer Creek	153.7	2		--	
	Benway Canyon Creek	148.9	--		--	
	Wilson Creek	147.0	3		--	
	Cherry Creek	147.0	4		4	Measured
140.4			28	Measured subtotal	67	Measured
	Umtanum Creek	139.8	1		--	
	McPherson Canyon Creek	136.2	<1		--	
	Squaw Creek	135.0	2		--	
	Burbank Creek	130.0	<1		--	
127.9			32	Measured subtotal	--	
	Roza Canal intake	127.9	NA		-33	Estimated
	Selah Creek	123.7	2		--	
	Wenas Creek	122.4	3		--	
	Naches River	116.3	20		43	Estimated
	Roza canal power return	113.3	NA		21	Measured
	Moxee Drain	107.6	3		--	
	Wide Hollow Creek	107.4	1		--	
	Ahtanum Creek	106.9	3		2	Measured
107.2			65	Measured subtotal 1/	100	Measured
	Wapato Canal intake	106.7	NA		-23	Measured
	Sunnyside Canal	103.8	NA		-15	Measured
103.7					64	Measured
	Unnamed slough	91.1	--		--	
	East Toppenish Drain	86.0	--		--	
	Sub-Drain 35	83.2	--		--	
	Granger Drain	82.8	--		--	
	Marion Drain	82.6	NA		--	
	Toppenish Creek	80.4	12		--	
	Satus Creek	69.6	12		--	
	Sulphur Creek	61.0	3		--	
59.8			--		91	Measured
55.4			96	Measured subtotal	--	
	Chandler Canal Intake	47.1	--		-28	Measured
46.3			97	Measured subtotal	--	
	Spring and Snipes Creeks	41.8	1		--	
	Chandler Plant Return	35.8	--		25	Measured
	Kennewick Canal intake	35.8	--		3	Estimated
	Kiona Canal	34.9	--		1	Estimated
	Corral Canyon Creek	33.5	--		--	
29.9	Includes water diverted by Kiona and Kennewick Canals		100	percent	100	percent -- Measured

1/ Flow at Yakima river mile 106.8 plus flow in Roza Canal mile 11 was 112 percent of mean-annual streamflow at or diverted downstream of Yakima RM 29.9.

equivalent to 100 percent of the annual streamflow at Kiona. When one considers the additional flow that is diverted around the Union Gap site in Roza Canal for irrigation, the annual contribution from upstream from RM 107.2 is 112 percent of the streamflow at Kiona. Therefore, the surface-water losses due to evapotranspiration and percolation into the ground water in the lower valley are at least 12 percent of the annual streamflow at Kiona plus the additional water losses from about 1,800 mi^2 of contributing drainage area between Union Gap and Kiona. Assuming an annual average of 10 inches of precipitation downstream from Union Gap, the loss is estimated to be equivalent to about 50 percent of the streamflow observed at Kiona.

The Wapato and Sunnyside Canal intakes are located at Yakima RM's 106.7 and 103.8, respectively. These canals divert an equivalent of about 38 percent of the annual streamflow at Kiona. These diversions reduce summer streamflows at the Yakima River near Parker site (RM 103.7) to a few hundred cubic feet per second; consequently, the annual flow near Parker is reduced to an equivalent of 64 percent of the Kiona flow.

Between Mabton (RM 59.8) and Kiona (RM 29.9), an equivalent of about 28 percent of the annual streamflow at Kiona is diverted into Chandler Canal at Yakima RM 47.1 for power generation and irrigation. A water volume equivalent to 25 percent of the Kiona flow is diverted back to the main stem at RM 35.8. This power diversion reduces summer flows in the main stem to less than 200-300 ft^3/s, decreasing the stream's capacity to dilute point-source discharges from the City of Prosser. The point-source discharges from Prosser, however, are presently (1990) diverted upland when Yakima River flows are less than 200 ft^3/s.

Despite the extensive regulation of water for power generation and irrigation, monthly streamflow variations do occur in response to seasonal variations in precipitation and air temperature. Mean-monthly streamflows are shown in figure 22 for four sites down the main stem of the Yakima River. At these Yakima River sites (at Cle Elum, RM 183.1; at Umtanum, RM 140.4; near Parker, RM 103.7; and, at Kiona, RM 29.9) the larger flows begin to occur in April which coincides with the snowmelt period. Reservoir contents generally peak in May, June, or July and begin to decline as streamflows are maintained upstream from Parker by reservoir releases for irrigation and fisheries (to cover redds). The streamflows near Parker and at Kiona sites remain relatively small during the summer months due to the upstream diversions for irrigation. Shortly after irrigation, the streamflows in October and November are small upstream from Parker; however, the flows abruptly increase in December as winter precipitation increases. As the air temperatures decrease, the precipitation accumulates in the winter snowpack providing additional water storage for release later in the year; as a result, the variations in streamflow patterns do not coincide with the precipitation patterns.

The mean-monthly contribution of streamflow to the main stem from tributaries containing agricultural- and canal-return flow between the Yakima River near Parker (RM 103.7) and the Yakima River at Kiona (RM 29.9) is shown in figure 23. This contribution varies from a low of 20 percent of the equivalent monthly streamflow at Kiona during snowmelt to almost 80 percent during the summer months. As a result, the water quality of the agricultural- and canal-return flows dictates the river quality downstream from Parker during the summer.

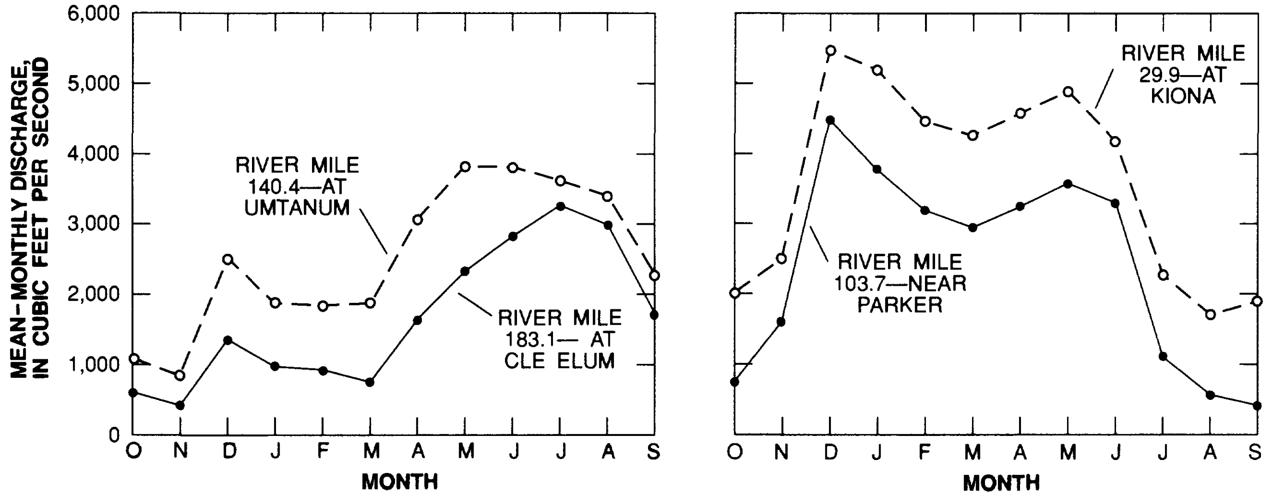


Figure 22.--Mean-monthly discharge for the Yakima River at Cle Elum, at Umtanum, near Parker, and at Kiona, Washington, 1974-81 water years.

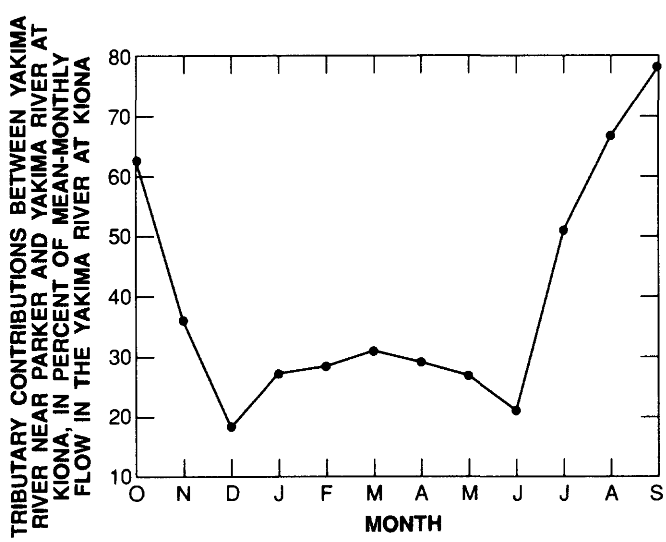


Figure 23.--Mean-monthly contribution of streamflow to the Yakima River at Kiona from tributaries between Yakima River near Parker (RM 103.7) and Yakima River at Kiona (RM 29.9), Washington, 1974-81 water years.

The seasonal variations of monthly mean streamflows are shown in figure 24 for intersite comparisons of main-stem sites during high- (1974 WY), low- (1977 WY), and median- (1980 WY) flow years. A description of streamflow for the months shown in figure 24 follows:

(1) JANUARY -- Large winter storms and warmer air temperatures (sometimes caused by Chinook winds) have resulted in extreme streamflows that are several times larger than those observed during median-flow years. For example, a large storm in January 1974 resulted in a maximum daily mean flow of 37,400 ft^3/s in the Yakima River at Kiona, which was equaled or exceeded less than 0.1 percent of time from 1974-81 WY. January flows

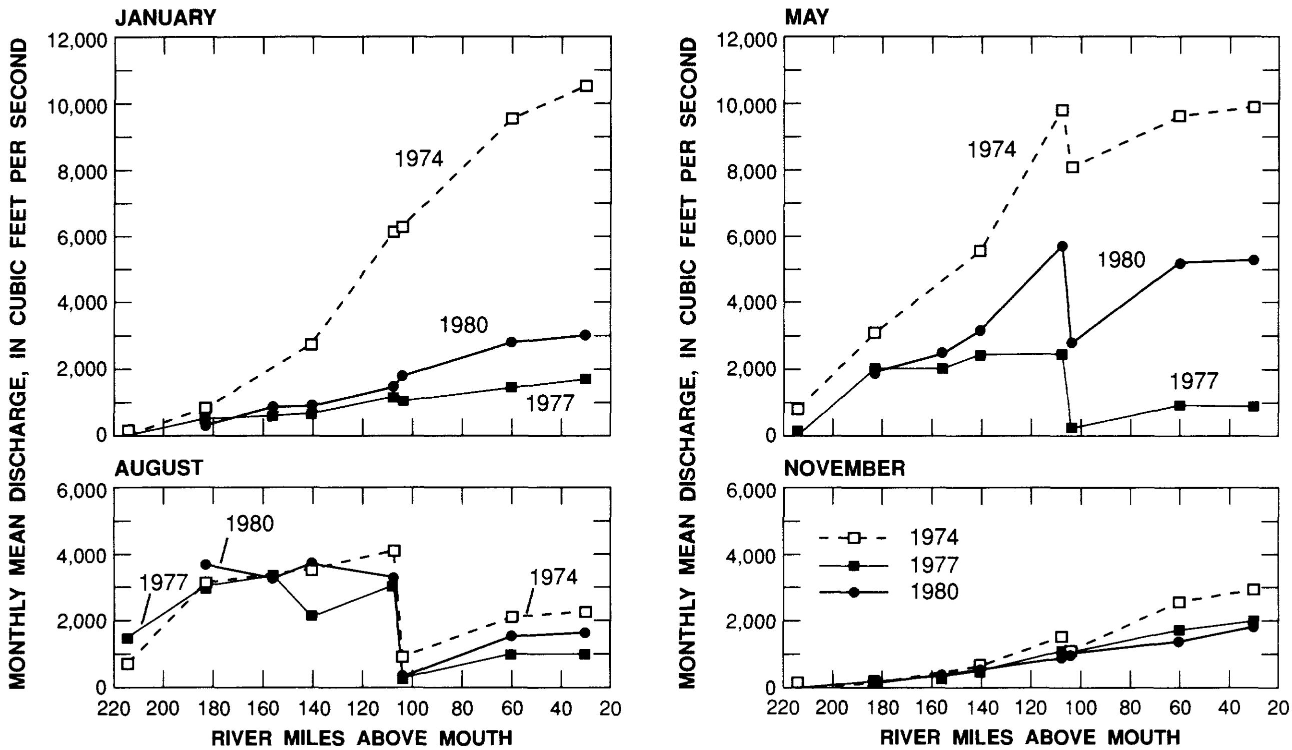


Figure 24.--Monthly-mean discharge for January, May, August, and November in the Yakima River, Washington, 1974, 1977, and 1980 water years. This figure should not be used for interpolating discharge between the measured points.

generally show a gradual increase down the main stem, and river diversions are near minimum (some diversions occur for power generation).

(2) MAY -- Snowmelt increased streamflows, and diversions for power generation and irrigation were near maximum. Streamflows generally increased down the main stem except during the low-flow conditions in 1977 WY. The 1977 WY flows resembled those that typically occur during the mid-summer irrigation season. The diversions into Wapato Canal (RM 106.7) and Sunnyside Canal (RM 103.8) accounted for large decreases in the main-stem flow.

(3) AUGUST -- Streamflows were extensively regulated for agriculture and power generation. August streamflows downstream from Parker are typically low each year owing to large upstream canal diversions. The streamflows in the main stem upstream from the City of Yakima (about RM 115) were maintained near maximum annual levels by releases from the large reservoirs in the headwaters of the Yakima and Naches Rivers. For each of these years, low flows were observed below the diversion dams at Roza (RM 127.9), Wapato (RM 106.7), Sunnyside (RM 103.8), and Prosser (RM 47.1). Decreases at Roza Dam and Prosser Dam are not shown in figure 24, because continuous streamflow data were not available.

(4) NOVEMBER -- During the seasonally low flows in November after irrigation, streamflows increased slightly down the main stem of the Yakima River. Water diversions were reduced greatly, and increases in main-stem flow may be attributed to ground-water seepage. The range of streamflows for November is relatively small when compared to January and May. The streamflows during November and August are less variable than streamflows during January or May among low, median, and high-flow years; regardless of the annual runoff conditions, the low flows in November and August are similar among years.

pH, Alkalinity, and Acidity

pH is a measure of hydrogen-ion activity, alkalinity measures the capacity of water to react with and neutralize acid (hydrogen ions), and acidity measures the capacity of water to react and neutralize a base (hydroxyl ions). Alkalinity is generally attributable to aqueous concentrations of bicarbonate and carbonate ions in most surface water, and acidity is attributable to several aqueous ions: carbonic acid, bisulfate, ferrous and ferric iron, and organic acids (Hem, 1985, p. 109-111). Water is neutral at a pH of 7 and may range from less than 0 (highly acidic) to more than 14 (highly alkaline). pH may change in a stream by an influx of acidic or alkaline wastes, or fluctuations in photosynthesis and respiration (due to the release and uptake of carbon dioxide by aquatic plants).

pH and alkalinity are especially important, because they either directly or indirectly affect the toxicity of several chemical constituents to aquatic organisms. Toxicity to freshwater aquatic life can occur when pH falls outside of the 6.5 to 8.5 range, and water is unsuitable for domestic-water supplies when the pH is outside of the 5 to 9 range (Washington State Administrative Code, 1988; U.S. Environmental Protection Agency, 1986). pH indirectly affects aquatic life by its ability to dissociate weak acids and bases. For example, as pH increases (more alkaline), the ammonium ion is dissociated to the toxic un-ionized ammonia form. Alkalinity in water serves to limit radical shifts in pH that might otherwise affect aquatic life. A minimum alkalinity of 20 mg/L as calcium carbonate ($CaCO_3$) has been established for the protection of aquatic life except where natural conditions are less (Washington State Administrative Code, 1988). Alkalinity also complexes certain trace metals, thereby reducing toxicity. For example, the chronic toxicity standard for cadmium ranges from 0.66 to 2.0 μg/L (micrograms per liter) for water ranging in hardness from 50 and 200 mg/L as $CaCO_3$, respectively, (Washington State Administrative Code, 1988). Alkalinity, which is carbonate hardness, is commonly a major contributor to total hardness in surface water.

Most (98 percent of the determinations) of the pH measurements and alkalinity concentrations in the basin ranged from 6.4 to 8.6 pH units and 14-182 mg/L as $CaCO_3$, respectively. In general, these concentrations are typical of natural river water not influenced by pollution. Natural river water ranges from 6.5 to 8.5 pH units with alkalinities less than 165 mg/L (Hem, 1985).

All pH and alkalinity data for the period of record, 1953-85, were evaluated against Washington State standards (table 15). No standards were available for acidity. Determinations not meeting pH standards are relatively few (table 15). Three percent of the 8,536 pH determinations did

Table 15.--Number of pH and alkalinity measurements not meeting selected Washington State water-quality standards and guidelines, Yakima River basin, Washington, 1953-85 water years

[State standards are published in the State of Washington Administrative Code (1988); "NA" not applicable; mg/L = milligrams per liter]

Map[1/] reference number	Station name	Number of observations	Number of observations not meeting selected standards or guideline: Freshwater aquatic life	Human health: Drinking water	Food-canning industry guideline
	pH: Freshwater aquatic life, unsuitable when outside range of 6.5 to 8.5 units. Drinking water, unsuitable for treatment when outside range of 5.0 to 9.0 units.				
4	Yakima River at Cle Elum	289	24	0	NA
5	Teanaway River near Cle Elum	46	2	0	NA
6	Yakima River near Thorp	47	1	0	NA
7	Wilson Creek at Thrall	107	3	0	NA
25	Naches River near Yakima	121	6	0	NA
26	Naches River near North Yakima	119	9	1	NA
27	Yakima River near Terrace Heights	98	9	0	NA
30	Wide Hollow Creek at Union Gap	60	2	0	NA
32	Yakima River at Union Gap	76	3	0	NA
33	North Fork Ahtanum Creek nr Tampico	24	2	0	NA
35	South Fork Ahtanum Creek nr Tampico	7	2	0	NA
40	Yakima River at Parker	240	7	1	NA
48	Yakima River near Toppenish	74	3	0	NA
60	Toppenish Creek at Alfalfa	14	2	1	NA
62	Toppenish Creek near Satus	47	1	0	NA
100	Yakima River at Kiona	957	25	3	NA
101	Yakima River at Van Geisen Bridge	59	6	3	NA
147	Domerie Creek above Roslyn intake	58	1	0	NA
150	Stave Creek 22	6	2	1	NA
156	Hyak Creek--head of Lake Keechelus	49	5	0	NA
160	Thetis Creek	10	1	0	NA
163	Rocky Run	1	1	0	NA
166	Silver Creek	24	1	0	NA
167	Cold Creek	10	3	0	NA
169	Meadow Creek at bridge	4	1	0	NA
170	Gale Creek at bridge	10	1	0	NA
172	Resort Creek 17	10	2	0	NA
180	Cabin Creek, 50 feet abv Log Creek	20	1	0	NA
181	Log Creek, 50 feet abv Cabin Creek	21	1	0	NA
185	Hyak Creek above sewage plant	1	1	0	NA
186	Silver Creek at Powerline Road	10	2	0	NA
187	North Fork Teanaway River	4	1	0	NA
199	Lion Gulch above Liberty Road	14	1	0	NA
210	Swauk Creek above Hurley Creek	11	1	0	NA
225	Manastash Creek	5	1	0	NA
227	South Fork Manastash Cr-Sec 17/16	2	1	0	NA
228	North Fork Manastash Cr-FS Boundary	2	1	0	NA
237	Quartz Creek	5	1	1	NA
238	Pile-up Creek	9	1	1	NA
240	Bear Creek	2	1	1	NA
241	Upper Little Naches River	2	1	0	NA
244	Upper American River	11	1	0	NA
246	Naches River	16	3	0	NA
247	Milk Creek	6	1	1	NA
249	Conrad Meadows	17	1	0	NA
250	Indian Creek	14	2	0	NA
251	Clear Creek	22	4	0	NA
252	Oak Creek at mouth	7	3	0	NA
253	Oak Creek	14	11	0	NA
254	North Fork Oak Creek	7	6	0	NA
255	South Fork Oak Creek	6	3	0	NA
256	Oak Creek at Counterfeit	9	3	0	NA
257	Middle Fork Oak Creek	6	4	1	NA
289	Hause Creek SENE Sec 28 T14N R14E	5	2	0	NA
299	KID Hover Wasteway near bottom	11	3	1	NA
300	KID Coyote Canyon Drain near bottom	64	1	0	NA
307	Chandler Canal--mile 0.6 nr Prosser	84	2	2	NA
308	Chandler Canal--mile 2.8 nr Prosser	85	3	2	NA
316	Kittitas Canal SE1/4 Sec 6 18N 19E	12	1	0	NA
318	Cowiche Creek SE1/4 Sec 9 13N 18E	21	1	0	NA

Table 15.--Number of pH and alkalinity measurements not meeting selected Washington State water-quality standards and guidelines, Yakima River basin, Washington, 1953-85 water years--Continued

Map[1/] reference number	Station name	Number of observations	Number of observations not meeting selected standards or guideline: Freshwater aquatic life	Human health: Drinking water	Food-canning industry guideline
	pH: Freshwater aquatic life, unsuitable when outside range of 6.5 to 8.5 units. Drinking water, unsuitable for treatment when outside range of 5.0 to 9.0 units.				
319	Cottonwood Canal Drain SE1/4 Sec 28	58	7	2	NA
320	Yakima River at Harrison Rd Bridge	73	1	0	NA
323	Drain at Birchfield Road	73	5	1	NA
324	Wide Hollow Creek near Gromore	35	1	0	NA
325	Wide Hollow Cr at W. Washington Ave	37	2	0	NA
327	Ahtanum Creek at mouth	73	2	0	NA
336	Griffin Lake Outlet	46	1	0	NA
338	Yakima River at bridge near Mabton	74	1	0	NA
347	Spring Creek at Hess Road	67	2	0	NA
348	Snipes Cr at Old Inland Empire Road	64	1	0	NA
349	Yakima River at Cle Elum	122	1	0	NA
353	Wilson Creek at Thrall Rd	68	1	0	NA
355	Yakima River at Umtanum	124	1	0	NA
363	Reecer Creek near mouth	10	1	0	NA
368	Cle Elum Res at Pump Barge	65	17	2	NA
378	Squaw Cr--0.3 mi abv Hwy 97 Bridge	19	2	1	NA
385	Rimrock Reservoir--100 m abv dam	58	3	0	NA
399	Yakima River at Kiona	45	5	0	NA
401	Big Creek	1	1	0	NA
402	Big Creek	1	1	0	NA
403	Jim Creek	1	1	0	NA
404	Big Creek	1	1	0	NA
405	Cabin Creek	1	1	0	NA
406	Cole Creek	1	1	0	NA
407	Cabin Creek	1	1	0	NA
408	Cabin Creek	1	1	0	NA
411	Tributary below Cabin Creek	1	1	0	NA
412	Cabin Creek	1	1	0	NA
413	Cabin Creek	1	1	0	NA
414	Silver Creek at Yakima River	1	1	0	NA
415	Silver Creek	1	1	0	NA
416	Yakima R at Easton	1	1	0	NA
417	Meadows Creek	1	1	0	NA
418	Upper Meadows Creek Main Stem	1	1	0	NA
419	North Fork Meadows Creek	1	1	0	NA
420	South Fork Meadows Creek	1	1	0	NA
422	Keechelus Lake	3	1	0	NA
428	Yakima River near Richland	18	3	0	NA
503	Sulphur Creek below Sheller Road	15	1	0	NA
	Alkalinity: Freshwater aquatic life, unsuitable when less than or equal to 20 mg/L as calcium carbonate. Food canning, unsuitable when greater than 300 mg/L as calcium carbonate.				
1	Yakima River above Cle Elum	24	7	NA	0
3	Cle Elum River near Cle Elum	24	5	NA	0
4	Yakima River at Cle Elum	195	10	NA	0
6	Yakima River near Thorp	24	2	NA	0
8	Yakima River at Roza Dam	121	2	NA	0
17	Bumping River at American River	23	14	NA	0
18	American River near Nile	24	5	NA	0
21	Naches River near Naches	47	1	NA	0
71	South Drain near Satus	4	0	NA	2
100	Yakima River at Kiona	501	0	NA	1
147	Domerie Creek above Roslyn intake	32	4	NA	0
156	Hyak Creek--head of Lake Keechelus	8	7	NA	0
166	Silver Creek	15	2	NA	0
180	Cabin Creek, 50 feet abv Log Creek	10	5	NA	0
181	Log Creek, 50 feet abv Cabin Creek	10	3	NA	0
218	Naneum Creek	7	1	NA	0
349	Yakima River at Cle Elum	5	1	NA	0
421	Keechelus Lake	3	3	NA	0
422	Keechelus Lake	3	3	NA	0
423	Keechelus Lake	3	2	NA	0

1/ For site locations, see plate 1.

not meet freshwater aquatic-life standards; 2 percent exceeded a pH of 8.5, and 1 percent were less than 6.5. More measurements did not meet standards during summer months (fig. 25) and probably were the result of increased photosynthetic activity from aquatic plants; however, more data also were collected in the summer than the winter.

About 3 percent of the 2,305 alkalinity determinations were less than the State standard for aquatic life (20 mg/L as $CaCO_3$). Most of these small alkalinities occurred at headwater sites in the Upper Yakima and Naches subbasins. The small alkalinities are not considered to be violations of standards, because they result from the local geology and soils which are lacking calcium carbonate. Fewer than 1 percent of the alkalinity determinations were greater than or equal to 300 mg/L as $CaCO_3$, the guideline for food canning (U.S. Environmental Protection Agency, 1986). Exceedances occurred with greater frequency during summer months; but, as with pH, some months have more alkalinity determinations than others. Exceedances of the food-canning guidelines occurred only at South Drain near Satus and at the Yakima River at Kiona (table 15).

The occurrence of acid deposition (wet and dry deposition) in the Yakima River basin depends on natural and man-caused influences. Precipitation that falls in the basin comes primarily from the west-southwest, passing over the urban-industrial Puget Basin on the west side of the Cascades. In addition to air contaminants from the Puget Basin in the Everett-Seattle-Tacoma-Olympia area, major sources of acid deposition (sulfur- and nitrogen-oxide emissions) in the Yakima River basin include a large smelter in Tacoma (closed in 1985), a coal-fired powerplant in Centralia, and volcanic activity from Mount St. Helens. Acid deposition has been documented in the the Puget Basin: (1) pH values in the Seattle-Tacoma area were 3.6-4.5 during a single storm at 40 locations in 1973 (Logan and others, 1982); and (2) a volume-weighted pH of 4.4 was observed in Seattle in 1983 (Duncan and others, 1986).

Acid deposition has not been documented on the eastern slopes of the Cascades in the Yakima River basin, even though its been observed in the Puget Basin. The Cascades receive greater amounts of precipitation than the valley floors in the Puget Basin. Consequently, increased dilution and contaminant washout from the atmosphere may account for the smaller acid-oxide concentrations in the Cascade Range. In addition, washout efficiencies of atmospheric contaminants, such as sulfate, may be greater for rain that occurs primarily in the Puget Basin than for snow that occurs primarily in the Cascades (Duncan and McGinty, 1989).

In 1984 and 1985, bulk precipitation samples were collected in the Central Cascades at Snoqualmie Pass and Stevens Pass, two high-elevation sites near the headwater streams of the Yakima River (Duncan and others, 1986). The precipitation had small concentrations of the strong acid ions, sulfate and nitrate, which were as small as or smaller than concentrations observed at five remote pristine stations throughout the world (Duncan and others, 1986). Values of pH at the two mountain passes ranged from 5.04 to 5.22 compared to 4.78 to 4.96 at the five pristine stations, further indicating that acid deposition was not occurring at the Yakima headwater sites. The chemistry of headwater lakes in the basin also has been sampled (Logan and others, 1982; Duncan, 1985). In 1981 and 1984, lakes near the headwaters of the Yakima and Naches Rivers were found to have low

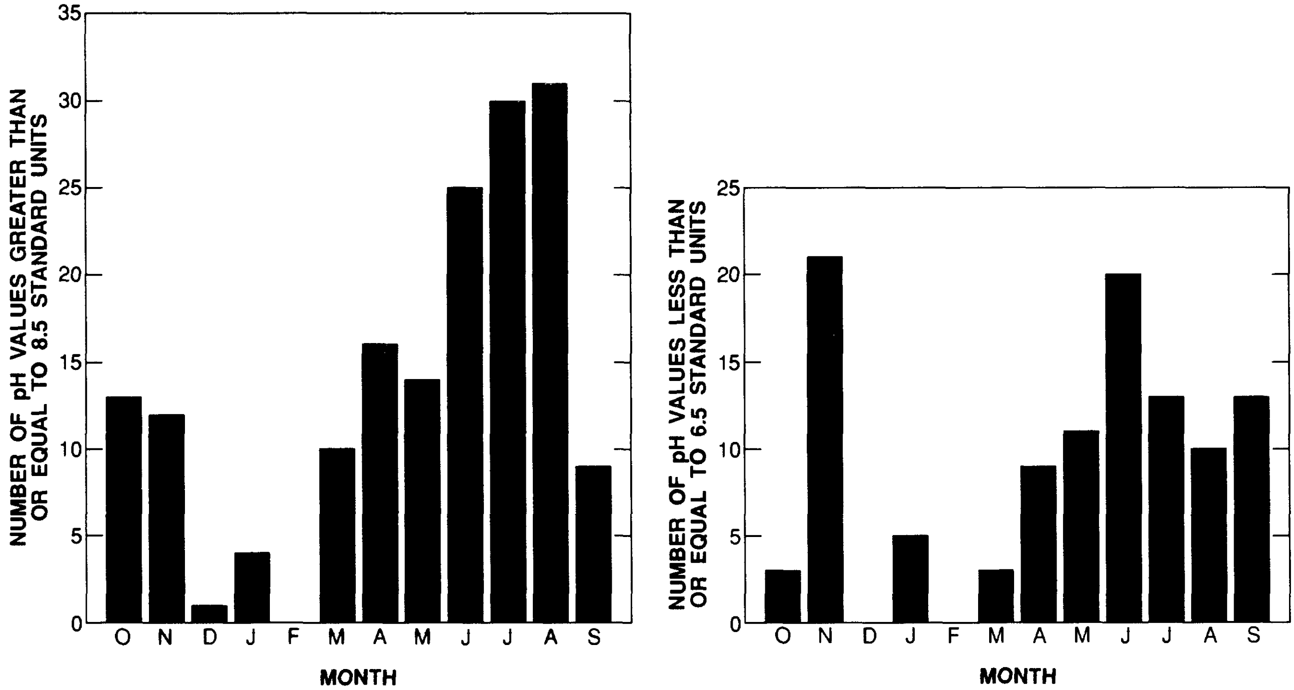


Figure 25.--Monthly distribution of pH values not meeting Washington State standards (less than or equal to 6.5 and greater than or equal to 8.5 standard units), Yakima River basin, Washington, 1953-85 water years.

alkalinities (4 to 331 microequivalents per liter) and consequently were highly susceptible to acid precipitation. On the basis of ratios of (1) alkalinity to calcium (Logan, 1982) and (2) alkalinity to the sum of major cations (Duncan, 1985), the lakes in the basin show no evidence of acidification. Low alkalinities occur in the surface water, because rates of chemical weathering (dissolution of minerals from rock resulting from exposure to water and atmospheric carbon dioxide) is low in igneous terranes.

Acidity determinations were made from 1980-81 at six locations in the Ahtanum and Toppenish Creek subbasins. The determinations range from 0 to 15 mg/L as $CaCO_3$. These determinations are too few, both spatially and temporally, to draw any meaningful conclusions, except that the acidity values in these subbasins are small when compared with surface water affected by acid mine drainage (Hem, 1985).

Distributions of pH and alkalinity measurements are summarized in table 49 at the back of the report. The pH data provide good monthly coverage from 1974-81 WY for both intrasite and intersite comparisons; alkalinity data are limited in monthly coverage except in 1975 WY, so only the 1975 WY data were used for intersite comparisons.

Median pH values down the main stem range from 7.5 at Cle Elum to 8.0 at Kiona (fig. 26). Median pH values begin to increase at Parker (RM 104.6), which is located immediately downstream from the Wapato diversion canal. From 1974-81 WY, only the sites in the Yakima River at Harrison Road bridge (RM 121.2), Parker, and Kiona have pH values exceeding the 8.5 standard. pH values exceeding 8.5 in the Yakima River at Parker generally occurred from March to August in 1974-81 WY and coincide with large summer diversions that

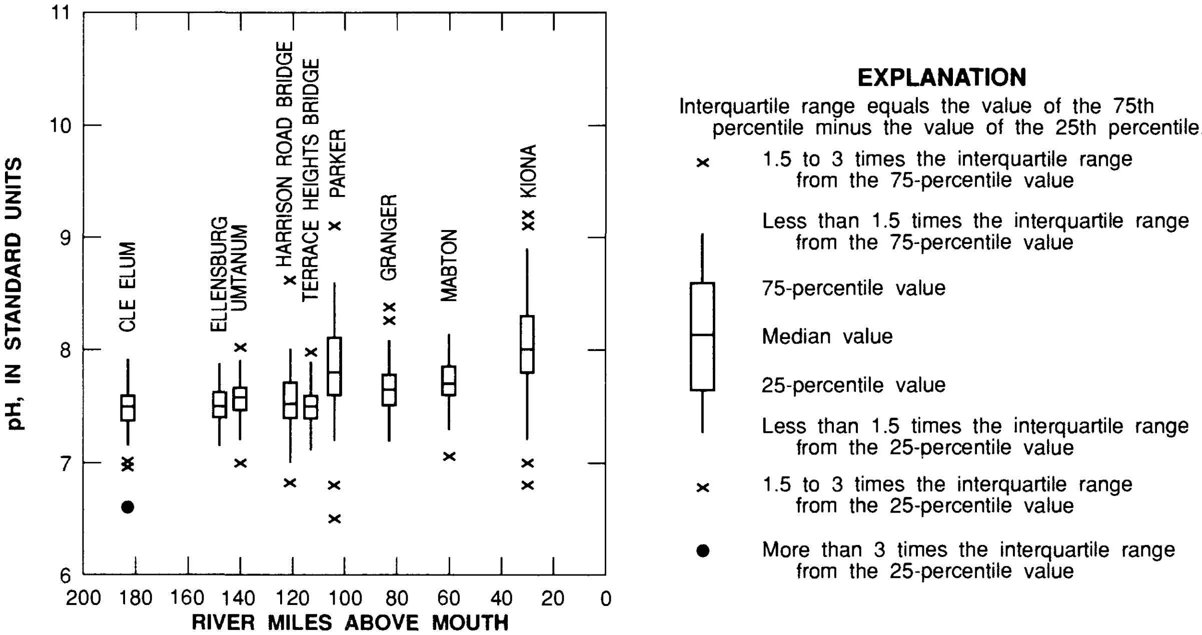


Figure 26.--Values of pH in the Yakima River, Washington, 1974-81 water years.

reduce streamflows at Parker. The small Parker streamflows increase the bed-surface area to water-volume ratio, thus enabling stream productivity due to periphytic growth to increase daytime stream pH. pH values that did not meet standards were few in the main stem and occurred almost exclusively as exceedances above 8.5 pH units.

Monthly distributions of pH values from Yakima River at Kiona (agriculturally-affected site at RM 29.9) and Yakima River at Cle Elum (non-agriculturally-affected site at RM 183.1) are noticeably different, especially during irrigation season (April to mid-October; fig. 27). pH values range from 6.8 to 9.2 at Kiona and from 6.6 to 7.9 at Cle Elum. During irrigation season, the interquartile pH range (75-percentile minus the 25-percentile) at Kiona is two to three times larger than the range at Cle Elum.

In the Yakima River at Kiona (RM 29.9) from 1974-81 WY, non-flow adjusted values (seasonal Kendall test for time trends) of pH increased about 0.05 pH units per year, or an estimated increase of 0.4 pH units for the 8-year period. Most of the pH measurements at Kiona were made from 11 a.m. to 1 p.m. when effects from photosynthesis are near maximum. Trend results may differ for nighttime pH measurements when respiration becomes a dominant control of stream pH. The flow-adjusted trend for pH at Kiona was not significant ($\rho \leq 0.1$), indicating that the increasing non-flow-adjusted trend in pH may be associated with the significant decreasing streamflow trend at Kiona (estimated average decrease of 222 ft^3/s per year from 1974-81 WY).

Alkalinity concentrations increase down the main stem of the Yakima River. Median values range from 24 mg/L as $CaCO_3$ near Cle Elum (RM 191) to

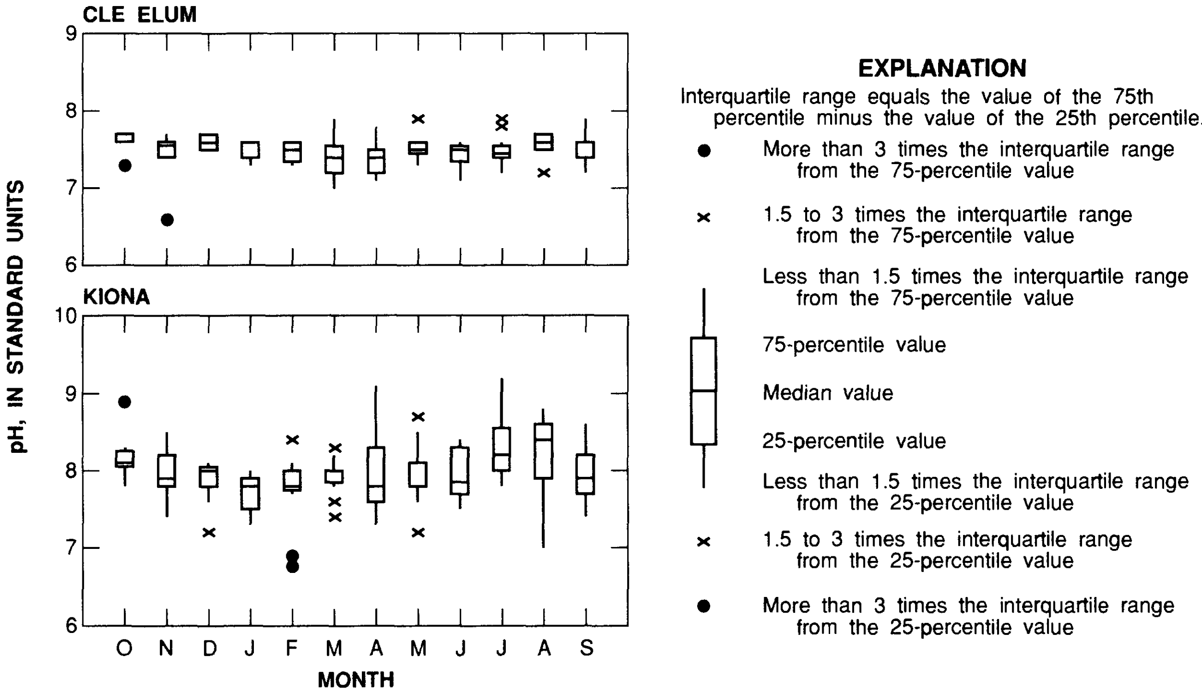


Figure 27.--Monthly distribution of pH values for the Yakima River at Cle Elum and at Kiona, Washington, 1974-81 water years.

90 mg/L at Prosser (RM 47.4) in 1975 WY (fig. 28; table 49 at the back of the report). Interquartile ranges are as small as 7 and as large as 61 mg/L as $CaCO_3$ at Cle Elum and at Kiona, respectively. Increases in alkalinity from Toppenish (RM 93.0) and Mabton (RM 59.8) most likely result from agricultural-return flow and point-source effluent to the main stem. Median concentrations of alkalinity in these agricultural-return flows (containing point-source effluent) are more than twice the median concentration in the Yakima River near Toppenish (RM 93.0).

Median alkalinity concentrations vary monthly in the Yakima River at Kiona, 1974-81 WY, (fig. 29). Concentrations are small from January through May, probably as a result of the diluting effects of winter storms and spring snowmelt. The larger alkalinities are due to increased contributions of carbonate-enriched ground water, agricultural-return flows, and point-source effluent. Median alkalinities increase over the summer months, peaking at the end of the irrigation season in October. Median alkalinities decrease from October to January because of winter storms and the subsidence of ground-water seepage.

The historical data base for the Yakima River basin contains both field and laboratory measurements of pH and alkalinity. Field measurements are usually preferred for interpretation, because they are more representative of actual stream conditions. Differences between laboratory and field measurements are not readily predictable. For example, laboratory pH measurements of samples collected at the Yakima River at Union Gap were generally positively biased, and laboratory measurements from the Yakima River at Kiona were generally negatively biased (fig. 30) when compared with field measurements. Much of the historical pH and alkalinity data prior to the mid-1970's were laboratory measurements that may be inappropriate for comparison to field measurements made after the mid-1970's.

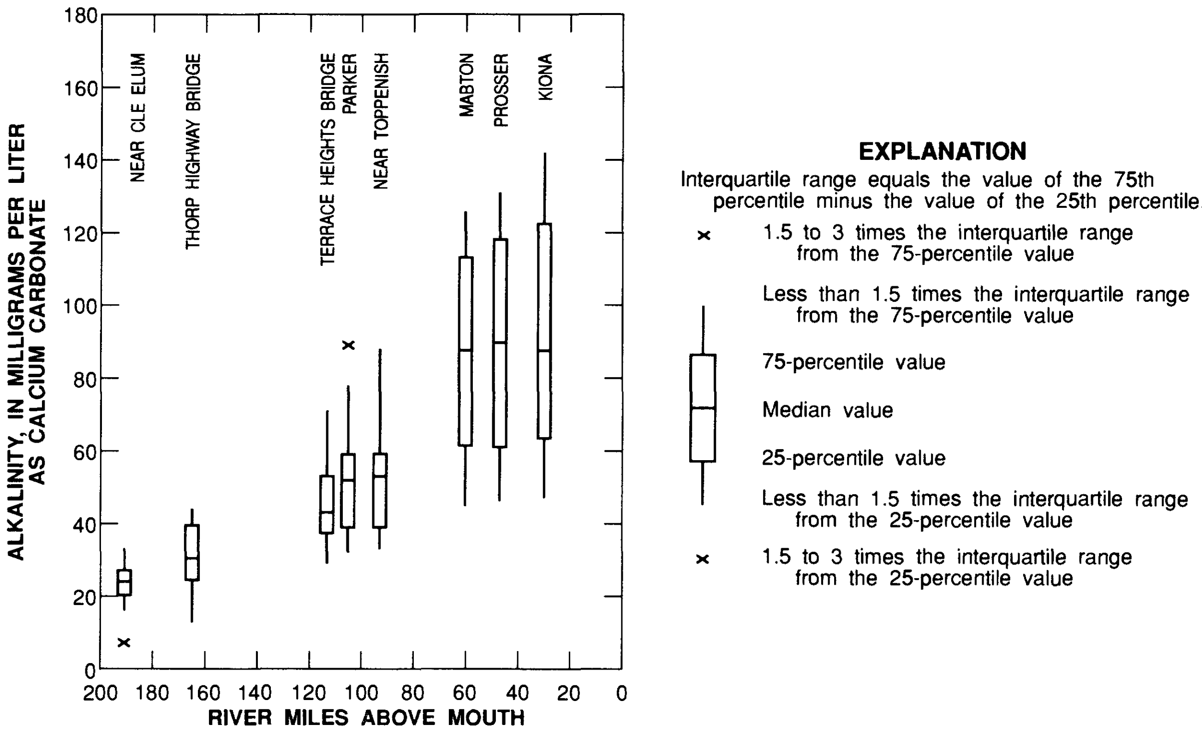


Figure 28.--Alkalinity in the Yakima River, Washington, 1975 water year.

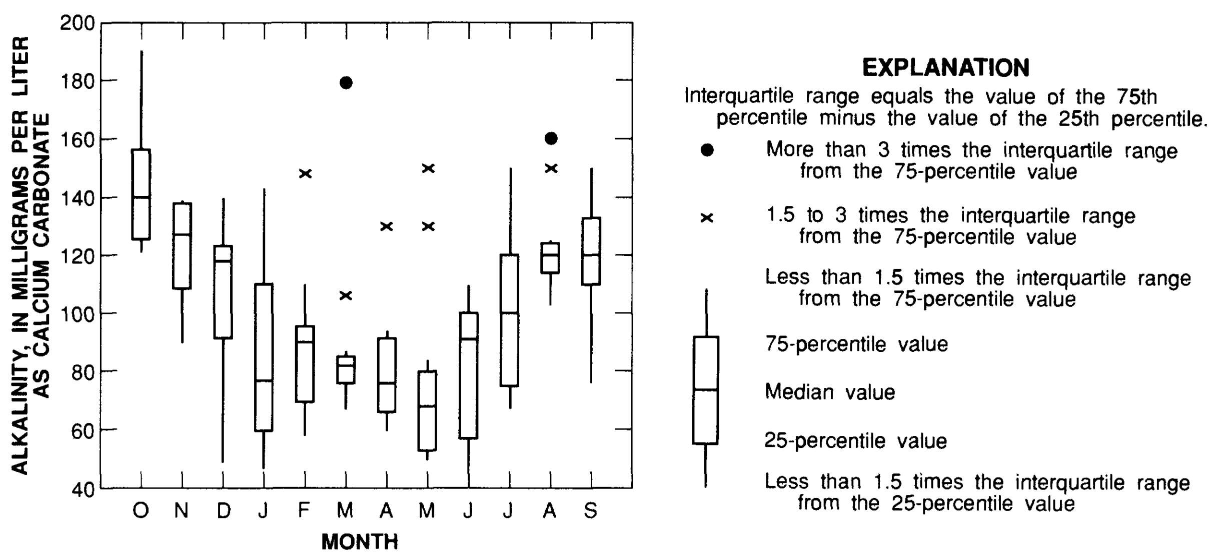


Figure 29.--Monthly distribution of alkalinity for the Yakima River at Kiona, Washington, 1974-81 water years.

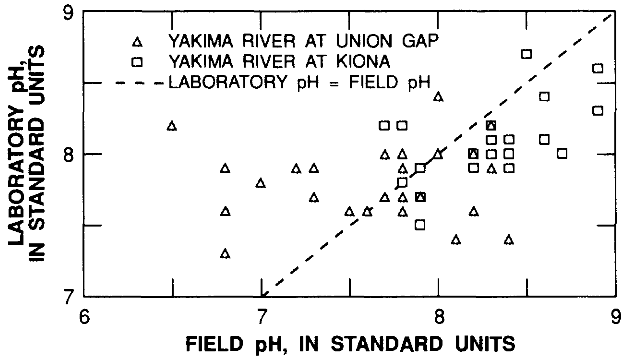


Figure 30.--Relation between laboratory and field pH measurements for the Yakima River at Union Gap and at Kiona, Washington,1980-85 water years.

Major Cations and Anions, and Related Measures

Sources of total-dissolved solids (TDS) in water include: mineral and organic assemblages in rocks and soils, which contact surface and ground water; natural weathering (solubilizing) processes; and, point and nonpoint sources. TDS concentrations commonly are dependent on the residence time of the water in a ground-water system or storage reservoir. TDS, also referred to as "filterable residue," are comprised of inorganic salts and organic matter. A major part of the TDS consists of the cations: calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); and the anions: bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3).

Large concentrations of TDS may be objectionable in drinking water or detrimental to aquatic life, agricultural uses, and industrial uses. In drinking water, large concentrations may result in physiological effects, unpalatable tastes, and higher costs associated with corrosion and other treatment. Physiological effects include laxative effects from sodium sulfate and magnesium sulfate, and sodium effects on (1) certain people afflicted with cardiac disease and (2) pregnant women with toxemia (U.S. Environmental Protection Agency, 1986).

Specific conductance is a measure of the ability of water to conduct an electrical charge and is related to the concentration of major ions dissolved in water. For most surface water in the Yakima River basin, specific conductance (in microsiemens per centimeter at 25 degrees Celsius) multiplied by 0.65 is approximately equal to the TDS concentration (in milligrams per liter). Because of the ease of measurement, specific conductance usually is measured on water samples in lieu of analyzing dissolved solids. For irrigation water, increased TDS concentrations indicate an increased salinity hazard that may interfere with crop growth.

Through processes of evaporation and evapotranspiration, the TDS content that resides in irrigation water within topsoils becomes concentrated. Excessive TDS can be leached from topsoil through precipitation or irrigation in areas that are well drained. In areas of poor drainage, continued irrigation often raises the water table and evapotranspiration charges topsoils with residual salts. Often these salts occur as white deposits and are characteristically composed of sodium sulfate and chloride, but may also contain calcium and magnesium (Hem, 1985, p. 216). Such salts can be seen along Granger Drain between the towns of Granger and Sunnyside and in the lower drainage of Sulphur Creek Wasteway (confluent with Yakima RM 61). The tendency of Na in irrigation water to replace adsorbed Ca and Mg ions from soils (known as the sodium hazard), thereby degrading soils to the point that they may not support plant growth, is measured using an empirically derived relation known as the SAR (sodium-adsorption ratio; Hem, 1985). Large values for SAR coincide with an increased capacity of Na to replace Ca and Mg in soils.

Median concentrations of Ca, Mg, Na, K, Cl, SO_4, and TDS (13, 4.9, 7.1, 1.6, 2.5, 4.4, and 120 mg/L) in the Yakima River basin were similar to or smaller than the mean concentrations observed in natural rivers throughout the world (14, 3.7, 5.7, 1.8, 6.8, 9.6, and 81 mg/L, respectively; Hem, 1985). The predominant major ions in the surface water in the Yakima River basin are calcium and bicarbonate. The water generally has high Ca:Na ratios and small fluoride concentrations (most less than 0.3 mg/L) which are typical of water from basalt terranes (White and others, 1963).

TDS and major-ion data for the 1947-85 WY were compared with EPA criteria for domestic water supplies and EPA guidelines for irrigation water (U.S. Environmental Protection Agency, 1986). Cl and SO_4 each should not exceed 250 mg/L for drinking water (EPA criteria), TDS should not exceed 500 mg/L for irrigation water for sensitive crops (EPA guideline), and SAR should not exceed 4 (EPA guideline) for sensitive fruit crops (U.S. Environmental Protection Agency, 1986). The historical data for TDS were expanded from about 2,500 to 5,000 determinations by combining analytical determinations made at two different evaporation temperatures (105 °C and 180 °C). Combining results from methods is an acceptable practice for water low in organic matter and total-mineral content (American Public Health Association, 1975, p. 90) as well as most natural waters (Hem, 1970, p. 218).

About 3 percent of the TDS concentrations (table 16) exceeded the recommended limit of 500 mg/L established for irrigation water (U.S. Environmental Protection Agency, 1986). These exceedances occurred predominately in agricultural-return flows located in Wide Hollow Creek, Moxee Drain, Granger Drain, Satus Creek, and Sunnyside subbasins. The salinity hazard in the basin ranged from low to medium with more than 50 percent of the specific-conductance measurements less than 250 $\mu S/cm$ (microsiemens per centimeter at 25 degrees Celsius), indicating a low hazard (Hem, 1985, p. 218). SAR values did not exceed guidelines for sensitive fruit crops like apples, pears, and peaches; however, at a few sites, they were close to the threshold of 4. For example, Sulphur Creek at Green Valley Road, Moxee Drain at Birchfield Road, and Satus Drain 302 have SAR values that exceed 3. Sulfate exceedances (250 mg/L for domestic-water-supply use) represented about 0.1 percent of all the SO_4 determinations and occurred only at Satus Drain 302 where they represent 7 percent of the SO_4 determinations at that site (table 16).

Salt-balance studies within the Wapato Irrigation District (1940-41 and 1970-71) show that drainage-water output loads of HCO_3, Ca, Na, and Mg are larger than the loads in the irrigation-input water (Nelson and Weaver, 1971). The larger output loads could result from processes such as the solution of soil-sorbed ions by irrigation water, ungaged ground-water seepage, addition of fertilizers, and to some extent ungaged surface-water inputs. Nelson and Weaver (1971) also reported that the streamflow of the

Table 16.--Number of dissolved-solid and sulfate measurements not meeting the U.S. Environmental Protection Agency guideline for irrigation or the criterion for drinking water, Yakima River basin, Washington, 1947-85 water years

[mg/L = milligrams per liter; KID = Kennewick Irrigation District; DID = Drainage Improvement District; STP = sewage treatment plant; # = number; see plate 1 for site locations]

Map reference number	Site name	Number of observations	Number of exceedances in irrigation water
Total dissolved-solids guideline: Irrigation water, unsuitable for use on sensitive crops when greater than 500 mg/L			
71	South Drain near Satus	4	2
300	KID Coyote Canyon Drain near bottom	42	13
311	Satus Drain 302 NW1/4 Sec 34 9N 22E	61	24
313	Coleman Cr NW 1/4 Sec 20 17N 19E	52	1
323	Drain at Birchfield Road	63	20
326	Wide Hollow Creek at Union Gap STP	65	24
329	Sulphur Cr Wasteway at Factory Road	54	8
330	Drain DID #3 at South Hill Road	36	9
331	Drain DID #3 at Duffy Road	36	9
332	Sulphur Cr Wasteway at Duffy Road	54	1
333	Sulphur Cr Wasteway at Morse Road	53	2
334	Sulphur Cr Wasteway at McGee Road	65	4
345	South Drain at Highway 22 nr Satus	64	17
346	Granger Drain at Hwy 223 abv Granger	64	2
347	Spring Creek at Hess Road	63	10
348	Snipes Cr at Old Inland Empire Road	61	14
356	Drain DID #3 abv Rendering Plant	25	6
Total sulfate criterion: Drinking water, unsuitable for use when greater than 250 mg/L			
311	Satus Drain 302 NW1/4 S34 9N 22E	60	4

drainage-water output was approximately 70 percent of the irrigation-water input (1970-71), and the average annual Ca concentrations in drainage-water output was found to be approximately three times greater than the concentration in irrigation-water input.

Specific conductance data for the Yakima River basin, 1947-85 WY, were classified according to the four channel-conveyance types: (1) main stem, (2) tributaries minimally affected by man, (3) canal, and (4) drains affected by point sources and agricultural activities. Sources of drain water include agricultural-return flow, ground-water seepage, dairy and feedlot runoff, canal spillage, and effluent from point sources. The 90th-percentile specific conductance value was computed for each conveyance type within each subbasin. This value was compared to the percentile distribution of all available specific-conductance data for the Yakima Basin, 1947-85 WY. The 90th percentile value for each conveyance type within a subbasin was qualified as low ($\leq$ the 25th percentile for all data), medium (> 25th, but < 75th percentiles), or high ($\geq$ 75th percentile). Drains clearly have the largest conductance values indicating that they also have the largest TDS concentrations (fig. 31).

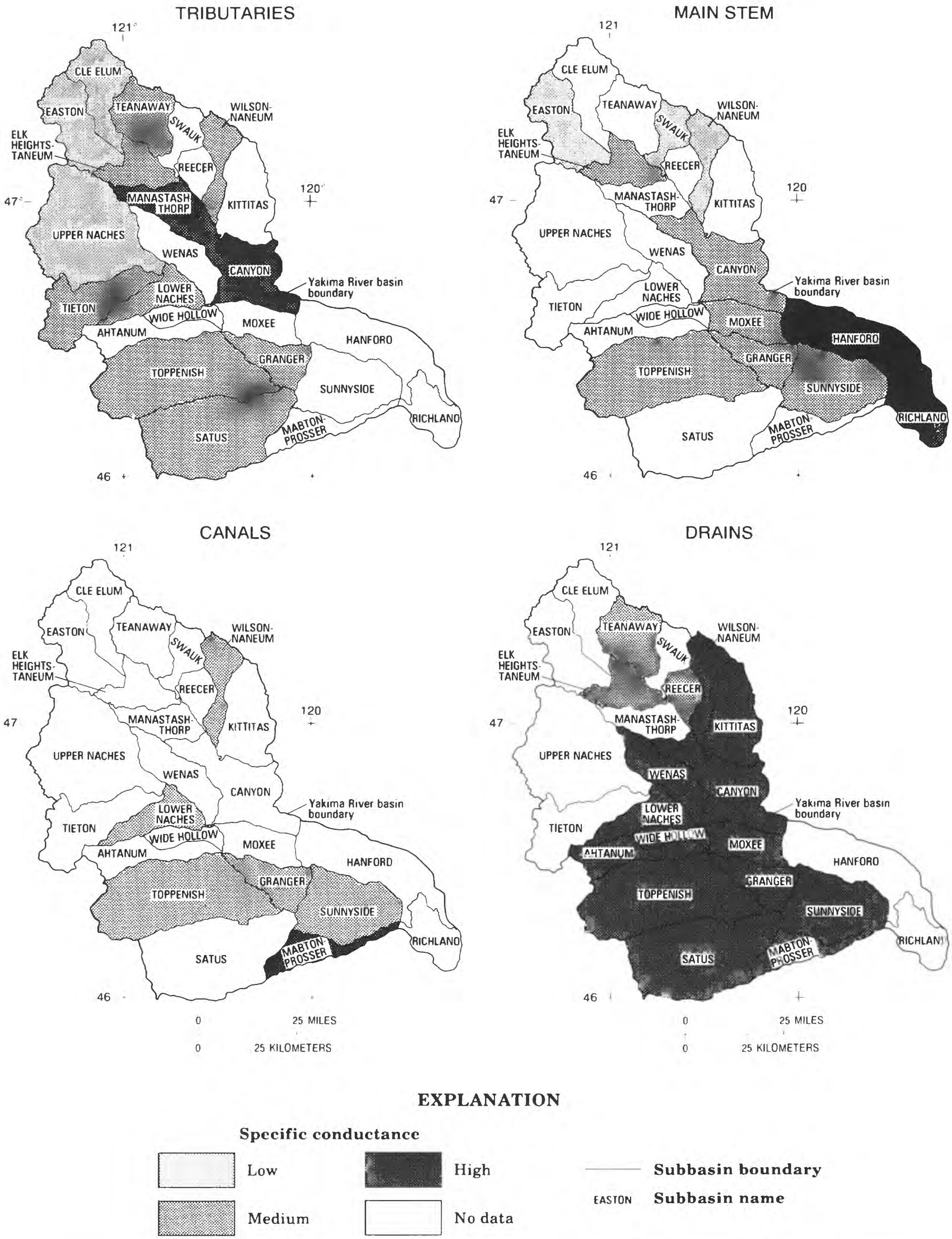


Figure 31.--Ninetieth-percentile values for specific conductance by site type and subbasin, Yakima River basin, Washington, 1947-85 water years. The 90th-percentile value for each site type within a subbasin was qualified as low (less than or equal to the25th-percentile value for all data), medium (greater than 25th, but less than 75th-percentile value), or high (greater than or equal to 75th-percentile value).

The Yakima River at Kiona (RM 29.9) was the only main-stem site sampled monthly, for major ions 1974-81 WY. Seven other main-stem sites, in addition to Kiona, were sampled monthly during the 1975 WY. For the Kiona site, the 1975 WY data were found to be similar to the 1974-81 WY data.

Specific conductance values (major-ion concentrations) for the 1975 WY increase down the main stem of the Yakima River; however, the composition of the major ions remain similar. Median specific conductance values increase (fig. 32) down the main stem from 62 μS/cm at Cle Elum (RM 183.1) to 250 μS/cm at Kiona (RM 29.9). As evidenced by the relatively uniform composition of ions in the main stem from Cle Elum (RM 183.1) to Kiona (RM 29.9), these increases in conductance do not appear to be dominated by the dissolution or precipitation of a single ion (fig. 33). Mechanisms that likely account for this uniform increase include evapotranspiration that equally concentrates all ions or dissolution of ions from geologically similar rock and soil types.

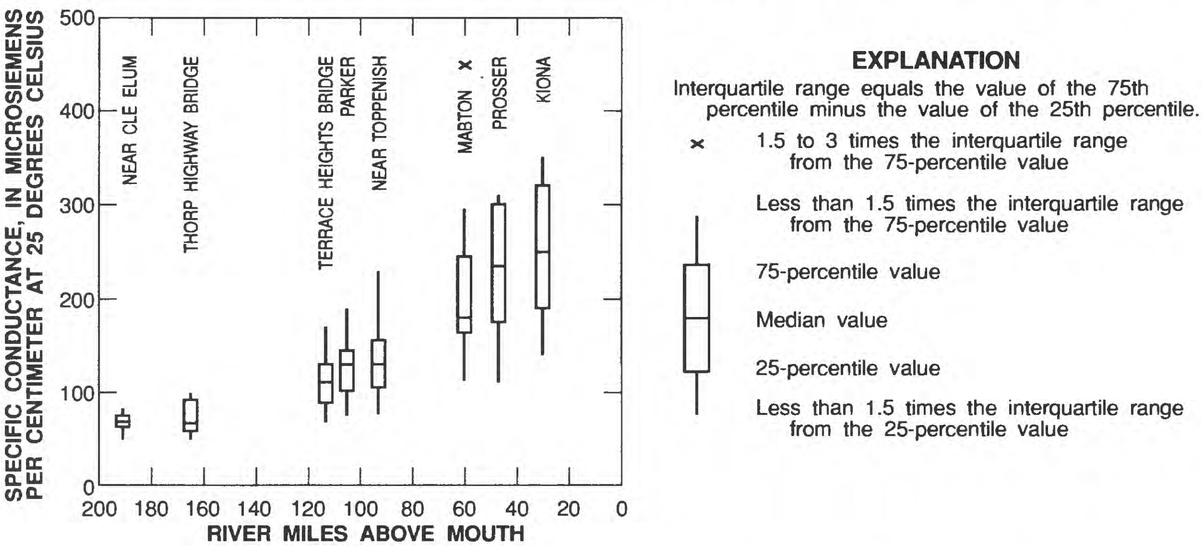


Figure 32.--Specific conductance in the Yakima River, Washington, 1975 water year.

Concentration increases of TDS, as measured by specific conductance, are evident downstream from the Yakima River near Toppenish (RM 93.0), because the combined flow of the agricultural-return flows constitutes most of the main-stem water, especially during irrigation season (fig. 32). Seasonally, the largest concentrations occur following the end of irrigation in October (fig. 34) when agricultural drainage water is a major source of water in the main stem. Median TDS concentrations decrease from November to May, as a result of dilution from winter storms and spring-snowmelt.

Water hardness near municipal-surface-water intakes was evaluated relative to the soap-consuming capacity of the water, and encrustations left by the water when heated in hot-water tanks and low-pressure boilers. Raw surface-water supplies for the cities of Yakima (Naches

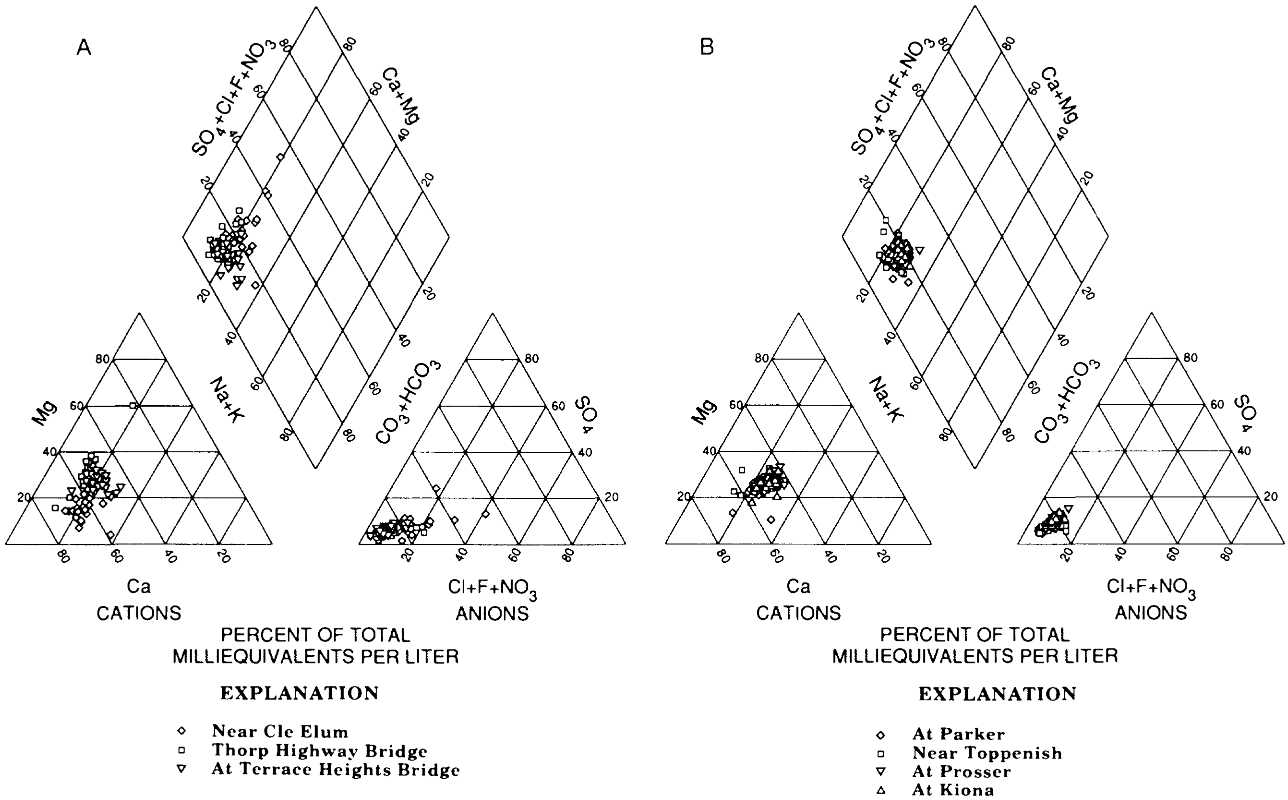


Figure 33.--Major-ion concentrations in the Yakima River (A) near Cle Elum, at Thorp Highway Bridge, and at Terrace Heights Bridge; (B) at Parker, near Toppenish, at Prosser, and at Kiona, Washington, 1975 water year.

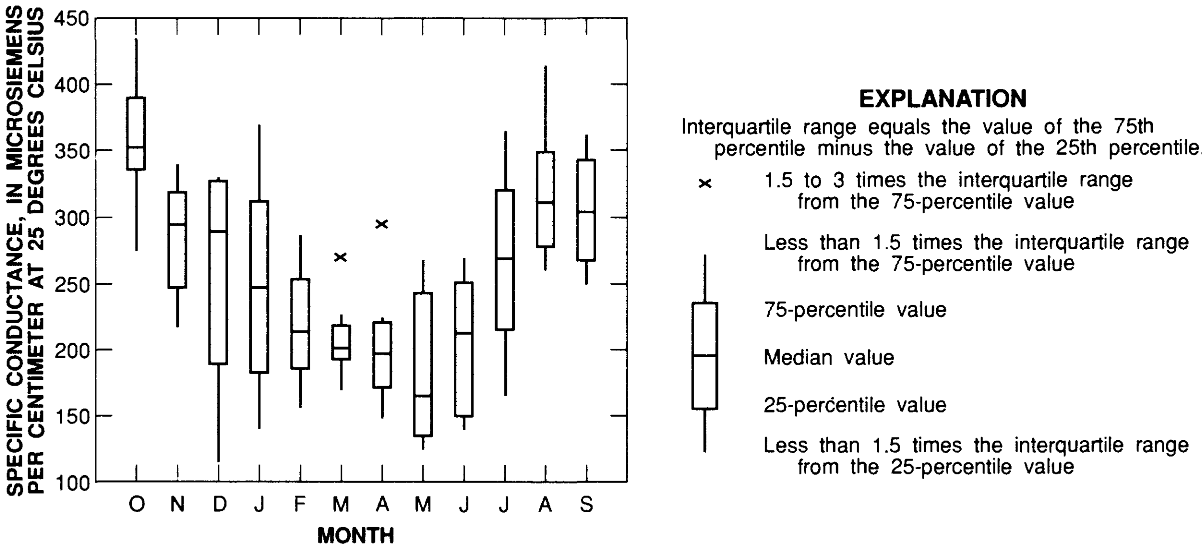


Figure 34.--Monthly distribution of specific conductance for Yakima River at Kiona, Washington, 1974-81 water years.

River at RM 18.4) and Cle Elum (Yakima River at Cle Elum at RM 183.1) are rated as soft (0 to 60 mg/L as $CaCO_3$) based on the classification scheme developed by Durfor and Becker (1964, p. 27).

The Yakima River basin was divided into upper and lower river reaches to compare TDS loads. The upper reach comprises drainage from the Naches River (RM 116.3) and all drainage upstream from the Yakima River at Umtanum (RM 140.4). The lower reach comprises drainage downstream from the Yakima River at Umtanum, excluding the contribution from the Naches River.

TDS loads were estimated at three main-stem sites in the upper reach (above RM 140.4), one site on the Naches River (Naches RM 0.1), and three main-stem sites in the lower reach (below RM 140.4) for WY 1974, 1977, and 1980 (table 17). The load for the upper reach was obtained by adding the load above RM 140.4 to that of the Naches River. The load of the lower reach was obtained from the difference between the load of Yakima River at Kiona (RM 29.9) and the load in the upper reach.

The annual TDS load of the upper and lower reaches are similar and vary only in proportion to the streamflow. The TDS load for the median-flow 1980 WY in the upper reach is 220,000 t/yr (tons per year) and is 230,000 t/yr in the lower reach (450,000 t/yr at Kiona minus 220,000 t/yr from upper reach). The similarity of loads in the upper and lower reach is not a result of comparable amounts of irrigable lands, because the lower reach (425 mi^2 of irrigable land) has more than twice the irrigable land of the upper reach (186 mi^2). TDS loadings from the lower reach result from increased TDS concentrations within that reach, and not an increase in annual-mean streamflow. The flow-weighted-mean concentration for 1980 WY is 134 mg/L in the Yakima River at Kiona and

Table 17.--Estimated dissolved-solids loads for 1974, 1977, and 1980 water years, Yakima River basin, Washington.

[Load values not in parenthesis are based on calibration data from water years 1970-85; load values in parenthesis are based on calibration data that were collected 3 months prior to, during, and 3 months following the specified water year; "--" indicates insufficient data; WY - water year]

River mile	Map reference number	Site name	Mean daily flows			Total dissolved-solids load, in tons per year		
			1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY
183.1	349	Yakima River at Cle Elum	1,770	1,418	1,596	58,000 (54,000)	47,000 (50,000)	57,000 (59,000)
148.0	354	Yakima River at Ellensburg	1,770	1,442	1,922	83,000 (--)	73,000 (70,000)	100,000 (98,000)
140.4	355	Yakima River at Umtanum	3,040	1,735	2,347	180,000 (--)	120,000 (120,000)	150,000 (150,000)
[1]/116.3	321	Naches River near Yakima	2,367	544	1,346	136,000 (137,000)	36,000 (32,000)	70,000 (70,000)
107.2	32	Yakima River above Ahtanum Creek at Union Gap[3]/	5,265	1,884	3,249	350,000 (--) [2]/350,000	160,000 (--) [2]/150,000	250,000 (230,000) [2]/240,000
59.8	338	Yakima River at Mabton	5,497	1,215	3,237	500,000 (540,000)	200,000 (210,000)	410,000 (380,000)
29.9	100	Yakima River at Kiona	5,794	1,293	3,393	650,000 (720,000)	280,000 (260,000)	450,000 (480,000)

[1]/Mouth of Naches River at Naches River mile 0.1.
[2]/Based on actual measurements of dissolved solids at 180 degrees Celsius.
[3]/Loads in river exclude loads passing Union Gap in Roza Canal.

60 mg/L in the upper reach. Thus, by difference, the flow-weighted-mean concentration increased 74 mg/L from the upper reach to the lower reach, with no significant change in streamflow (1980 mean-daily flow in upper reach is 3,693 ft^3/s--2,347 ft^3/s at Umtanum plus 1,346 ft^3/s in Naches River--compared with 3,393 ft^3/s in the Yakima River at Kiona).

The estimated TDS load in 1980 WY from the City of Yakima and surrounding areas is about 63,000 t/yr (250,000 t/yr at Union Gap + 33,000 t/yr passing Union Gap in Roza Canal - 150,000 t/yr at Umtanum - 70,000 t/yr from Naches River). This load includes inputs from (1) local point and nonpoint sources, (2) urban and surburban Yakima, (3) Moxee and Wide Hollow subbasins, and (4) ground-water seepage. Point sources include effluent from the Yakima STP (Yakima RM 111) and the Wide Hollow STP (Yakima RM 107.4) [closed in September 1979].

Specific-conductance trends were calculated for 43 sites using data from 1974-81 WY (table 51 at the back of report and table 18). Significant non-flow-adjusted trends ($\rho \leq 0.1$) were detected at 5 of 7 main-stem sites and at 12 of 36 tributary sites. All significant main-stem and tributary-concentration trends (non-flow adjusted) were positive (increasing), except for Drain at Birchfield Road, Wide Hollow Creek at Union Gap, and Sub-Drain 35 at Parton Road (fig. 35 and table 18). Wide Hollow Creek received effluent from the City of Union Gap STP until September of 1979 when the Yakima STP began processing Union Gap waste (Ken Harris, City of Union Gap Public Works, oral commun., 1989). The closure of the Union Gap STP accounts for the decreasing specific conductance trend.

Table 18.--Summary of significant (probability level less than or equal to 0.1) trends for specific conductance and streamflow, Yakima River basin, Washington, 1974-81 water years

[Site types listed as: "M" = main stem, and "D" = agriculturally or point-source-affected surface waters; cm = centimeter, "NT" = no significant trend]

Site type	Site number and name	Water yeers of record	Specific conductance: Non-flow-adjusted: Trend, micro-siemens/cm/year	Specific conductance: Non-flow-adjusted: Trend, percent of median per year	Specific conductance: Non-flow-adjusted: Median, micro-seimens per cm	Specific conductance: Flow-adjusted: Trend, percent of median per year	Streamflow: Trend, percent of median per year
M	349 Yakima River at Cle Elum	1974-81	2.7	4.3	62	NT	-8.4
M	320 Yakima River at Harrison Rd bridge	1974-81	2.5	2.1	120	NT	NT
M	322 Yakima River-Terrace Heights bridge	1974-81	3.3	3.3	101	1.7	-6.7
M	40 Yakima River at Parker	1974-81	NT	NT	130	-2.1	-8.2
M	337 Yakima River at bridge near Granger	1974-81	13.3	7.3	182	4.8	-8.2
M	338 Yakima River at bridge near Mabton	1974-81	6.5	2.7	244	2.2	NT
M	100 Yakima River at Kiona	1974-81	NT	NT	265	-1.7	-9.2
D	312 Cherry Creek SE1/4 Sec 29 T17N R19E	1974-79	7.7	2.5	301	NT	NT
D	353 Wilson Creek at Thrall Road	1974-81	4.8	2.3	210	2.1	NT
D	325 Wide Hollow Cr at W. Washington Ave	1974-77	NT	NT	286	-7.0	NT
D	326 Wide Hollow Creek at Union Gap STP	1974-81	-73.1	-12.1	605	-13.8	-4.8
D	323 Drain at Birchfield Road	1974-81	-5.6	-1.6	358	NT	NT
D	340 Sub-Drain 35 at Parton Road	1974-80	-1.9	-.7	284	NT	NT
D	346 Granger Drain--Hwy 223 abv Granger	1975-81	NT	NT	475	4.0	11.0
D	341 Marion Drain at Highway 97	1974-80	2.4	.8	296	NT	-8.0
D	342 Wanity Slough at Myers Road	1974-80	NT	NT	187	-1.3	-13.3
D	311 Satus Drain 302 NW1/4 Sec 34 9N 22E	1974-80	12.0	3.1	386	5.9	NT
D	335 Griffin Lake Inlet	1974-79	17.5	4.9	358	4.4	NT
D	333 Sulphur Cr Wasteway at Morse Road	1974-79	13.3	3.4	389	NT	-6.7
D	307 Chandler Canal--mile 0.6 nr Prosser	1974-80	8.0	3.4	236	NT	-2.7
D	308 Chandler Canal--mile 2.8 nr Prosser	1974-80	6.5	2.6	246	NT	-3.0
D	348 Snipes Cr at Old Inland Empire Road	1975-80	NT	NT	205	7.0	4.8
D	319 Cottonwood Canal Drain SE1/4 Sec 28	1974-77	NT	NT	282	-4.1	NT
D	300 KID Coyote Canyon Drain nr bottom	1975-79	18.4	3.5	518	-2.4	-14.8

In the main stem, significant positive non-flow-adjusted trends in specific conductance ($\rho \leq 0.1$) occurred at the Yakima River at Cle Elum (RM 183.1), Harrison Road bridge (RM 121.2), Terrace Heights Bridge (RM 113.2), at bridge near Granger (RM 82.7), and near Mabton (RM 59.8) [fig. 35]. The smallest annual increases in specific conductance occurred at the upstream sites at Cle Elum (2.7 μS/cm per year) and Harrison Road bridge (2.5 μS/cm per year), and the largest increases

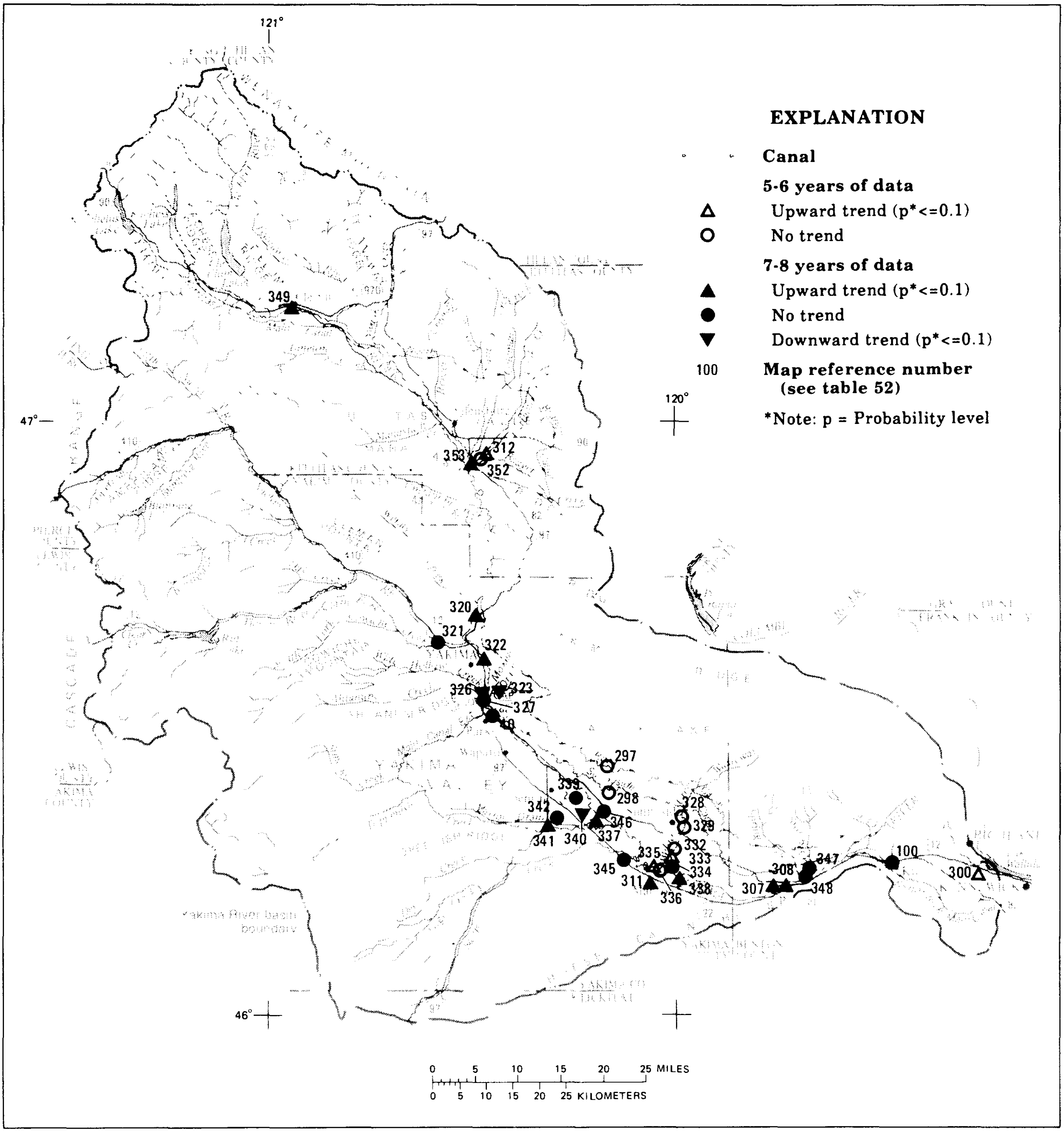


Figure 35.--Non-flow-adjusted seasonal Kendall trends in specific conductance for the Yakima River basin, Washington, 1974-81 water years.

occurred at the downstream sites near Granger (13.3 μS/cm per year) and near Mabton (6.5 μS/cm per year). The main-stem sites with the largest increases also receive large quantities of agricultural-return flows. For example, Yakima River at bridge near Granger (RM 82.7) receives nearby return flow from Granger Drain (RM 82.8), Sub-Drain 35 (RM 83.2), nearby East Toppenish Drain (RM 86), and many smaller drains; Yakima River near Mabton (RM 59.8) receives return flow from Marion Drain (RM 82.6), Toppenish Creek (RM 80.4), Satus Creek (RM 69.6), South Drain (RM 69.3), Satus Drain 302 (RM 62.4), Sulphur Creek (RM 61.0), Satus Drain 303 (RM 60.2), and many smaller drains. The similarity of the non-flow-adjusted seasonal Kendall slope estimators (specific-conductance trends) for main-stem and drain sites suggests that the drains are controlling specific-conductance trends in the lower main stem (fig. 36).

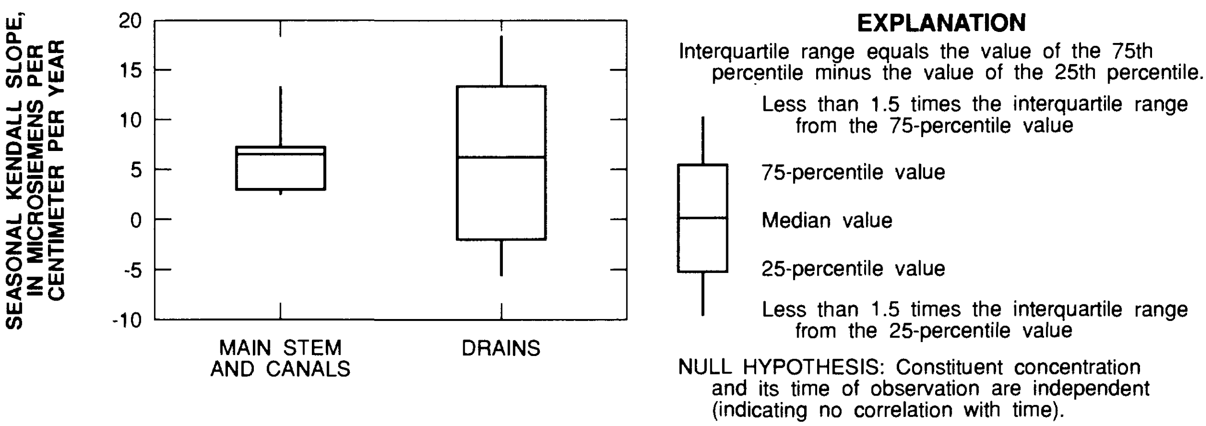


Figure 36.--Distribution of significant (probability level less than or equal to 0.1) seasonal Kendall slope estimators for non-flow-adjusted, specific-conductance trends, Yakima River basin, Washington, 1974-81 water years (one extreme value not shown).

Flow-adjusted trends at some main-stem and drain sites are negative (downward trend). The flow-adjusted trends at Cle Elum and Harrison Road bridge are not significant, indicating that the non-flow-adjusted trends were associated with decreasing streamflow rather than increased inputs from man's activities.

Suspended Sediment and Turbidity

Suspended-sediment movement in streams is an important factor in the transport and fate of chemicals in the environment. Many parameters, including trace metals, organic compounds, indicator bacteria, and nutrients are associated with suspended sediment. Sediment may be transported in the water column or may settle out as streambed sediment for a period of time. Sediment deposition can cover streambeds thereby (1) reducing benthic invertebrate populations (which are a source of food for fish), (2) inundating gravel-spawning beds, and (3) if organically enriched, depleting dissolved oxygen in the overlying water for fish and in the pore water of bed material for redds (Edberg and Hofsten, 1973). Consequently, large suspended-sediment concentrations and associated contaminants probably will affect water used for domestic-water supplies, aquatic-life propagation, and recreation. Large suspended-sediment concentrations often are associated with intense storm events that increase streamflows, erosion, and resuspension of bed sediment.

Suspended-sediment concentrations analyzed by the USBR (U.S. Bureau of Reclamation) are determinations of nonfilterable (suspended) solid residues at 105 °C (STORET parameter code 00530; Kopp and McKee, 1979), and the USGS analyses are determinations of suspended-sediment concentrations at 105 °C (STORET parameter code 80154; Guy and Norman, 1970). USBR samples were generally point samples collected from midflow or from some other single point in the cross section in flowing water just below the water surface; USGS samples were depth-and width-integrated samples collected isokinetically relative to stream velocities. USBR analytical procedures require that an aliquot of sample be withdrawn from a well-mixed sample bottle for analyses, whereas USGS procedures require analysis of the entire contents of sediment and water in a sample container. As a result of these differences in sampling and analytical procedures, USBR and USGS data may not be comparable, depending on a river's flow characteristics, suspended-sediment concentration, and particle-size distribution. Greater differences occur as both the sediment concentrations and the percentages of sand-size particles increase. All of the quantitative data shown in table 49 at the back of the report were collected either by the USGS or USBR. The collection and analysis differences between the two agencies may limit the usage of the data for intersite comparisons, especially for annual load computations, which require an accurate definition of transport curves at the larger streamflows.

Turbidity is an optical property whereby fine-grained-sized sediment particles scatter and absorb light that is passed through a water sample in a straight line. Increases in turbidity generally are caused by increases in suspended-sediment concentrations. According to State standards, the turbidity of class AA and class A streams shall not exceed 5 NTU over background when the background turbidity is 50 NTU or less. When the background turbidity is more than 50 NTU, the turbidity of class AA and class A streams shall not increase by more than 10 percent. Class B streams shall not exceed 10 NTU over background when the background turbidity is 50 NTU or less. When the background turbidity is more than 50 NTU, the turbidity of class B streams shall not increase by more than 20 percent. To fully evaluate the effects of a point or nonpoint source of turbidity on the main stem, data need to be collected synoptically in the main stem, upstream and downstream from the sources. Data from the upstream sites may be used to define background turbidity and increases at the downstream sites may be compared with State standards. The historical data generally were not collected synoptically, making it inappropriate for comparison with standards.

Spatial Variation

The frequency distributions of suspended-sediment concentrations and turbidity for main-stem sites with monthly quantitative data collected from 1974-81 WY are shown in figure 37. These distributions for the main-stem sites and other sites throughout the basin are listed in table 49 at the back of report. Median suspended-sediment concentrations and turbidity values at sites upstream from the Yakima River at Terrace Heights (RM 113.2) were less than 10 mg/L and 3 NTU, respectively. The first significant increase in median and 75-percentile values occurred in the Yakima River at Union Gap (RM 107.2) for suspended sediment and at Parker (RM 104.6) for turbidity. Possible

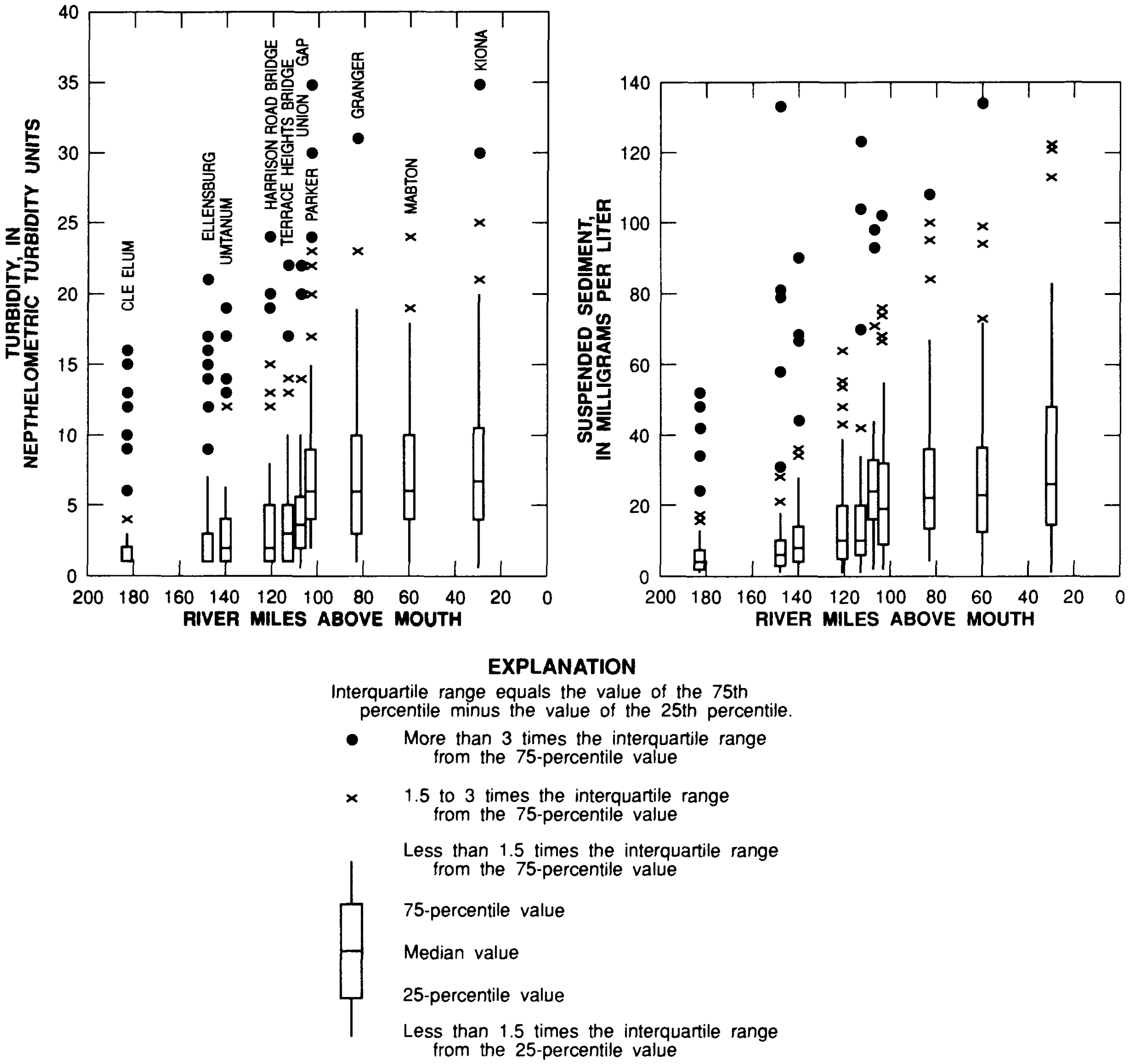


Figure 37.--Turbidity values and suspended-sediment concentrations in the Yakima River, Washington, 1974-81 water years (some large values are not shown).

sources of sediment in this reach are Moxee Drain, Wide Hollow Creek, and Ahtanum Creek. Intersite comparisons of the sediment and turbidity values downstream from the Yakima River at Union Gap indicates they are similar (1) from site to site and (2) to values in the major tributaries (primarily agricultural-return flows) in the downstream reach. This similarity is expected, because major sources of water in the main stem (except during winter runoff and spring snowmelt) include the agricultual-return flows. The sediment from agricultural activities in the lower Yakima River basin may be causing exceedances of State turbidity standards in the lower Yakima River.

Analysis of available data (includes data not tabulated in table 49) collected through 1985 WY indicates that most of the sites with the largest sediment concentrations and turbidity values (90-percentile values greater than 500 mg/L and 40 NTU) were located in the Sunnyside subbasin, where the steeper subbasin slopes may be contributing to increased erosion. Additional sites that had large concentrations were Satus Drains 302 and 303 and two forested headwater sites, Log Creek above Cabin Creek and Swauk Creek at Swauk Forest Camp. Few samples have been collected from headwater sites, and data are insufficient to determine the significance of their sediment contributions during major runoff events.

Seasonal Variation

Concentrations of suspended sediment in a stream are related to stream characteristics and to the sediment sources that are affected by land- and water-use activities. These complex relations cause extreme variations in the range of annual suspended-sediment concentrations. For example, analysis of available data through 1985 WY indicates that suspended-sediment concentrations in agricultural-return flows in the Sunnyside subbasin range from 10 mg/L during low flows to more than 35,000 mg/L during a major storm event, and turbidity values range from 1 to more than 600 NTU.

Largest suspended-sediment concentrations in the Yakima and Naches Rivers occur from April to June during periods of snowmelt and large streamflow velocities (fig. 38). The largest suspended-sediment concentrations in the major agricultural-return flows occur during irrigation season from April to September, but large concentrations also occur during periods of large streamflows. Peak concentrations have been observed during the start of irrigation season when soils have been freshly tilled and when canals and ditches are layered with sediment from recent mechanical cleaning and wind-blown sources. In contrast, the smallest concentrations occur after the irrigation season during the period from October to December when the smallest flows occur.

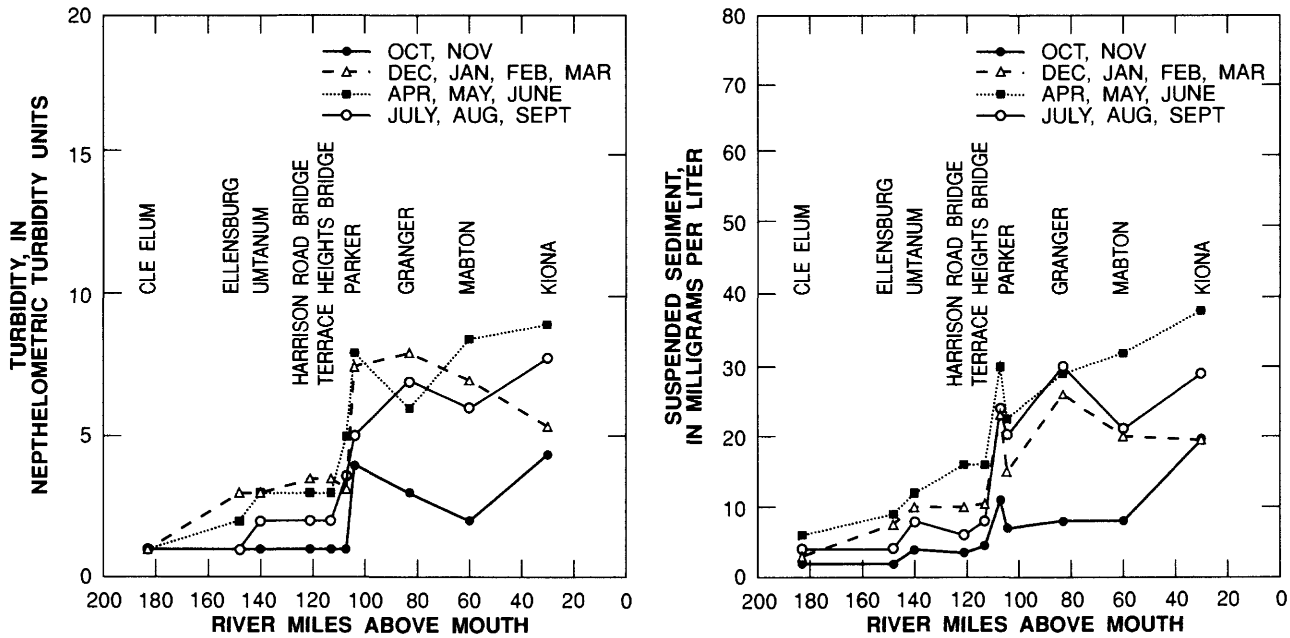
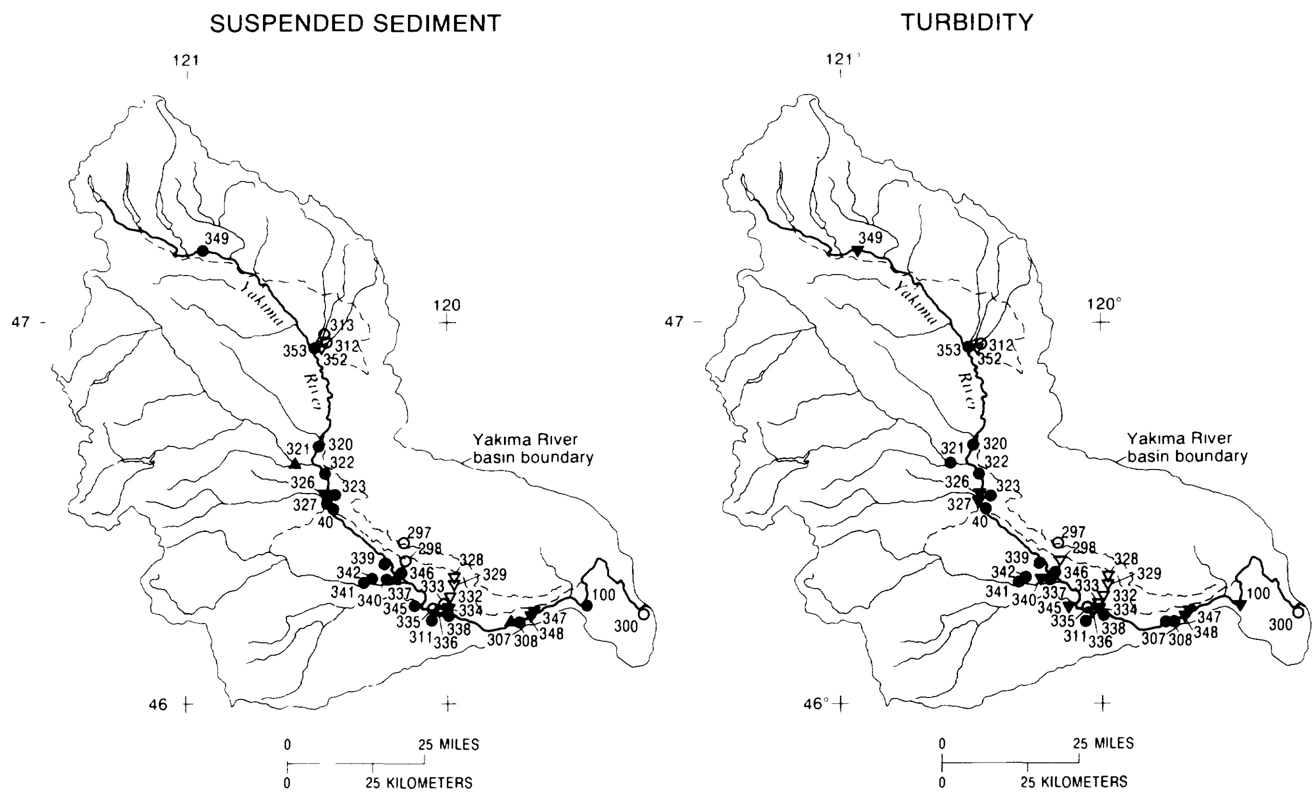


Figure 38.--Median turbidity values and suspended-sediment concentrations for selected seasons in the Yakima River, Washington, 1974-81 water years.

Trends

Results of the seasonal Kendall trend test for suspended sediment and turbidity indicate that downward trends occurred at several sites in the basin (fig. 39; table 51 at the back of the report). Some of these downward trends may be associated with decreasing streamflows from 1974-81 WY that coincide with decreasing precipitation in the Cascades. Other downward trends may be associated with the agricultural transition over the last 30 years from row crops to more permanent crops. For example, orchards in the



EXPLANATION

------ **Canal**

5-6 years of data

△ Upward trend (p*<=0.1)

○ No trend

7-8 years of data

▲ Upward trend (p*<=0.1)

● No trend

▼ Downward trend (p*<=0.1)

322 **Map reference number (see table 52)**

*Note: p = Probability level

Figure 39.--Non-flow-adjusted seasonal Kendall trends in suspended-sediment concentrations and turbidity values in the Yakima River basin, Washington, 1974-81 water years.

Roza Irrigation District have increased from 9,700 to 19,000 acres, while the total acres of irrigated land have remained relatively constant (about 66,000 acres). Orchard crops have less erosive potential than row crops, because they require less tillage and because grass is commonly planted between the trees to reduce erosion. Significant ($\rho \leq 0.1$) downward trends (non-flow adjusted) of suspended sediment range from 1.2 mg/L per year at Wide Hollow Creek to 6 mg/L per year at Sulphur Creek Wasteway at Factory Road (table 19). The largest significant decreases occur at several sites along Sulphur Creek and may be related to the conversion of row crops to less erosive crops. In addition, these decreases also may be related to the placement of sediment-detention ponds in the Sulphur Creek drainage to reduce the erosion of soils (CH2M HILL, 1975). Likewise, turbidity trends at Sulphur Creek sites generally are decreasing in accordance with suspended-sediment trends.

The seasonal Kendall slope estimators for significant ($\rho \leq 0.1$) non-flow-adjusted, suspended-sediment and turbidity trends are shown in table 19. The median of the seasonal Kendall slope estimators for suspended sediment is 1.7 mg/L per year for main-stem and canal sites and -4.1 mg/L per year for

Table 19.--Summary of significant (probability level less than or equal to 0.1) trends for suspended sediment, turbidity, and streamflow, Yakima River basin, Washington, 1974-81 water years

[Site types listed as: "M" = main stem, "C" = canal, and "D" = agriculturally or point-source-affected surface waters; m = meter, mg = milligram, L = Liter, yr = year, "NT" = no significant trend, NTU = nephelometric turbidity unit]

Site type	Site name and number	Water years of record	Non-flow adjusted: Trend, mg/L/yr or NTU/yr	Non-flow adjusted: Trend, percent of median per year	Non-flow adjusted: Median, mg/L or NTU	Flow adjusted: Trend, percent change per year	Streamflow: Trend, percent of median per year
	Suspended Sediment (use mg/L for "Trend" and "Median")						
M	320 Yakima River at Harrison Rd Bridge	1974-81	NT	NT	10	11.7	NT
M	322 Yakima River-Terrace Heights Bridge	1974-81	NT	NT	10	10.1	-6.7
M	40 Yakima River at Parker	1974-81	NT	NT	19	21.4	-8.2
M	337 Yakima River at bridge near Granger	1974-81	2.5	11.4	22	9.6	-8.2
M	321 Naches River at Nelson bridge	1974-81	1.0	20.0	5	29.4	-6.7
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	1.7	5.9	29	6.1	-2.7
D	352 Wipple Wasteway at Thrall Road	1974-79	-2.3	-9.7	24	-20.9	8.0
D	326 Wide Hollow Creek at Union Gap STP	1974-81	-1.2	-6.3	19	-6.9	-4.8
D	342 Wanity Slough at Meyers Road	1974-81	NT	NT	18	8.4	-13.3
D	328 Sulphur Cr at North above Sunnyside	1974-79	-5.0	-19.2	26	-23.6	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	-6.0	-14.3	42	-16.6	-6.3
D	331 Drn DID #3 at Duffy Road	1974-77	NT	NT	126	25.0	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	-4.5	-8.0	56	NT	-7.5
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	-4.1	-9.1	45	-11.8	-1.5
D	347 Spring Creek at Hess Road	1974-81	-1.5	-3.9	38	NT	NT
D	348 Snipes Cr at Old Inland Empire Road	1974-81	-4.1	-15.8	26	-16.8	4.8
D	300 KID Coyote Canyon Drain near bottom	1975-79	NT	NT	10	22.9	-14.8
	Turbidity (use NTU for "Trend" and "Median")						
M	349 Yakima River at Cle Elum	1974-81	-.1	-10.0	1	-10.3	-8.4
M	100 Yakima River at Kiona	1974-81	-.6	-7.9	7	NT	-9.2
C	297 Roza Main Canal at Beam Road	1974-79	NT	NT	3	-14.2	-3.6
C	298 Sunnyside Canal at Beam Road	1974-79	-.8	-15.0	5	-15.0	-5.9
D	313 Coleman Creek NW1/4 Sec 20 T17N R19E	1974-77	-.6	-12.7	5	NT	-16.5
D	352 Wipple Wasteway at Thrall Road	1974-79	-.5	-8.3	6	-16.2	NT
D	326 Wide Hollow Creek at Union Gap STP	1974-81	-2.0	-22.2	9	-23.5	-4.8
D	327 Ahtanum Creek at mouth	1974-81	-.3	-11.1	3	NT	-5.0
D	340 Sub-Drain 35 at Parton Road	1974-81	-.4	-13.3	3	-12.1	NT
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	NT	NT	18	-12.0	11.0
D	345 South Drain at Highway 22 nr Satus	1974-81	-.3	-3.7	9	NT	NT
D	336 Griffin Lake Outlet	1974-79	-3.0	-27.3	11	-28.6	-15.0
D	328 Sulphur Cr at North above Sunnyside	1974-79	-1.0	-18.2	6	-19.0	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	-1.7	-15.2	11	-18.4	-6.3
D	331 Drn DID #3 at Duffy Road	1974-77	-4.0	-16.7	24	NT	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	-1.5	-12.5	12	-10.3	-7.5
D	333 Sulphur Cr Wasteway at Morse Road	1974-79	-1.4	-9.7	15	-8.1	-6.7
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	-1.0	-7.7	13	-8.0	-1.5
D	347 Spring Creek at Hess Road	1974-81	-1.1	-12.0	9	-13.4	NT
D	348 Snipes Cr at Old Inland Empire Road	1974-81	-1.0	-16.7	6	-18.9	4.8
D	300 KID Coyote Canyon Drain near bottom	1975-79	NT	NT	3	20.5	-14.8

drain sites (fig. 40). For these comparisons, the Naches River at Nelson Bridge is classified as a main-stem site. If the median trend for drain sites was constant, it would correspond to a decrease of about 33 mg/L over the 8-year period, 1974-81 WY. Main-stem sites do not reflect the decreasing sediment concentrations observed at the drain sites, which indicates that these drains with historical data are not totally controlling main-stem sediment trends.

The median trend (non-flow adjusted seasonal Kendall slope) for turbidity is -0.55 NTU per year for main-stem and canal sites and -1.0 NTU per year for drain sites (fig. 40). If these trends were constant, they would correspond to decreases of 4.4 NTU for main-stem and canal sites and 8.0 NTU for drain sites over the 8-year period, 1974-81 WY. This similarity in trends could indicate that the drains are causing or are at least partly responsible for the turbidity trends in the main stem.

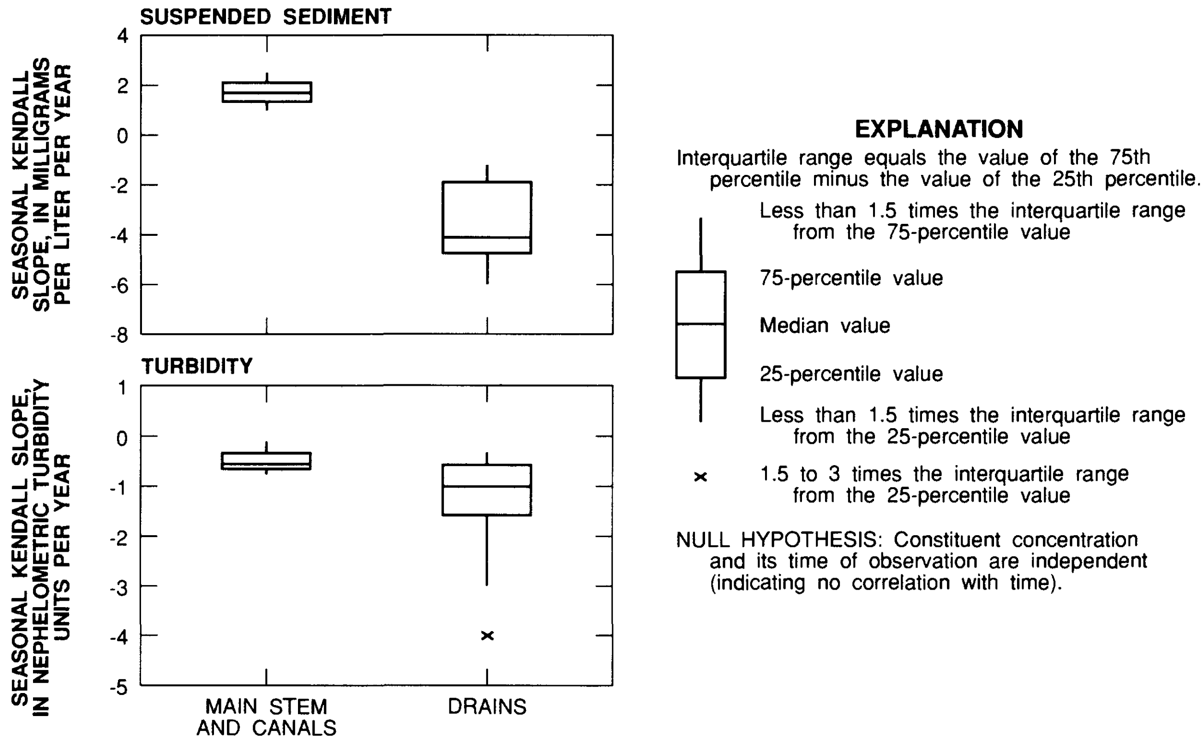


Figure 40.--Distribution of significant (probability level less than or equal to 0.1) seasonal Kendall slope estimators for non-flow-adjusted suspended-sediment and turbidity trends, Yakima River basin, Washington, 1974-81 water years.

Significant, upward, flow-adjusted trends of suspended sediment occurred at 21 percent of the sites (table 19 and 51). Prior to flow adjustment, only one main-stem site (Yakima River at bridge near Granger) had a significant trend. After flow adjustment, however, four of the seven Yakima River sites had significant upward trends. Significant, downward, flow-adjusted trends of suspended sediment occurred at 14 percent of the sites, all of which were agricultural drains. The increasing main-stem trends may be attributed to increasing sediment loads from unsampled tributaries.

Sediment Loads

Annual suspended-sediment loads were calculated for main-stem sites that had daily streamflows and monthly sediment data collected from 1974-81 WY. Monthly sediment data, however, were insufficient to accurately represent sediment transport over the range of flows that normally occur each month, especially for those months with large flows. The Yakima River at Union Gap site did not have any water-quality data collected in either 1974 or 1977 WY; therefore, the load estimates for the Union Gap site in these years are suspect. Because of the paucity of data, sediment loads in this report should be considered as estimates and should be used only to identify potential sources.

Loads were estimated for the low-, median-, and high-flow years (fig. 41 and table 20). Sediment loads for each of these years were relatively constant for the Yakima River at Cle Elum and at Ellensburg. The approximate doubling of loads from Ellensburg (Yakima RM 148.0) to Umtanum (Yakima RM 140.4) may be attributed to the sediment load from Wilson Creek (confluence at Yakima RM 147) and several other creeks in the reach. During the low-flow year, loads were relatively constant from Umtanum to Kiona, probably because streamflows and associated velocities in the basin were too small to transport large sediment loads. As a result, suspended sediment probably was deposited in the agricultural-return-flow channels and in the main stem.

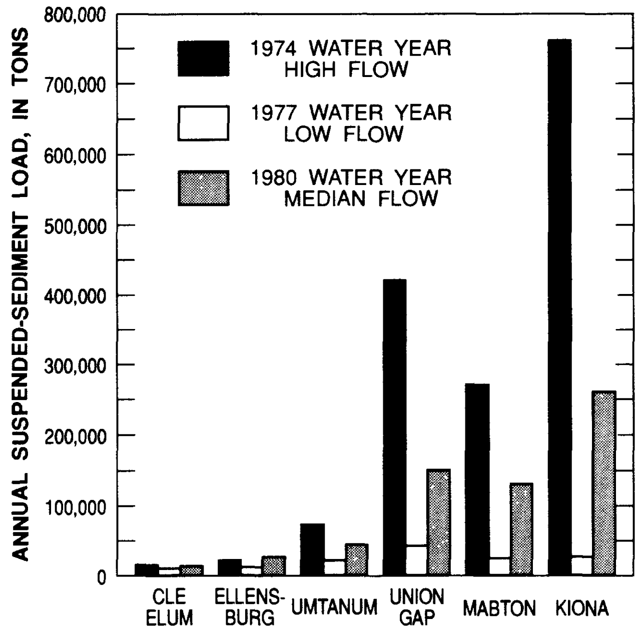


Figure 41.--Suspended-sediment loads in the Yakima River, Washington, 1974, 1977, and 1980 water years.

Large increases in sediment load were observed in the main stem from Umtanum (RM 140.4) to Union Gap (RM 107.2) and also from Mabton (RM 59.8) to Kiona (RM 29.9) in 1974 and 1980 WY (table 20). The suspended-sediment load from the Naches River (which is the major tributary in the reach between Umtanum and Union Gap) is insufficient to account for the increased load from

Umtanum to Union Gap in 1974 and 1980 WY. Likely sediment sources include Moxee Drain and Wide Hollow Creek (daily flow data from these drains are not available to estimate annual loads).

Load estimates show a substantial increase in loads from Union Gap (RM 107.2) to Kiona (RM 29.9) in 1974 and 1980 WY. This load increase is due to increases in the suspended-sediment concentrations during high- and median-flow years (fig. 41), because annual flows passing the two sites in either 1974 or 1980 WY are similar (table 20). The annual mean suspended-sediment concentration of 47 mg/L at Union Gap for the median-flow year (1980 WY) increased by more than 50 percent to 78 mg/L at Kiona, possibly indicating the effects of increased erosion from increased agricultural activity in the lower basin.

Large annual fluctuations occur depending on the characteristics of the flow year. For example, suspended-sediment loads at the Yakima River at Kiona increase from 27,000 t/yr during the low-flow year (1977 WY) to 760,000 t/yr for the high-flow year (1974 WY). This difference emphasizes the importance of comparing constituent loads among sampling sites during the same flow year or at least during the same flow conditions (for example, high-flow year to high-flow year). In addition to annual variations, seasonal variations in flow also affect monthly loads (fig. 42). In the Yakima River at Kiona, the major transport of sediment occurs during the months with the largest flows. As observed at Kiona during a median-flow year (1980 WY), loads range from a low of about 2,000 tons in October to a high of about 80,000 tons during April (influenced primarily by snowmelt). This monthly pattern of loads may not be consistent from year to year. For example, a large winter storm occurring during the December-to-February period could significantly increase monthly loads to levels comparable to snowmelt months.

Nutrients

Phosphorus and nitrogen are essential nutrients for aquatic plant growth and, in sufficiently large concentrations, can adversely affect water quality through (1) eutrophication (abundant accumulation of nutrients causing excessive aquatic plant growth), (2) toxicity to aquatic life, and (3) toxicity to warm-blooded animals that drink the water. Forms of nutrients that are readily available for biological uptake include orthophosphate (soluble-reactive phosphorus) and nitrite plus nitrate.

Increases in phosphorus concentrations in freshwater have been associated with eutrophication. To discourage excessive growth of aquatic plants in flowing water, it is recommended that total phosphorus (as P) concentrations should not exceed 0.1 mg/L (U.S. Environmental Protection Agency, 1986). Total phosphorus is a measure of the organic and inorganic forms of dissolved and suspended phosphorus. Sources of phosphorus in the Yakima River basin include the breakdown and erosion of phosphorus-bearing minerals in soils, decaying vegetation, phosphate fertilizers, sewage effluent, and metabolic wastes from animals.

Total nitrogen is a measure of organic and inorganic forms of dissolved and suspended nitrogen. Nitrogen generally is concentrated in soils and organic matter and, to a lesser extent, in rocks. Nitrogen sources in the Yakima River basin include agricultural fertilizers (that contain nitrate and

Table 20.--Estimated suspended-sediment loads at selected sites in the Yakima River, Washington, 1974, 1977, and 1980 water years

[Loads reported in tons per year; load values not in parenthesis are based on calibration data collected from 1970-85 water year; load values in parenthesis are based on calibration data that were collected 3 months prior to, during, and 3 months following the specified water year; "--" indicates insufficient data; WY = water year]

River mile	Map reference number	Site name	Mean daily flows 1974 WY	Mean daily flows 1977 WY	Mean daily flows 1980 WY	Suspended-sediment loads 1974 WY (high flow)	Suspended-sediment loads 1977 WY (low flow)	Suspended-sediment loads 1980 WY (median flow)
183.1	349	Yakima River at Cle Elum	1,770	1,418	1,596	15,000 (15,000)	11,000 (5,400)	13,000 (7,900)
148.0	354	Yakima River at Ellensburg	1,770	1,442	1,922	22,000 (--)	12,000 (7,700)	26,000 (23,000)
140.4	355	Yakima River at Umtanum	3,040	1,735	2,347	73,000 (--)	21,000 (12,000)	44,000 (40,000)
1/116.3	321	Naches River near Yakima	2,367	544	1,346	34,000 (--)	3,800 (2,200)	21,000 (56,000)
107.2	32	Yakima River above Ahtanum Creek at Union Gap3/	5,265	1,884	3,249	420,000 (--)	42,000 (--)	150,000 (310,000)
59.8	338	Yakima River near Mabton	5,497	1,215	3,237	270,000 (190,000)	25,000 (25,000)	130,000 (95,000)
29.9	100	Yakima River at Kiona	5,794	1,293	3,393	760,000 (--)	27,000 (25,000)	260,000 (710,000) 2/517,440

1/ Confluence of Naches and Yakima Rivers. Naches River site located at Naches River mile 0.1.
2/ Based on daily and hourly samples.
3/ Loads in river exclude loads passing Union Gap in Roza Canal.

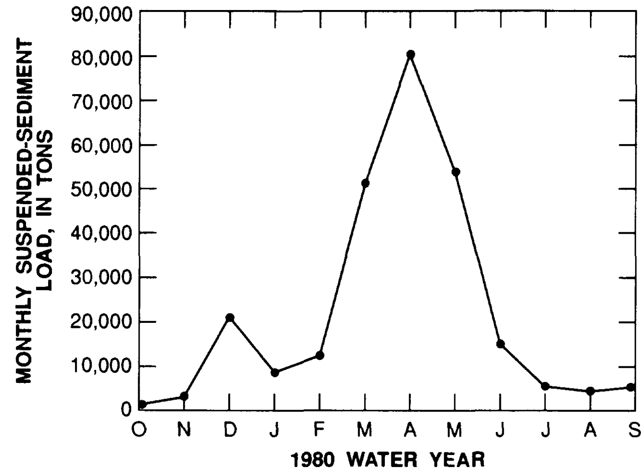


Figure 42.--Monthly suspended-sediment loads in Yakima River at Kiona, Washington, 1980 water year.

ammonium), organic wastes (such as sewage effluent, food-processing wastes, decaying plants, animal wastes), and atmospheric deposition. The breakdown of proteinaceous organic matter and urea results in releases of the ammonium ion (U.S. Environmental Protection Agency, 1986). The ammonium ion in water is in chemical equilibrium with un-ionized ammonia, a nitrogen species that is toxic to freshwater aquatic life above certain concentrations. Un-ionized ammonia concentrations are dependent on such factors as the total ammonium concentration, pH, and temperature of the stream. As any of these factors increase, concentrations of un-ionized ammonia become larger and can cause increased toxic effects. Ammonium ions in aerobic soil or water undergo bacterial oxidation to nitrite and then nitrate. In addition, certain types of algae can extract nitrogen from the atmosphere and convert it into nitrate. In the process of denitrification, nitrite and nitrate may be reduced to nitrogen gas in anaerobic soils and water. The process of denitrification removes nitrogen from the stream and helps to prevent undesirable growths of algae and other aquatic plants in nitrogen-limited streams. Large nitrite-plus-nitrate concentrations in a water supply are a hazard to warmblooded animals. Within the gastrointestinal tract of the animal where anaerobic conditions exist, nitrate may be reduced to nitrite and react with hemoglobin to cause impairment of oxygen transport. The maximum contaminant level for nitrate (as N) in domestic drinking water supplies is 10 mg/L (U.S. Environmental Protection Agency, 1986); however, concentrations less than 1 to 2 mg/L probably could be maintained to help minimize the growth of aquatic-plant nuisances.

Nutrient concentrations in the Yakima River basin from 1941-85 are similar to those concentrations observed in many rivers in the United States from 1974-81 (Smith and others, 1987). Median concentrations in the United States rivers are 0.13 and 0.41 mg/L for total phosphorus (as P) and nitrite plus nitrate (as N), respectively; median concentrations for all data from the Yakima River basin are 0.12 and 0.36 mg/L for total phosphorus and nitrite plus nitrate, respectively. Median concentrations at main-stem sites upstream from Parker (RM 104.6) are generally more than 50 percent smaller than those for United States rivers; downstream from Parker, the median concentrations are similar to or greater than those for rivers in the United States.

Generalized land- and water-use characteristics suggest that eutrophication due to man's activities is having its greatest impact in the lower Yakima River basin downstream from the City of Yakima. More than 70 percent of the irrigated land, 80 percent of the population, and generally 90 percent of the point-source nutrient loads occur in the lower basin (table 21). In addition, large main-stem flows are maintained in the upper basin by flow augmentation and dilute the concentrations of inflowing nutrients from point and nonpoint sources. In contrast, smaller streamflows occur in the lower basin owing to large irrigation-water diversions that leave reduced volumes available for dilution of nutrients in the main stem.

Spatial Variation

From 1974-81 WY, the Yakima River had small background concentrations of total phosphorus, dissolved orthophosphate, total ammonia, and nitrite plus nitrate (median values less than or equal to 0.04, 0.02, 0.02, and 0.13 mg/L, respectively) in the upper main stem from Cle Elum (RM 183.1) downstream to Terrace Heights Bridge (RM 113.2) [fig. 43]. The diluting effect of the Naches River at RM 116.3 and the Roza powerplant return flow at RM 113.3 reduces nutrient concentrations. Farther downstream in the vicinity of Parker at RM 104.6, median concentrations increase by about a factor of two or more, and except for ammonia, which decreases downstream from Parker, the nutrient concentrations are larger at Kiona (RM 29.9). The increased concentrations at Parker may be attributed to nutrient inputs from a STP at RM 111 (table 8), Wide Hollow Creek at RM 107.4, Moxee Drain at RM 107.3, and Ahtanum Creek at RM 106.9 (table 49 at the back of this report).

Table 21.--Estimated point-source discharges and nutrient loads in the upper and lower Yakima River basin, Washington, for 1974, 1977, and 1980 water years

["Upper basin" refers to the point sources in the subbasins that are upstream of the confluence of the Naches and Yakima Rivers (RM 116.3); "Lower basin" refers to point sources in the subbasins downstream of the confluence; N = nitrogen; P = phosphorus; BOD5 = 5-day biochemical oxygen demand; all data except flows are in thousands of pounds per year]

Location	Discharge, in cubic feet per second	Dissolved nitrite plus nitrate as N	Total ammonia as N	Total ammonia plus organic nitrogen as N	Dissolved ortho-phosphate as P	Total phos-phorous as P
1974 water year						
Upper basin	10	13	110	250	24	96
Lower basin	48	96	750	1,250	240	750
1977 water year						
Upper basin	8	9	37	160	35	50
Lower basin	41	81	650	1,100	240	760
1980 water year						
Upper basin	10	12	47	52	41	57
Lower basin	41	82	680	1,200	260	800

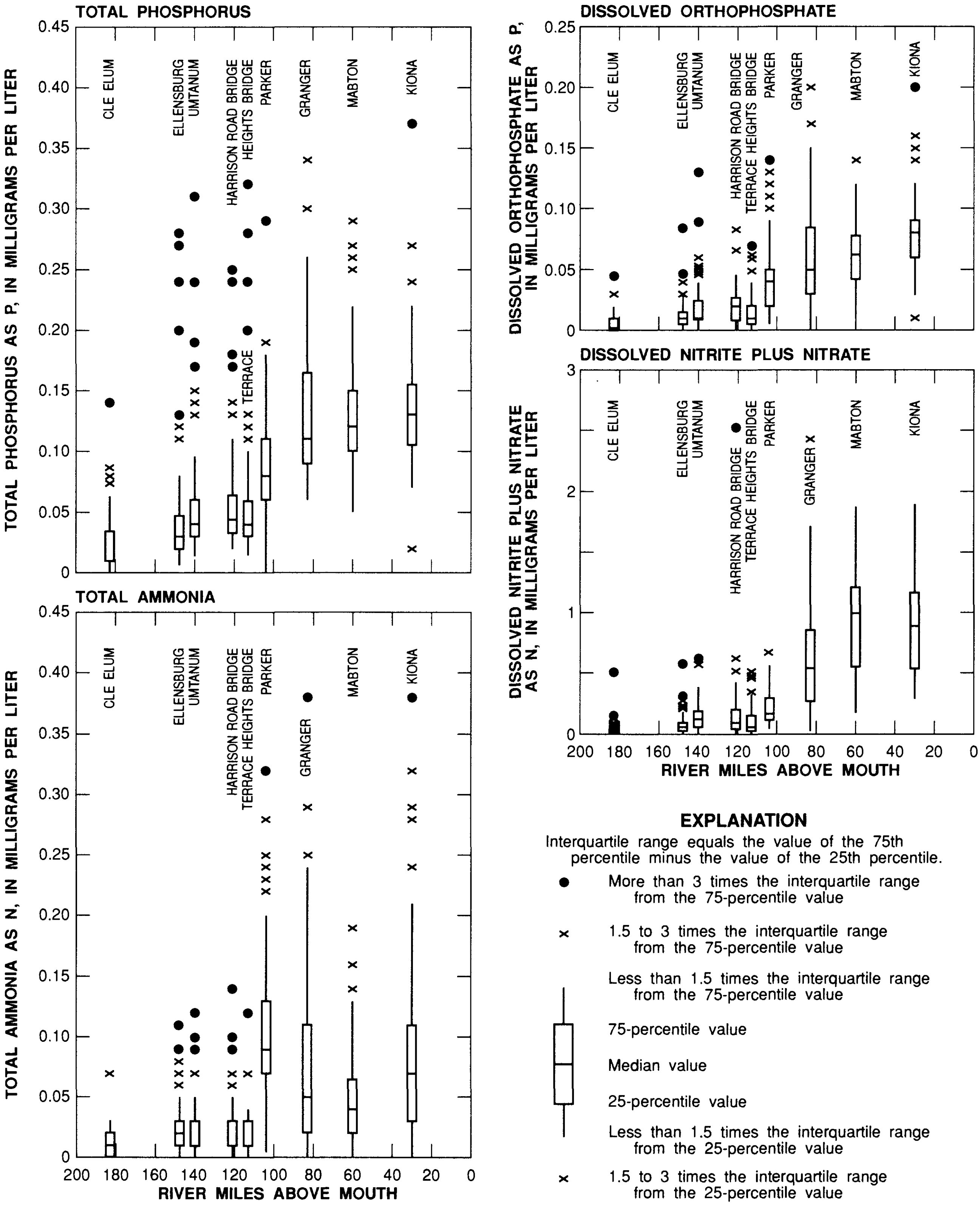


Figure 43.--Concentrations of total phosphorus, dissolved orthophosphate, dissolved nitrite plus nitrate, and total ammonia, in the Yakima River, Washington, 1974-81 water years (some large values are not shown).

Downstream from the Wapato and Sunnyside Canal diversions near Parker (RM 103.7), the streamflow during most of the irrigation season (April through October) is small. Consequently, point and nonpoint discharges (including agricultural-return flows) from tributaries downstream from Parker cause substantial increases in median nutrient concentrations (fig. 43). Median nutrient concentrations in the major downstream tributaries are generally greater than or equal to median concentrations observed in the main stem; therefore, these tributaries at least partially account for increases in main-stem nutrient concentrations.

At and downstream from the Yakima River near Granger (RM 82.7), median total phosphorus concentrations are greater than 0.1 mg/L (recommended guideline for preventing aquatic-plant nuisances), with the largest median values occurring in the main stem at Kiona (0.13 mg/L). Nutrient enrichment during warm summer months results in some scattered patches of dense macrophytic and rooted-plant growth in the sluggish-moving (low velocity) reaches of Yakima River downstream from its confluence with Satus Creek (as observed by U.S. Geological Survey personnel from 1986-90). However, concentrations of total phosphorus in excess of 0.1 mg/L do not alone produce eutrophy. Eutrophication is also a function of the: (1) availability of nitrogen, phosphorus, and micronutrients; (2) presence of toxic contaminants that are harmful to aquatic plants; (3) stream temperature; (4) light penetration and water depth relative to the photosynthetic zone; (5) water-detention time, including stream velocity (Rickert and others, 1977); and (6) predation by consumer organisms (benthic invertebrates, fish, and birds).

Higher river velocities in the lower Yakima River may reduce localized plant productivity by increasing the dispersion and transport of plant cells. As river velocities decrease during the summer months, especially in the vicinity of diversion dams, the shoal areas become covered with dense aquatic growth, as observed just upstream from Horn Rapids Dam (Yakima RM 18.0) in August 1987. Dense growth also may occur in shallow stream reaches that have large surface areas (relative to water volume) available for algal-growth attachment.

Stream turbidity resulting from soil erosion in agricultural areas may be limiting the threat of plant nuisances in low-velocity reaches by decreasing sunlight penetration that is needed for photosynthesis. Historical summer data indicate that dissolved inorganic forms of both phosphorus and nitrogen occurred in the lower basin at sufficiently large concentrations to support eutrophic conditions. Consequently, if stream turbidity was reduced without also reducing dissolved nutrient concentrations (which is mostly dissolved orthophosphate and dissolved nitrate plus nitrate), eutrophic conditions will likely become worse during the warm summer months.

Sites where eutrophic conditions might have occurred (median total phosphorus concentrations greater than or equal to 0.1 mg/L) are listed in table 22. Total phosphorus determinations in the water column during the active summertime growth periods exclude the amount of phosphorus associated with bed sediment and the settled, attached, and rooted biomass. As a result, some of the sampling sites not listed in table 22 also may have exhibited eutrophic conditions.

Table 22.--Sites with median total phosphorus concentrations greater than or equal to 0.1 milligrams per liter, Yakima River basin, Washington, 1941-85 water years

[Median values are not necessarily representative of the annual conditions nor are they necessarily representative of the seasonal variations, because all months and years were not equally represented. Concentrations are shown for identification of potential problem areas and should not be used for intersite comparisons]

Map reference number	Site name	Water-year period	Number of observations	Median total phosphorus as P, in milligrams per liter
	Main-stem sites in downstream order			
337	Yakima River at bridge near Granger	1974-81	72	0.11
432	Yakima River at Granger--North Side	1971-71	18	.16
433	Yakima River at Granger--South Side	1971-71	18	.11
92	Yakima River at Mabton	1971-75	63	.12
338	Yakima River at bridge near Mabton	1971-81	74	.12
94	Yakima River at Prosser	1971-75	66	.13
100	Yakima River at Kiona	1971-85	250	.12
399	Yakima River at Kiona	1968-72	45	.15
101	Yakima River at Van Geisan Bridge	1972-77	54	.12
428	Yakima R nr Richland	1971-71	18	.21
	Canals, tributaries, and drains in order of increasing median concentrations of total phosphorus			
14	Roza Cnl at Wilgus Road	1976-77	19	.10
351	Wilson Creek Dammon Road	1974-77	37	.10
315	Cascade Canal NE1/4 Sec 31 18N 19E	1971-74	14	.10
348	Snipes Cr at Old Inland Empire Road	1974-81	64	.10
299	KID Hover Wasteway near bottom	1968-71	9	.11
342	Wanity Slough at Myers Road	1974-81	68	.11
378	Squaw Cr--0.3 mi abv Hwy 97 Bridge	1983-84	19	.11
52	Wanity Slough at Rocky Ford Road	1974-75	12	.12
353	Wilson Creek at Thrall Road	1974-81	58	.12
42	Sunnyside Canal at Maple Grove Road	1976-77	19	.12
313	Coleman Cr NW 1/4 Sec 20 T17N R19E	1971-79	74	.12
325	Wide Hollow Cr at W. Washington Ave	1974-77	37	.12
344	Satus Cr east of North Satus Road	1974-74	2	.12
43	Sunnyside Canal blw Sulphur Creek	1976-77	19	.13
70	Satus Creek at Satus	1974-75	47	.13
111	Lower Pump 14 Lateral below Wilgus Rd	1976-76	2	.13
307	Chandler Canal--mile 0.6 nr Prosser	1970-81	83	.13
318	Cowiche Cr SE1/4 Sac 9 T13N R18E	1971-74	21	.13
327	Ahtanum Creek at mouth	1974-81	73	.13
458	Ahtanum Creek near Tampico damsite	1970-71	3	.14
44	Sunnyside Canal at Edison Road	1976-77	19	.14
45	Sunnyside Canal at Bethnay Road	1976-77	18	.14
104	Turbine Lateral above Griffin Road	1976-76	2	.14
308	Chandler Canal--mile 2.8 nr Prosser	1970-81	84	.14
319	Cottonwood Can Drain SE1/4 S 28	1971-77	58	.14
328	Sulphur Cr at North above Sunnyside	1974-79	54	.14
341	Marion Drain at Highway 97	1974-81	68	.14
53	Marion Drain near Granger	1974-75	48	.15
302	Main Drain at Highway No. 22	1968-74	45	.15
309	Satus 2 Canal, NW1/4 S17 9N 21E	1971-73	16	.15
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	.15
347	Spring Creek at Hess Road	1974-81	67	.15
37	Ahtanum Creek at Goodman Road	1974-75	12	.16
46	Sunnyside Canal at Grandview	1976-77	19	.16
62	Toppenish Creek near Satus	1974-75	47	.16
301	KID Main Canal near head at gage	1968-73	26	.16
303	WID Main Drain at Robbins Road	1968-77	19	.16
115	Snipes Mountain Lateral at Drop 4	1976-76	2	.17
310	Nequist Drain NW1/4 S 25 9N 21E	1971-74	22	.17
110	Snipes Mountain Lateral at mile 9.0	1976-76	2	.18
343	Toppenish Creek at Cook Road	1974-74	2	.18
112	Snipes Mountain Lateral, mile 9.09	1976-76	1	.18
324	Wide Hollow Creek near Gromore	1974-77	35	.18
29	Wide Hollow Creek at Goodman Road	1941-74	42	.19
336	Griffin Lake Outlet	1974-79	46	.20
30	Wide Hollow Creek at Union Gap	1971-74	59	.20
105	Grandview Canal at County Line Road	1976-76	2	.20
304	WID Main Drain at Lateral C Road	1968-71	19	.21
312	Cherry Cr SE 1/4 Sec 29 T17N R19E	1971-79	71	.21
352	Wipple Wasteway at Thrall Road	1974-79	54	.21
293	Mile 28 Drain at State Highway	1968-74	40	.22
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	.22
345	South Drain at Highway 22 nr Satus	1974-81	67	.22
108	Snipes Mountain Lateral at Drop 8	1976-76	2	.22
71	South Drain near Satus	1974-75	12	.24
7	Wilson Creek at Thrall	1973-75	48	.24
106	Snipes Mt. Wasteway abv DID 3 Drain	1976-76	2	.24
311	Satus Drn 302 NW1/4 Sec 34 9N 22E	1971-81	83	.25
58	Mud Lake Drain near Harrah	1974-75	6	.26
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	.29
335	Griffin Lake Inlet	1974-79	50	.29
292	DID No. 25 at State Highway No. 12	1968-83	43	.31
333	Sulphur Cr Wasteway at Morse Road	1974-79	54	.31
127	Outlook Canal blw Independence Road	1976-76	2	.34
89	DID 9 Drain near Sunnyside	1976-77	64	.35
339	East Toppenish Drain at Wilson Road	1974-81	68	.36
323	Drain at Birchfield Road	1974-81	74	.38
294	DID 2 East Branch at Mile 28 Drain	1968-74	41	.39
91	Sulphur Creek Wasteway nr Sunnyside	1976-77	65	.40
346	Granger Drain--Hwy 223 abv Granger	1974-81	72	.42
295	Drain 27.2 at Knowles Road	1968-73	23	.42
357	Drain at Elks Golf Course	1978-81	36	.56
88	Black Canyon Creek at Waneta Road	1976-77	64	.63
87	Washout Drain at Sunnyside	1976-77	65	.64
296	26.6 Drain at Kirk Rd crossing	1968-74	28	.68
326	Wide Hollow Creek at Union Gap STP	1974-81	74	.80
86	DID 18 Drain at Sunnyside	1976-77	65	.84
331	Drain DID #3 at Duffy Road	1974-77	37	1.1
90	DID 3 Drain near Sunnyside	1976-77	65	1.1
356	Drain DID #3 abv Rendering Plant	1975-77	25	1.2
330	Drain DID #3 at South Hill Road	1974-77	37	1.4

A critical concentration for biologically available inorganic orthophosphate (soluble-reactive as P) occurs between 0.01 to 0.025 mg/L (Sawyer and McCarty, 1967; U.S. Environmental Protection Agency, 1986). If exceeded, the concentration may cause nuisance growths of algae and other aquatic plants. Summary of all available dissolved orthophosphate data (collected through 1985 WY; qualitative data set) indicates that the median concentrations upstream from the Terrace Heights Bridge (RM 113.2) are below this critical level (0.025 mg/L) and generally account for less than 35 percent of the total phosphorus in a water sample. In contrast, the median dissolved orthophosphate concentrations in the lower basin are more than twice this critical level and account for at least 50 percent of the total phosphorus. In addition to producing eutrophic conditions, orthophosphate concentrations in excess of 0.1 mg/L as P may interfere with coagulation during the removal of fine-grained sediment at water treatment plants (U.S. Environmental Protection Agency, 1976). Median dissolved orthophosphate concentrations in the agricultural-return flows that also receive point-source discharges were generally greater than or equal to 0.1 mg/L.

Large ammonia concentrations in streams are detrimental to fish, causing chronic problems and, in extreme cases, acute toxicity. Ammonia toxicity is a function of stream temperature and pH, both of which may vary at a site as a result of diurnal changes in solar radiation, photosynthesis, and respiration. Most ammonia samples in the Yakima River basin have been collected during daylight hours, but not necessarily during the warmest daily stream temperatures, when the percent of un-ionized ammonia (toxic species) in equilibrium with ionized ammonia is at a maximum. To evaluate worst-case conditions and to help identify potential problem areas, ammonia concentrations initially were related to EPA criteria (U.S. Environmental Protection Agency, 1986) by assuming that stream temperatures were 30 °C (the observed field pH for each sample was used for this evaluation). A summary of instantaneous total ammonia concentrations listed in table 23 shows those sites where the criterion (based on 4-day average of total ammonia concentrations for salmonids or other sensitive coldwater species) would have been exceeded if stream temperatures had been 30 °C and if the concentrations had been 4-day averages rather than instantaneous values. The number of samples that exceeded EPA criteria at the field-measured temperature also are listed in table 23. Evaluation of all ammonia data collected through 1985 WY indicates that 100 of the 6,475 determinations exceeded the criteria at the field-measured temperature and pH. One-third of these exceedances occurred prior to 1980 at Wide Hollow Creek downstream from the Union Gap STP, which was closed in 1979. Many of the other sites with values exceeding criteria were located on agricultural-return flows that also receive point-source discharges. The frequency of occurrence of ammonia exceedances was equally distributed throughout most of the year except for January (cause unknown), when the number of exceedances increased by more than 50 percent.

Large nitrite-plus-nitrate concentrations in the presence of other nutrients help to stimulate undesirable plant growth in streams; however, a nitrite-plus-nitrate criterion for controlling these growths has not been established. EPA's drinking-water maximum contaminant level for nitrite-plus-nitrate concentrations is 10 mg/L. All sites

Table 23.--Selected sites with large total ammonia concentrations, Yakima River basin, Washington, 1968-85 water years

[Ammonia criteria are based on 4-day average concentrations for the protection of salmonids or other sensitive coldwater species (U.S. Environmental Protection Agency, 1986); criteria varies relative to stream temperature and stream pH; mg/L = milligrams per liter; N = nitrogen]

Map reference number	Site name	Number of observations	Number of samples exceeding EPA criteria assuming 30 degrees Celsius at measured field pH	Number of samples exceeding EPA criteria at measured field temperature and pH	Maximum total ammonia as N (mg/L)
7	Wilson Creek at Thrall	48	12	0	0.80
26	Naches River near North Yakima	48	2	0	.09
27	Yakima River near Terrace Heights	92	1	0	.13
30	Wide Hollow Creek at Union Gap	58	1	0	.51
32	Yakima River at Union Gap	38	7	0	.33
40	Yakima River at Parker	213	6	0	.22
48	Yakima River near Toppenish	67	1	0	.06
53	Marion Drain near Granger	48	1	0	.53
62	Toppenish Creek near Satus	47	3	1	.46
70	Satus Creek at Satus	47	1	0	.23
94	Yakima River at Prosser	65	2	0	.51
100	Yakima River at Kiona	220	11	5	.55
101	Yakima River at Van Geisan Bridge	54	6	0	.50
292	DID No. 25 at State Highway No. 12	44	2	1	4.2
293	Mile 28 Drain at State Highway	41	1	0	1.2
294	DID 2 East Branch at Mile 28 Drain	43	1	0	.24
295	Drain 27.2 at Knowles Road	25	1	1	.62
296	26.6 Drain at Kirk Rd cossing	30	9	8	19.7
308	Chandler Canal--mile 2.8 nr Prosser	83	1	0	.06
311	Satus Drain 302 NW1/4 Sec 34 9N 22E	83	3	1	6.1
323	Drain at Birchfield Road	73	8	1	.55
326	Wide Hollow Creek at Union Gap STP	73	45	33	9.1
327	Ahtanum Creek at mouth	72	1	1	1.6
328	Sulphur Cr at North above Sunnyside	53	3	1	1.8
329	Sulphur Cr Wasteway at Factory Road	54	2	1	2.7
330	Drain DID #3 at South Hill Road	36	32	13	4.0
331	Drain DID #3 at Duffy Road	36	25	5	2.8
332	Sulphur Cr Wasteway at Duffy Road	54	3	0	1.9
333	Sulphur Cr Wasteway at Morse Road	53	13	1	2.4
334	Sulphur Cr Wasteway at McGee Road	72	13	3	2.3
335	Griffin Lake Inlet	50	4	1	1.8
339	East Toppenish Drain at Wilson Road	67	23	6	5.9
342	Wanity Slough at Myers Road	67	2	0	.64
346	Granger Drain--Hwy 223 abv Granger	71	16	1	3.9
347	Spring Creek at Hess Road	66	1	0	.10
356	Drain DID #3 abv Rendering Plant	24	18	7	3.8
357	Drain at Elks Golf Course	36	12	7	5.1
378	Squaw Cr--0.3 mi abv Hwy 97 Bridge	19	2	2	.74
399	Yakima River at Kiona	39	2	0	.10

with data were compared with this standard, because the streams in the basin, except Sulphur Creek, are classified by the State of Washington for use as domestic-water supplies.

Evaluation of about 7,900 determinations (historical data through 1985) of nitrite plus nitrate from more than 250 sites indicates that only Satus Drain 302 (map reference number 311) had concentrations larger than 10 mg/L. The largest concentrations at this site occurred during low-flow periods from October to March when flows were approximately 10 percent of those during the irrigation season. This time period suggests that the source of nitrite plus nitrate is associated with contributions from ground water and (or) point sources.

To further evaluate nitrite-plus-nitrate enrichment, those sites with median concentrations greater than or equal to 1 mg/L (sufficiently large concentration to support eutrophication) are summarized in table 24. Most of these sites are located at agricultural-return flows downstream from the Yakima River at Granger (RM 82.7). Most sites with median concentrations greater than 2 mg/L were located in the Sunnyside subbasin. Instantaneous load estimates during irrigation season indicate that the Sunnyside STP contributes only 5 percent of the nitrite-plus-nitrate load from the Sunnyside subbasin. In addition to impacts from irrigated agriculture, a large number of dairies and feedlots are located in the Sunnyside subbasin (Jim Corliss, Conservation District, oral commun., 1989) and may contribute significantly to the nitrate enrichment. Other subbasins with streams exhibiting nutrient enrichment include Satus and Toppenish Creeks.

Large concentrations of $(ORG+NH_4)$-N (organic nitrogen plus ammonia nitrogen) result from agricultural and livestock runoff and domestic waste effluent. Water-quality standards or criteria have not been established for organic nitrogen compounds. These compounds may undergo bacterial decomposition and oxidation to the toxic forms of nitrogen (ammonia, nitrite, and nitrate). Stream reaches with relatively large $(ORG+NH_4)$-N concentrations should be considered as potential water-quality problem areas.

Compilation of about 2,200 $(ORG+NH_4)$-N determinations collected through 1985 WY indicates that headwater tributaries, main-stem sites, and canals have the smallest $(ORG+NH_4)$-N concentrations, with median values less than 0.6 mg/L. With few exceptions, sites with median concentrations greater than 0.6 mg/L are drains located in the Sunnyside subbasin. Their locations coincide with those sites that also have the large nitrite-plus-nitrate concentrations.

Seasonal Variation

The concentration of suspended and dissolved nutrients in a river is related to many factors. Three important factors are the (1) capacity of a stream to transport large concentrations of suspended nutrients (including nutrients in the sediment matrix and those adsorbed onto the sediment), (2) sources of the water and nutrients (for example, from pristine sources, point sources, or agricultural-affected nonpoint sources), (3) volume of water available for diluting the nutrients, and (4) biological and chemical processes in the water column and bed sediment. Each of these factors interrelate causing seasonal fluctuations of nutrient concentrations in the Yakima River basin (table 25).

General observations concerning seasonal variations in nutrient concentrations are as follows:

(1) Largest suspended-sediment and total-phosphorus concentrations generally occur from April through June and coincide with the largest streamflows. Spring snowmelt increases streamflows in the main stem, and the start up of irrigation activities increases flows

Table 24.--Selected sites with median nitrite-plus-nitrate concentrations greater than or equal to 1 milligram per liter, Yakima River basin, Washington, 1947-85 water years

Map reference number	Site name	Period of record	Number of observations	Median value of nitrite plus nitrate as N, in milligrams per liter
338	Yakima River at bridge near Mabton	1971-81	74	1.0
29	Wide Hollow Creek at Goodman Road	1971-74	42	1.4
30	Wide Hollow Creek at Union Gap	1971-74	60	1.3
52	Wanity Slough at Rocky Ford Road	1974-75	12	1.4
53	Marion Drain near Granger	1974-75	47	1.7
58	Mud Lake Drain near Harrah	1974-75	6	1.4
68	Satus Creek near Satus	1980-80	1	1.2
71	South Drain near Satus	1974-80	13	1.7
86	DID 18 Drain at Sunnyside	1976-77	65	3.6
87	Washout Drain at Sunnyside	1976-77	65	2.5
88	Black Canyon Creek at Waneta Road	1976-77	64	3.9
89	DID 9 Drain near Sunnyside	1976-77	65	3.1
90	DID 3 Drain near Sunnyside	1976-77	65	2.4
91	Sulphur Creek Wasteway nr Sunnyside	1976-77	65	1.9
102	08N/22E-02M01, Washington	1980-80	1	4.6
103	Drain 302 at Hwy 22 Br near Mabton	1980-80	1	3.6
107	North Drain at Farm Road	1980-80	1	2.3
109	Coulee Drain at North Satus Road	1980-80	1	2.4
292	DID No. 25 at State Highway No. 12	1968-83	43	1.5
293	Mile 28 Drain at State Highway	1968-74	40	1.5
294	DID 2 East Branch at Mile 28 Drain	1968-74	42	2.1
300	KID Coyote Canyon Drain near bottom	1968-79	63	2.1
302	Main Drain at Highway No. 22	1968-74	44	2.1
303	WID Main Drain at Robbins Road	1968-77	19	2.6
304	WID Main Drain at Lateral C Road	1968-71	19	1.9
309	Satus 2 Canal, NW1/4 S17 9N 21E	1971-73	16	1.1
310	Nequist Drain NW1/4 S 25 9N 21E	1971-74	22	2.7
311	Satus Drain 302 NW1/4 S 34 9N 22E	1971-81	83	3.2
323	Drain at Birchfield Road	1974-81	74	1.0
326	Wide Hollow Creek at Union Gap STP	1974-81	74	1.1
328	Sulphur Cr at North above Sunnyside	1974-79	54	3.5
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	1.5
330	Drain DID #3 at South Hill Road	1974-77	37	2.8
331	Drain DID #3 at Duffy Road	1974-77	36	2.5
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	2.8
333	Sulphur Cr Wasteway at Morse Road	1974-79	54	2.7
334	Sulphur Cr Wasteway at McGee Road	1974-81	73	2.7
339	East Toppenish Drain at Wilson Road	1974-81	68	2.4
340	Sub Drain 35 at Parton Road	1974-81	68	2.1
341	Marion Drain at Highway 97	1974-81	68	2.5
342	Wanity Slough at Myers Road	1974-81	68	1.4
345	South Drain at Highway 22 nr Satus	1974-81	67	1.8
346	Granger Drain--Hwy 223 abv Granger	1974-81	72	2.3
347	Spring Creek at Hess Road	1974-81	67	1.4
356	Drain DID #3 abv Rendering Plant	1975-77	25	3.0
357	Drain at Elks Golf Course	1978-81	36	1.7
378	Squaw Cr--0.3 mi abv Hwy 97 Bridge	1983-84	19	1.0
500	Sulphur Creek at Green Valley Road	1974-75	15	2.0
501	Sulphur Creek at Duffy Road	1974-75	15	2.1
502	Sulphur Creek at Alexander Road	1974-75	15	1.4
505	DID 3 Drain on Needham Feedlot	1974-75	15	1.5
506	DID 9 Drain at Sunnyside-Mabton Hwy	1974-75	15	2.9
507	DID 5 Drain along Tear Road	1974-75	15	2.8
508	Washout Drain at Allen Road	1974-75	15	2.1
509	DID 18 Drain at Vernita Highway	1974-75	15	2.8
510	DID 3 at E. 1st St in Sunnyside	1974-74	3	1.4
512	DID 3 Drain at Duffy Road	1974-74	2	2.0
513	DID 3 Drain-Yakima Rendering Plant	1974-74	2	2.3
514	Tributary to DID 3 at Midvale Road	1974-74	2	2.0
515	DID 3 Drain at South Hill Road	1974-74	2	2.3
516	Outfall of Sunnyside STP into DID 3	1974-74	3	2.3
517	DID 3 Drain at Highway 12	1974-74	2	1.3
518	DID 3 Drain at Outlook Road	1974-74	2	1.1
520	Trib. to DID 9 at Euclid Road	1974-74	2	1.6
521	Trib. to DID 9, 500 yd N. Stover Rd	1974-74	2	3.3
522	Trib. to DID 5 Drain at Allen Road	1974-74	2	3.1
523	Trib. to DID 5 at Alexander Road	1974-74	2	3.6
524	Trib. to DID 5 Drain at Factory Road	1974-74	1	1.6
525	Washout Drain--Van Belle/Washout Rd	1974-74	2	1.9
526	DID 17 Drain at Vernita Highway	1974-74	2	2.6
527	Trib. to DID 18 at Van Belle Road	1974-74	2	2.1

Table 25.--Seasonal variation of median values of nutrients, suspended sediment, streamflow, and specific conductance for selected sites in the Yakima River basin, Washington, 1974-81 water years

[Oct-Dec = October-December, irrigation ends, low flows; Jan-Mar = January-March, cold temperatures, winter storms; Apr-Jun = April-June, irrigation begins, snowmelt occurs; Jul-Sep = July-September, summer irrigation; * indicates period with largest median; nutrient and sediment concentrations in milligrams per liter; specific conductance in microsiemens per centimeter at 25 degrees Celsius; streamflow in cubic feet per second]

Map reference number	Site name	Total phosphorus as P				Dissolved orthophosphate as P				Nitrite plus nitrate as N				Total ammonia as N			
		Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
349	Yakima River at Cle Elum	0.01	0.01	*0.02	0.01	*0.004	0.001	0.003	*0.004	0.02	*0.04	0.02	0.03	*0.01	*0.01	*0.01	*0.01
353	Wilson Creek	.09	*.13	.12	.11	.05	.04	.06	*.08	.27	*.36	.24	.24	.02	*.03	.02	.01
321	Naches River	.01	*.03	*.03	.02	.006	*.01	.008	.007	*.06	*.06	.03	.02	*.01	*.01	*.01	*.01
323	Moxee Drain1/	.36	.41	*.42	.36	*.32	.31	.14	.16	*2.73	2.53	.67	.80	.05	*.08	.05	.03
322	Yakima River at Terrace Heights Br	.04	*.05	.04	.03	.01	*.02	.01	.008	.14	*.18	.04	.03	*.02	*.02	*.02	.01
341	Marion Drain	.14	.14	*.15	.13	.09	*.10	.07	.08	3.14	*3.45	1.90	2.16	*.02	*.02	*.02	*.02
339	East Toppenish Drain	.54	*.75	.34	.22	.50	*.64	.20	.14	*3.01	2.78	1.80	2.20	.46	*1.04	.30	.09
346	Granger Drain	.31	.29	*.61	.42	.16	.17	*.19	.16	3.32	*3.68	2.02	1.66	.17	*.25	.24	.10
334	Sulphur Creek at McGee Road	.27	.31	*.34	.27	.18	*.21	.13	.12	5.24	*5.75	1.69	1.92	.19	*.28	.15	.09
100	Yakima River at Kiona	.13	*.14	*.14	.13	*.08	.06	.05	*.08	*1.12	.80	.46	.96	.07	*.10	.08	.06

Map reference number	Site name	Suspended sediment				Streamflow				Specific conductance			
		Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
349	Yakima River at Cle Elum	2	3	*6	4	412	565	1,860	*2,470	67	*83	57	52
353	Wilson Creek	10	*26	21	10	65	75	*105	95	*239	216	195	208
321	Naches River	2	6	*14	4	430	1,000	*2,500	1,340	*84	81	64	76
323	Moxee Drain1/	11	38	*168	130	25	9	50	*64	*822	794	276	322
322	Yakima River at Terrace Heights Br	4	14	*16	8	1,230	2,600	*4,000	3,170	*135	116	92	93
341	Marion Drain	8	20	*33	15	150	150	*250	200	*379	351	256	278
339	East Toppenish Drain	8	8	*28	14	17	8	25	*44	318	*329	248	265
346	Granger Drain	42	41	*204	116	28	27	*37	*37	657	*689	405	391
334	Sulphur Creek at McGee Road	27	38	*96	66	120	80	230	*250	*688	291	337	318
100	Yakima River at Kiona	16	32	*54	32	2,280	4,200	*4,980	2,120	*325	209	166	290

1/ Also called Drain at Birchfield Road.

in the surface-water drains. These increased flows and agricultural activities result in increased erosion and resuspension of bed sediment. Phosphorus compounds sorbed to this sediment account for increases in suspended- and total-phosphorus concentrations in the water from April through June.

(2) Smallest streamflows occur from October through March and are associated with the largest concentrations of the dissolved constituents including: nitrite plus nitrate, orthophosphate, and specific conductance. Total ammonia has a seasonal concentration pattern that is similar to the other dissolved nutrients. This similarity indicates that a large part of the total ammonia may be in the dissolved phase. When streamflows are small, ground-water and point-source nutrient contributions to the surface water are relatively large and receive minimal dilution; consequently, dissolved nutrient concentrations increase. When the ground is frozen during periods of rapid snowmelt in the lower basin, overland runoff from dairies and feedlots also may be a significant contributor of dissolved nutrients to surface-water drains. In addition, the cold-water temperatures may be reducing rates of nitrification and aquatic-plant productivity, resulting in increased concentrations of ammonia, nitrite plus nitrate, and orthophosphate.

Trends

Time-trend results for nutrient concentrations from 1974-81 water years are listed in table 51 (at back of report) and figure 44; significant trends ($\rho \leq 0.1$) are summarized in table 26.

Increases in non-flow-adjusted and flow-adjusted concentrations of ammonia and nitrite-plus-nitrate concentrations are prevalent in the basin from 1974-81 WY. Ammonia concentrations show increases as far upstream as Yakima River at Cle Elum (RM 183.1) and nitrite-plus-nitrate concentrations show increases as far upstream as Wilson Creek at Thrall Road (Yakima RM 147). Fifty-six and 53 percent of the sites had significant increasing ($\rho \leq 0.1$) non-flow-adjusted concentrations of ammonia and nitrite plus nitrate, respectively. About 7 percent of the sites had decreasing concentrations of ammonia. Increases in both of these nutrient concentrations occur at several of the same sites, probably because they are biochemically related (for example, nitrification) and because their sources are similar.

From 1974-81 WY, the median seasonal Kendall slope estimator (fig. 45) for non-flow-adjusted, nitrite-plus-nitrate concentrations (as N) in the basin was +0.06 mg/L per year for main-stem and canal sites and +0.09 mg/L per year for tributaries (includes agricultural-return flows). The median change in nitrite-plus-nitrate concentrations in the Yakima River at Kiona is +0.054 mg/L per year; if this annual increase was constant, it would correspond to an increase of 0.43 mg/L (about 50 percent of the median concentration at Kiona) from 1974-81 WY.

From 1974-81 WY, the median change in non-flow-adjusted ammonia concentrations (as nitrogen) was small: +0.003 mg/L per year for main-stem and canal sites, and 0.005 mg/L per year for tributaries. Assuming that the annual change was constant from 1974-81 WY, ammonia concentrations at the main-stem and canal sites and the tributaries

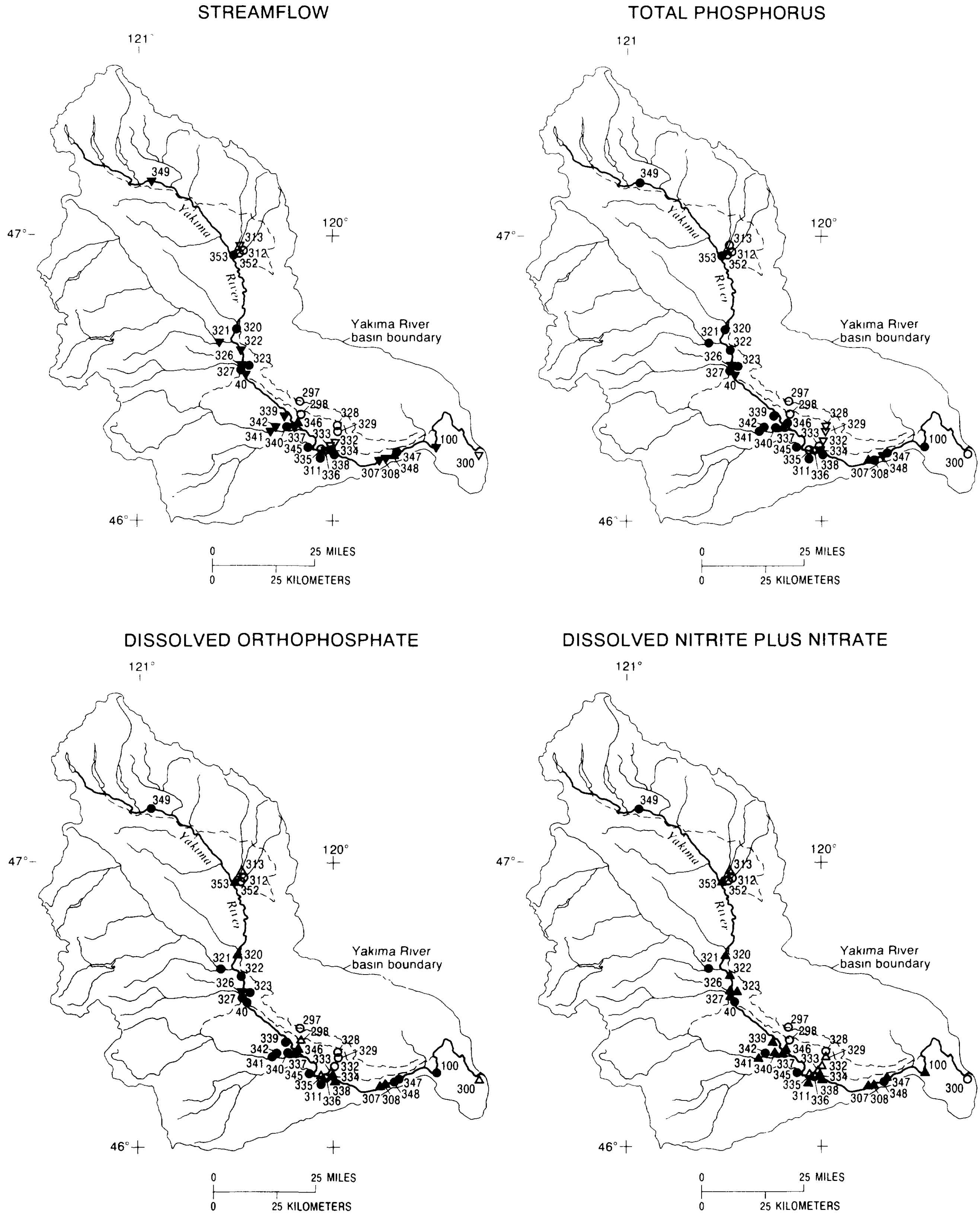


Figure 44.--Non-flow-adjusted seasonal Kendall trends in streamflow, total phosphorus, dissolved orthophosphate, dissolved nitrite plus nitrate, and total ammonia, in the Yakima River basin, Washington, 1974-81 water years.

TOTAL AMMONIA

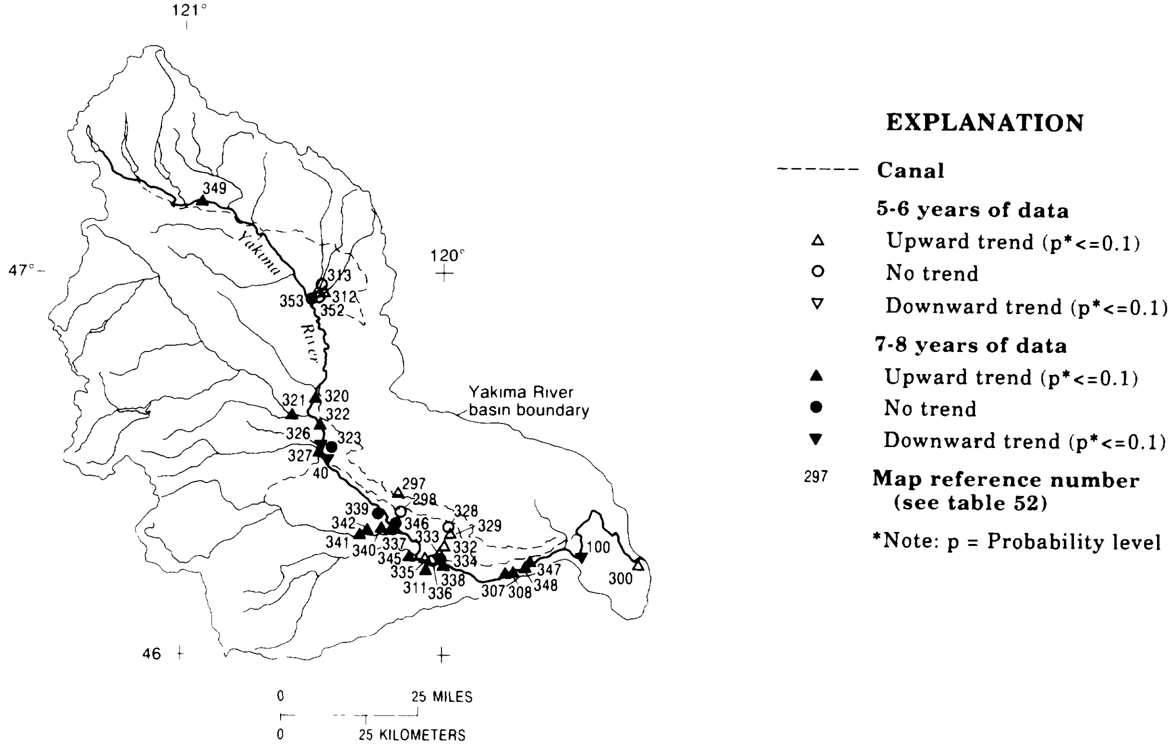


Figure 44.--Non-flow-adjusted seasonal Kendall trends in streamflow, total phosphorus, dissolved orthophosphate, dissolved nitrite plus nitrate, and total ammonia, in the Yakima River basin, Washington, 1974-81 water years--Continued.

Table 26.--Summary of significant (probability level less than or equal to 0.1) trends for selected nutrients and streamflow, Yakima River basin, Washington, 1974-81 water years

[Site types listed as: "M" = main stem, "T" = tributaries, "C" = canals, and "D" = agriculturally or point-source-effected surface waters; mg/L = milligrams per liter; yr = year; "NT" = no significant trend]

Site type	Site number and name	Water years of record	Non-flow adjusted: Trend mg/L/yr	Non-flow adjusted: Trend, percent of median per year	Non-flow adjusted: Median, mg/L	Flow adjusted: Trend, percent change per year	Streamflow: Trend, percent of median per year
			Total ammonia as nitrogen				
M	320 Yakima River at Harrison Rd Bridge	1974-81	.003	30.0	.01	35.1	NT
M	322 Yakima River-Terrace Heights Bridge	1974-81	.003	30.0	.01	24.9	-6.7
M	40 Yakima River at Parker	1974-81	-.006	-6.7	.09	-6.2	-8.2
M	337 Yakima River at bridge near Granger	1974-81	.010	20.0	.05	19.4	-8.2
M	338 Yakima River at bridge near Mabton	1974-81	.003	7.5	.04	7.9	-4.5
M	100 Yakima River at Kiona	1974-81	-.010	-14.3	.07	-15.9	-9.2
T	321 Naches River at Nelson Bridge	1974-81	.002	20.0	.01	18.1	-6.7
C	297 Roza Main Canal at Beam Road	1974-79	.001	10.0	.01	NT	NT
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	.003	15.0	.02	12.1	-2.7
C	308 Chandler Canal--mile 2.8 nr Prosser	1974-81	.005	25.0	.02	17.5	-3.0
D	327 Ahtanum Creek at mouth	1974-81	.000	.0	.02	NT	NT
D	312 Cherry Cr SE 1/4 S 29 17N 19E	1974-79	.003	15.0	.02	NT	NT
D	326 Wide Hollow Creek at Union Gap STP	1974-81	-.330	-25.4	1.3	-49.8	-4.8
D	339 East Toppenish Drain at Wilson Road	1974-81	NT	NT	.33	-15.7	-10.0
D	340 Sub-Drain 35 at Parton Road	1974-81	.003	15.0	.02	13.0	NT
D	342 Wanity Slough at Myers Road	1974-81	.007	10.0	.07	NT	-13.3
D	341 Marion Drain at Highway 97	1974-81	.003	15.0	.02	16.7	-8.0
D	335 Griffin Lake Inlet	1974-79	.020	33.3	.06	42.3	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	.005	16.7	.03	NT	NT
D	330 Drn DID #3 at South Hill Road	1974-77	.243	27.6	.88	27.4	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	.010	20.0	.05	22.1	-7.5
D	333 Sulphur Cr Wasteway at Morse Road	1974-79	.018	10.0	.18	NT	-6.7
D	311 Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	.005	16.7	.03	17.3	NT
D	345 South Drain at Highway 22 nr Satus	1974-81	.004	10.0	.04	10.1	NT
D	347 Spring Creek at Hess Road	1974-81	.005	25.0	.02	16.9	NT
D	348 Snipes Cr at Old Inland Empire Road	1974-81	.003	30.0	.01	34.5	4.8
D	300 KID Coyote Canyon Drain near bottom	1975-79	.005	50.0	.01	37.6	-14.8

Table 26.--Summary of significant (probability level less than or equal to 0.1) trends for selected nutrients streamflow, Yakima River basin, Washington, 1974-81 water years--Continued

Site type	Site number and name	Water years of record	Non-flow adjusted: Trend mg/L/yr	Non-flow adjusted: Trend, percent of median per year	Non-flow adjusted: Median, mg/L	Flow adjusted: Trend, percent change per year	Streamflow: Trend, percent of median per year
	Dissolved nitrite plus nitrate as nitrogen						
M	320 Yakima River at Harrison Rd Bridge	1974-81	.011	11.0	.10	11.6	NT
M	322 Yakima River-Terrace Heights Bridge	1974-81	.010	16.7	.06	14.5	-6.7
M	337 Yakima River at bridge near Granger	1974-81	.095	17.6	.54	13.7	-8.2
M	338 Yakima River at bridge near Mabton	1974-81	.088	8.8	1.0	5.0	NT
M	100 Yakima River at Kiona	1974-81	.054	6.1	.89	NT	-9.2
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	.064	8.6	.74	8.8	-2.7
C	308 Chandler Canal--mile 2.8 nr Prosser	1974-81	.070	8.6	.81	8.6	-3.0
D	353 Wilson Creek at Thrall Road	1974-81	.028	11.2	.25	11.4	NT
D	313 Coleman Cr NW 1/4 S 20 17N 19E	1974-79	.028	10.0	.28	NT	-16.5
D	323 Drain at Birchfield Road	1974-81	.045	4.7	.96	5.1	NT
D	325 Wide Hollow Cr at W. Washington Ave	1974-77	NT	NT	.63	-16.6	NT
D	326 Wide Hollow Creek at Union Gap STP	1974-81	.070	6.4	1.1	NT	-4.8
D	327 Ahtanum Creek at mouth	1974-81	.031	6.5	.48	5.8	NT
D	339 East Toppenish Drain at Wilson Road	1974-81	.182	7.6	2.4	7.6	-10.0
D	340 Sub-Drain 35 at Parton Road	1974-81	.053	2.5	2.1	NT	NT
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	.060	2.6	2.3	6.1	11.0
D	341 Marion Drain at Highway 97	1974-81	.130	5.0	2.6	NT	-8.0
D	335 Griffin Lake Inlet	1974-79	.085	16.7	.51	16.7	NT
D	328 Sulphur Cr at North above Sunnyside	1974-79	NT	NT	3.5	10.0	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	.190	12.7	1.5	12.7	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	.177	6.3	2.8	NT	-7.5
D	333 Sulphur Cr Wasteway at Morse Road	1974-79	.202	7.5	2.7	NT	-6.7
D	311 Satus Drain 302 NW1/4 Sec 34 9N 22E	1974-81	.360	9.7	3.7	12.6	NT
D	347 Spring Creek at Hess Road	1974-81	.099	7.1	1.4	NT	NT
D	348 Snipes Cr at Old Inland Empire Road	1974-81	NT	NT	.38	12.0	4.8
D	300 KID Coyote Canyon Drain near bottom	1975-79	NT	NT	2.1	-3.9	-14.8
D	334 Sulphur Creek Wasteway at McGee Road	1974-81	.092	3.4	2.7	NT	NT
	Dissolved orthophosphate as phosphorus						
M	320 Yakima River at Harrison Rd Bridge	1974-81	.001	5.0	.02	2.9	NT
M	40 Yakima River at Parker	1974-81	NT	NT	.04	-7.1	-8.2
M	337 Yakima River at bridge near Granger	1974-81	.004	8.0	.05	8.3	-8.2
M	338 Yakima River at bridge near Mabton	1974-81	.003	5.0	.06	4.0	NT
C	298 Sunnyside Canal at Beam Road	1974-79	.000	1.7	.03	1.7	NT
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	.004	6.7	.06	NT	-2.7
C	308 Chandler Canal--mile 2.8 nr Prosser	1974-81	.003	5.0	.06	NT	-3.0
D	353 Wilson Creek at Thrall Road	1974-81	.004	6.7	.06	7.2	NT
D	313 Coleman Cr NW 1/4 S 20 17N 19E	1974-79	.005	8.3	.06	6.1	-16.5
D	319 Cottonwood Canal Drain SE1/4 S 28	1974-77	-.010	-11.1	.09	-11.1	NT
D	325 Wide Hollow at W. Washington Ave	1974-77	NT	NT	.08	-9.9	NT
D	326 Wide Hollow Cr at Union Gap STP	1974-81	-.096	-21.8	.44	-30.7	-4.8
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	.005	2.8	.18	2.8	11.0
D	335 Griffin Lake Inlet	1974-79	.014	8.2	.17	8.1	NT
D	333 Sulphur Cr Wasteway at Morse Road	1973-79	.010	6.7	.15	NT	-6.7
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	.006	3.8	.16	3.0	-1.5
D	300 KID Coyote Canyon Drain near bottom	1975-79	.005	25.0	.02	20.4	-14.8
	Total phosphorus as phosphorus						
M	40 Yakima River at Parker	1974-81	-.005	-6.2	.08	-5.5	-8.2
M	337 Yakima River at bridge near Granger	1974-81	.006	5.0	.12	4.6	-8.2
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	.010	7.7	.13	NT	-2.7
C	308 Chandler Canal--mile 2.8 nr Prosser	1974-81	NT	NT	.14	-7.5	-3.0
D	319 Cottonwood Canal Drain SE1/4 Sec 28	1974-77	-.010	-7.7	.13	.1	NT
D	326 Wide Hollow Creek Union Gap STP	1974-81	-.158	-19.5	.81	-22.4	-4.8
D	339 East Toppenish Drain at Wilson Road	1974-81	NT	NT	.36	-5.6	-10.0
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	NT	NT	.42	-4.8	11.0
D	336 Griffin Lake Outlet	1974-79	-.008	-4.0	.20	-3.8	-15.0
D	328 Sulphur Cr at North above Sunnyside	1974-79	-.010	-7.1	.14	-7.1	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	-.010	-6.7	.15	-6.7	NT
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	-.015	-5.2	.29	-4.0	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	-.020	-9.1	.22	0.2	-7.5
D	348 Snipes Cr at Old Inland Empire Road	1974-81	-.007	-7.0	.10	-11.9	4.8
D	300 KID Coyote Canyon Drain near bottom	1975-79	NT	NT	.07	18.0	-14.8
	Suspended phosphorus as phosphorus						
M	322 Yakima River-Terrace Heights Bridge	1974-81	-.001	-5.0	.02	NT	-6.7
D	352 Wipple Wasteway at Thrall Road	1974-79	NT	NT	.06	-12.9	NT
D	312 Cherry Cr SE 1/4 S 29 17N 19E	1974-79	-.005	-7.1	.07	NT	NT
D	323 Drain at Birchfield Road	1974-81	-.006	-4.3	.14	-8.6	NT
D	326 Wide Hollow Creek at Union Gap STP	1974-81	-.061	-25.4	.24	-24.3	-4.8
D	327 Ahtanum Creek at mouth	1974-81	-.003	-7.5	.04	NT	NT
D	339 East Toppenish Drain at Wilson Road	1974-81	NT	NT	.09	-10.0	-10.0
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	-.018	-9.5	.19	-11.6	11.0
D	336 Griffin Lake Outlet	1974-79	-.010	-6.7	.15	-6.7	-15.0
D	328 Sulphur Cr at North above Sunnyside	1974-79	-.010	-16.7	.06	-17.1	NT
D	329 Sulphur Cr Wasteway at Factory Road	1974-79	-.010	-12.5	.08	-12.5	NT
D	332 Sulphur Cr Wasteway at Duffy Road	1974-79	-.018	-13.8	.13	-16.7	-7.5
D	333 Sulphur Cr Wasteway at Morse Road	1974-79	-.015	-10.7	.14	-10.7	-6.7
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	-.014	-11.7	.12	-11.2	NT
D	348 Snipes Cr at Old Inland Empire Road	1974-81	-.005	-7.1	.07	-12.6	4.8

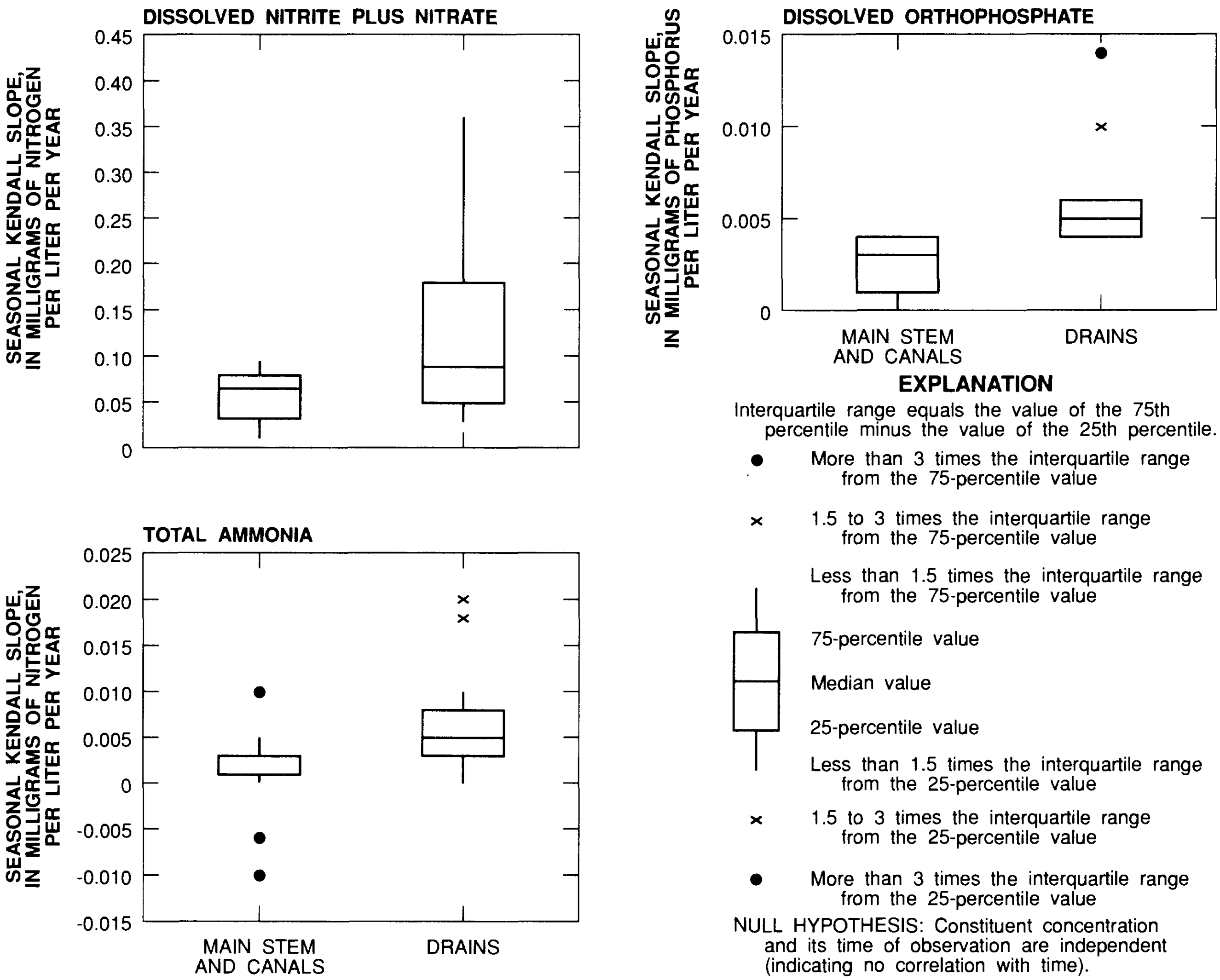


Figure 45.--Distribution of significant (probability level less than or equal to 0.1) seasonal Kendall slope estimators for non-flow-adjusted trends of dissolved nitrite plus nitrate, total ammonia, and dissolved orthophosphate, Yakima River basin, Washington, 1974-81 water years (some extreme values are not shown).

increased by 0.024 and 0.04 mg/L, respectively. These changes are relatively small when compared with EPA criteria for the protection of salmonids or other sensitive coldwater species (for example, 4-day average concentrations of total ammonia as nitrogen should not exceed 0.76 mg/L when pH is 8.0 and water temperature is 20 °C; U.S. Environmental Protection Agency, 1986).

In contrast to the general trend of increasing ammonia concentrations throughout the basin, ammonia concentrations decreased at Wide Hollow Creek (-0.33 mg/L per year; map reference number 326). This large decrease corresponds to the closing of the Union Gap STP in 1979.

Monthly determinations of total (ORG+NH4)-N from 1974-81 WY are available for only two sites, Yakima River at Parker (RM 104.6) and at Kiona (RM 29.9). These data indicate a significant increasing non-flow-adjusted concentration of 0.045 mg/L as nitrogen per year (10 percent increase per year) in the Yakima River at Kiona.

Compared with nitrogen trends, fewer significant trends were observed for non-flow-adjusted and flow-adjusted concentrations of total phosphorus (dissolved plus suspended phorphorus), dissolved orthophosphate, and suspended phosphorus. Non-flow-adjusted concentrations of total phosphorus show a decrease at 21 percent of the sites and an increase at 5 percent of the sites; dissolved orthophosphate concentrations show a decrease at 5 percent of the sites and an increase at 30 percent of the sites; and suspended phosphorus (total phosphorus minus dissolved orthophosphate) concentrations show a decrease at about 30 percent of the sites (table 51 at back of report). This variability in trend results indicates the importance of separately determining trends for each of the dissolved and suspended phosphorus species.

From 1974-81 WY, the median change (fig. 45) in non-flow-adjusted concentrations of dissolved orthophosphate was +0.003 mg/L (as P) per year in main-stem and canal sites and +0.005 mg/L (as P) per year for the tributaries. If this annual increase was constant from 1974-81 WY, dissolved orthophosphate concentrations would have increased by 0.024 and 0.040 mg/L at main-stem and canal sites and tributaries, respectively. These increases are of concern, because the critical level for this biologically available form of phosphorus ranges from 0.010 to 0.025 mg/L (as P). Even if the dissolved orthophosphate concentrations at a site were 0.000 mg/L in 1974, an increase of 0.024 mg/L over the 8-year time period could contribute to nuisance growths of aquatic plants (if the stream productivity was controlled by phosphorus concentrations).

The use of agricultural fertilizers within the basin is a possible explanation for the significant, increasing, flow-adjusted, concentrations of ammonia and nitrite plus nitrate. The estimated long-term use of nitrogen and phosphorus fertilizer in Yakima County, since 1965, is presented in figure 46. These gross estimates for Yakima County were computed from statewide use, on the basis of the proportion of agricultural-land area in the county relative to the total agricultural-land area in the state that receives fertilizer (Richard Alexander, U.S. Geological Survey, Reston, Virginia, written commun., 1988). The use of both nitrogen and phosphorus fertilizers has almost doubled from 1965 to 1985. Correspondingly, nitrite-plus-nitrate concentrations near the terminus of the basin in the Yakima River at Kiona have almost doubled from 1965-85 (fig. 47). Unlike nitrogen, total phosphorus concentrations at Kiona indicate a significant decrease from 1968-85 even though phosphorus fertilizer usage increased. A possible explanation for the different responses between nitrogen and phosphorus is the chemical nature of the nutrients. Nitrite plus nitrate is soluble in water and is readily transported to surface water with subsurface drainage. Conversely, many forms of phosphorus are hydrophobic, tending to sorb onto soils. The sorbed phosphorus may be retained in the soils until it is utilized by the plants or until the soils are eroded by extreme precipitation events and various water and land-use activities. The general decrease in flow-adjusted suspended-phosphorus concentrations may be associated with the transition in the basin from row crops to less erosive crops.

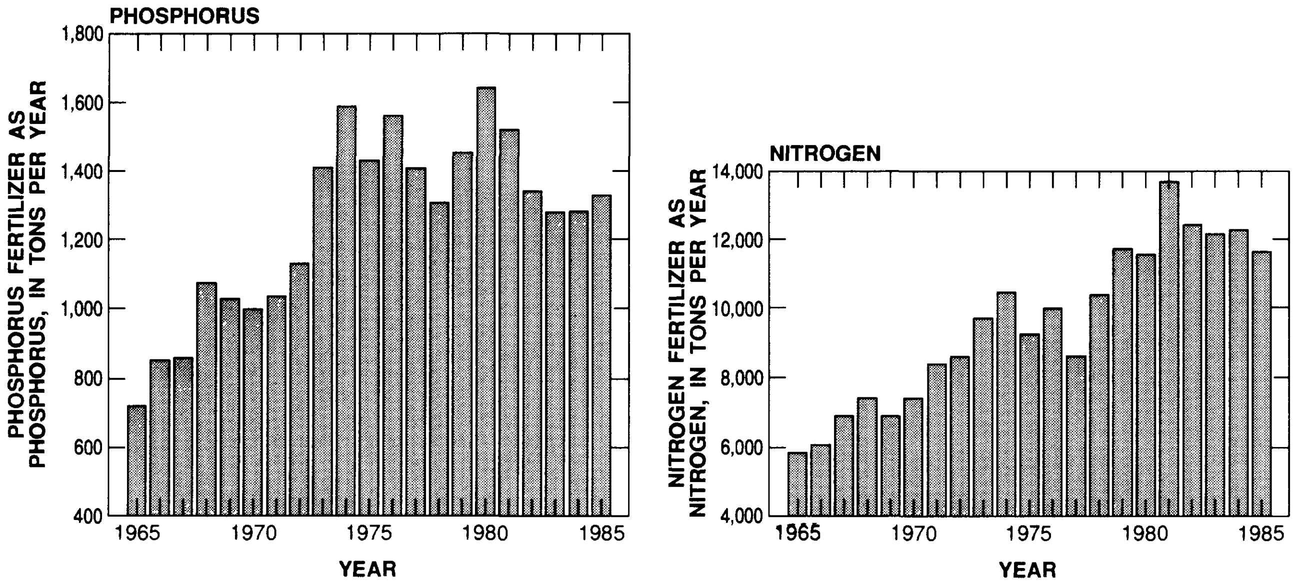


Figure 46.--Estimated fertilizer application in Yakima County, Washington, 1965-85.

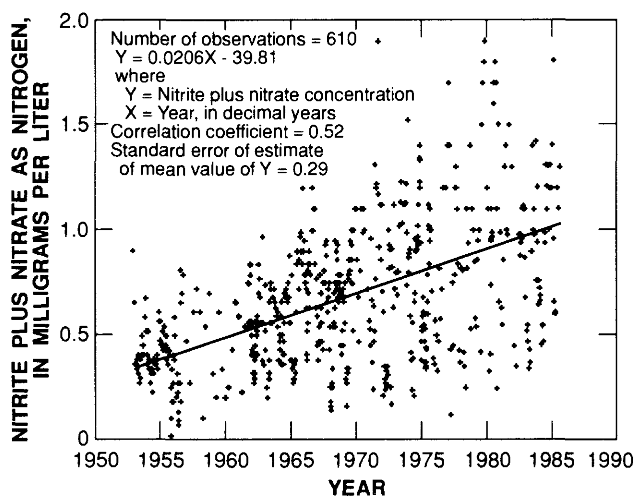


Figure 47.--Concentrations of nitrite plus nitrate in whole- and filtered-water samples from the Yakima River at Kiona, Washington, 1953-85 water years.

Loads

Nutrient loads are a multiplicative function of nutrient concentrations and streamflow. Large changes in either nutrient concentrations or streamflow often occur hourly, monthly, and annually as a result of natural variability (for example, climatic changes) and land- and water-use activities. These changes may alter the environmental importance of nutrient contributions from point and nonpoint sources. To evaluate the major sources of nutrients in the Yakima River basin, annual, monthly, and instantaneous loads are discussed in this section.

Annual nutrient loads were calculated for total phosphorus, dissolved orthophosphate, total organic-plus-ammonia nitrogen, total ammonia, and dissolved nitrite plus nitrate. Six main-stem sites and one Naches River site had daily mean streamflows and monthly nutrient concentrations for calculating nutrient loads. Even though monthly nutrient data were available for the major agricultural-return flows, daily-mean streamflows were not available for calculating annual loads.

Annual nutrient loads and streamflows generally increase in the lower main stem downstream from Umtanum (RM 140.4) [fig. 48 and table 27]. Regardless of the water year, annual streamflows are nearly constant from the Yakima River at Cle Elum (RM 183.1) to the Yakima River at Umtanum due to regulation by the large upstream reservoirs (Keechelus, Kachess, and Cle Elum Lakes). Similarly, total nitrogen and phosphorus loads are nearly constant from Yakima River at Cle Elum to Yakima River at Umtanum. Between Umtanum and Union Gap (RM 107.2), contribution from the Naches River accounts for less than one-third of the increase in phosphorus and nitrogen loads. The similarity in annual streamflows at Union Gap and Kiona indicates that increases in the annual nutrient loads from Union Gap to Kiona are due to increases in nutrient concentrations at Kiona.

Comparison of nutrient loads among the high-, low-, and median-flow years (1974, 1977, and 1980 WY, respectively) indicate that annual loads generally increase with increases in annual streamflow, especially at sites downstream from Union Gap (fig. 49). For example, two-to-five fold increases in annual streamflow from a low-flow to a high-flow year correspond to two-to-five fold increases in total nitrogen and total phosphorus loads. The relation between streamflow and constituent load emphasizes the need to make intersite load comparisons among subbasins during equivalent hydrologic conditions.

For further evaluation of potential nutrient sources, the Yakima River basin has been divided into three areas: (1) the area upstream from the Yakima River at Umtanum (section A of table 28), (2) the area upstream from the Yakima River at Umtanum plus the Naches River basin (section B of table 28), and (3) the area from the Yakima River at Umtanum to Union Gap excluding the Naches River drainage (section D of table 28). Nutrient loads from these areas were evaluated to help determine the source of the relatively large phosphorus-load increase in the reach from the Yakima River at Umtanum to Union Gap. Streamflow and

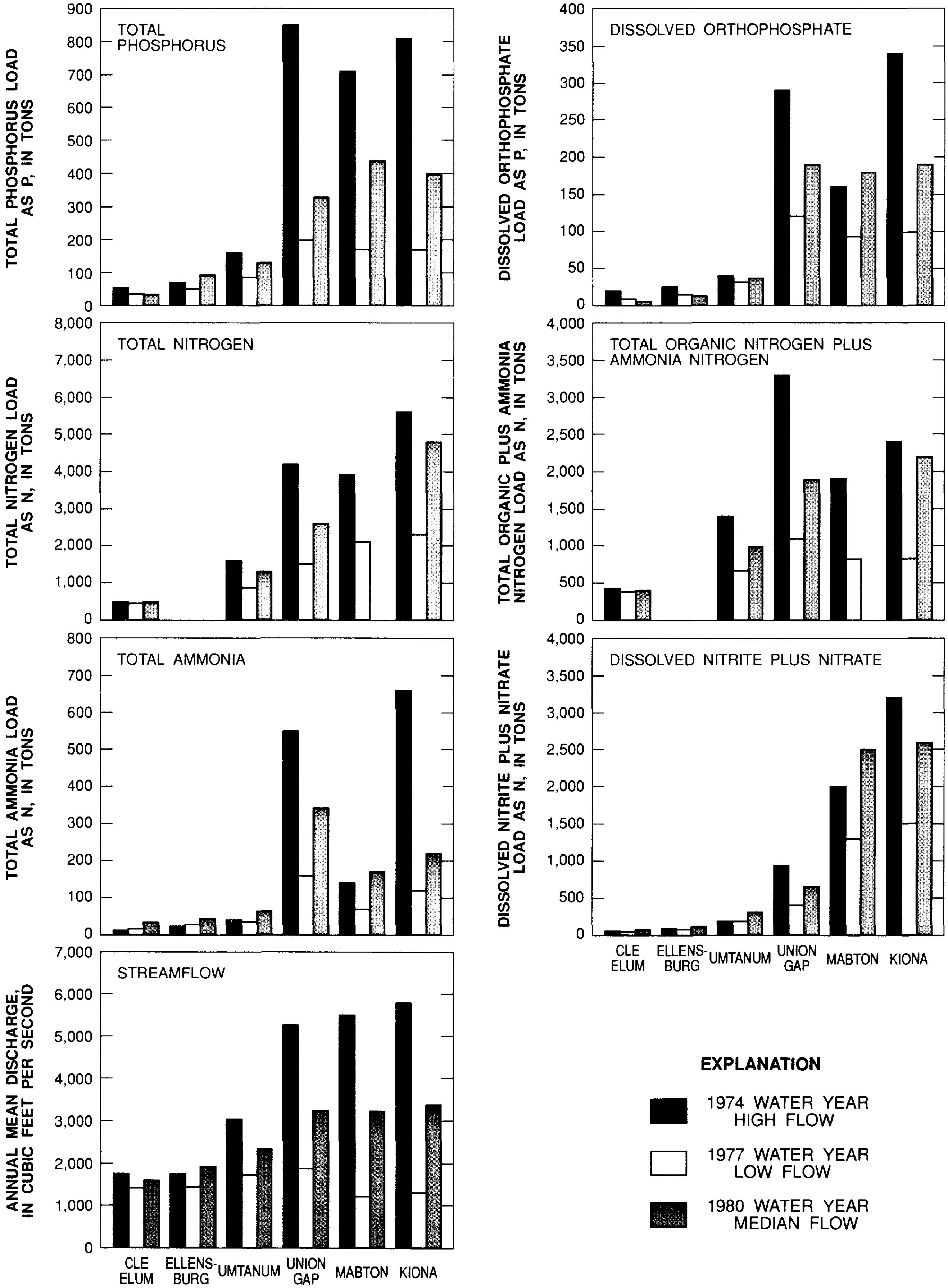


Figure 48.--Selected nutrient loads and annual-mean discharge in the Yakima River, Washington, 1974, 1977, and 1980 water years.

Table 27.--Estimated annual nutrient loads at selected sites in the Yakima River basin, Washington, 1974, 1977, and 1980 water years

[Loads reported in tons as phosphorus or nitrogen; load values are based on calibration data collected from 1970-85 water years; load values in parenthesis are based on calibration data that were collected 3 months prior to, during, and 3 months following the specified water year; "--" indicates insufficient data; 1974 water year was high flow, 1977 was low flow, and 1980 was median flow; WY = water year]

		Nutrient loads																	
		Total phosphorus			Dissolved orthophosphate			Total nitrogen			Total organic plus ammonia nitrogen			Dissolved nitrite plus nitrate			Total ammonia		
Yakima River mile	Site name	1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY	1974 WY	1977 WY	1980 WY
183.1	Yakima River at	55	36	35	20	9	6	480	440	480	430	390	410	53	51	73	14	17	34
	Cle Elum	(--)	(21)	(41)	(--)	(13)	(10)	(--)	(--)	(--)	(--)	(--)	(--)	(--)	(100)	(56)	(--)	(18)	(26)
148.0	Yakima River at	72	52	94	26	15	13	--	--	--	--	--	--	90	77	120	24	29	44
	Ellensburg	(--)	(51)	(80)	(--)	(14)	(15)	(--)	(--)	(--)	(--)	(--)	(--)	(--)	(91)	(170)	(--)	(44)	(58)
140.4	Yakima River at	160	87	130	40	32	37	1,600	860	1,300	1,400	670	990	190	190	310	40	36	65
	Umtanum	(--)	(68)	(120)	(--)	(32)	(26)	(--)	(--)	(--)	(--)	(--)	(--)	(--)	(260)	(370)	(--)	(32)	(65)
116.3	Naches River near																		
	Yakima 1/	120	16	48	35	5	10	660	170	450	540	140	390	120	30	63	92	19	50
		(106)	(11)	(54)	(27)	(4)	(12)	(--)	(--)	(--)	(--)	(--)	(--)	(140)	(21)	(81)	(100)	(6)	(22)
107.2	Yakima River above																		
	Ahtanum Creek at	850	200	330	290	120	190	4,200	1,500	2,600	3,300	1,100	1,900	930	410	650	550	160	340
	Union Gap 2/	(--)	(--)	(360)	(--)	(--)	(230)	(--)	(--)	(2,600)	(--)	(--)	(1,900)	(--)	(--)	(650)	(--)	(--)	(310)
59.8	Yakima River at	710	170	440	160	93	180	3,900	2,100	--	1,900	830	--	2,000	1,300	2,500	140	70	170
	Mabton	(770)	(200)	(380)	(160)	(87)	(140)	(--)	(--)	(--)	2,200)	(--)	(--)	(--)	(1,300)	(2,600)	(180)	(76)	(130)
29.9	Yakima River at	810	170	400	340	99	190	5,600	2,300	4,800	2,400	830	2,200	3,200	1,500	2,600	660	120	200
	Kiona	(1,000)	(200)	(690)	(370)	(100)	(270)	(6,200)	(2,300)	(6,000)	(2,800)	(890)	(2,800)	(3,400)	(1,400)	(3,200)	(920)	(190)	(250)

1/ Confluence of Naches and Yakima Rivers at Yakima RM 116.3.
2/ Loads in river exclude loads passing Union Gap in Roza Canal.

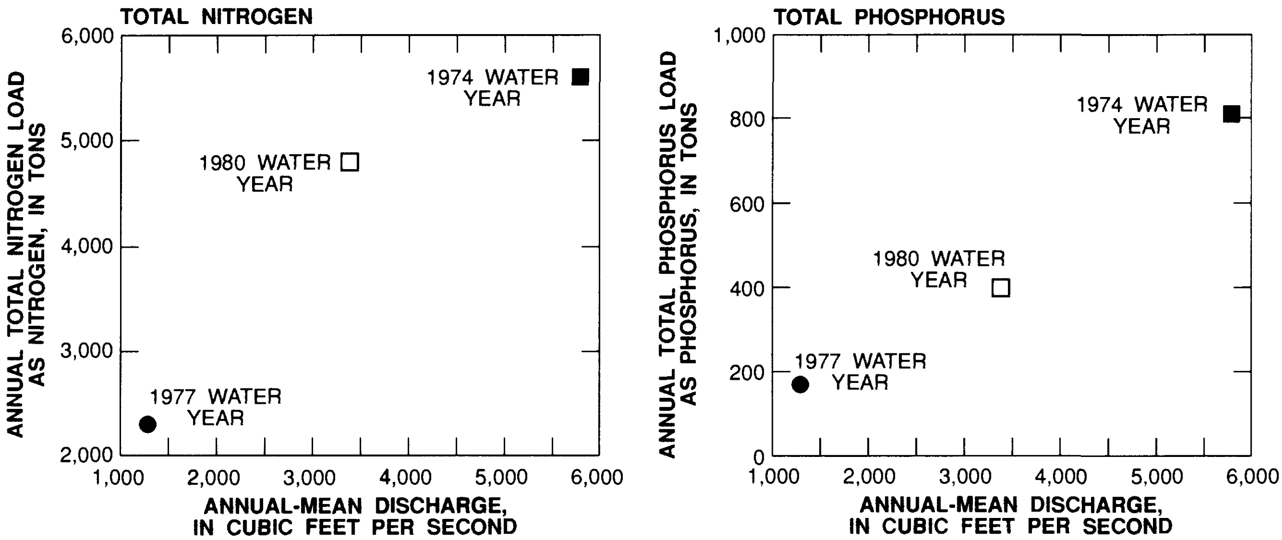


Figure 49.--Relation of nitrogen and phosphorus loads to annual-mean discharge, Yakima River at Kiona, Washington, 1974, 1977, and 1980 water years.

load contributions for the high- (1974), median- (1980), and low- (1977) flow years are shown in table 28; only those contributions during the median-flow year (table 28) will be discussed below:

Section A of table 28.--The area upstream from the Yakima River at Umtanum accounts for only 28 percent of the total drainage area in the Yakima River basin, but it contributes streamflow equal to about 69 percent of the streamflow at Kiona. In contrast, the area contributes phosphorus and nitrogen loads equal to 32 and 27 percent, respectively, of the loads at Kiona, which are in approximately equal proportion to the area's contributing drainage area.

Section B of table 28.--The area upstream from the Yakima River at Umtanum (RM 140.4) plus the Naches River is equivalent to 48 percent of the drainage area and provides streamflow equivalent to more than 100 percent of the streamflow at Kiona. Even though loads are a function of streamflow and constituent concentration, the nutrient-load contributions (equaling 44 percent of the total-phosphorus and 36 percent of the total-nitrogen load at Kiona) are also in nearly equal proportion to the contributing drainage area (48 percent).

Section C and D of table 28.--A relatively large source of total phosphorus occurs in the main stem of the Yakima River between Umtanum and Union Gap (compare Sections C and D). This area accounts for only 14 percent of the drainage area, but it has a load amounting to 38 percent of the total-phosphorus load measured at Kiona (this load estimate excludes the load passing Union Gap in Roza Canal).

Section E of table 28.--The largest point-source load of total phosphorus in the reach from Umtanum to Union Gap is probably the Yakima STP. Load estimates indicate that this plant could account

Table 28.--Drainage area, annual flow, and annual nutrient loads at selected locations in the Yakima River basin, Washington, 1974, 1977, and 1980 water years

[Drainage area, flow, and loads are reported as a percent of those annual values at Yakima River at Kiona (RM 29.9); "NA" indicates not applicable "RM" indicates river mile; 1974 water year was a high-flow year; 1977 water year was a low-flow year; 1980 water year was a median-flow year]

Water year	Drainage area, in percent of the drainage area upstream of Yakima River at Kiona	Annual flow, in percent of the flow of Yakima River at Kiona	Total phosphorus load, in percent of total phosphorus load of Yakima River at Kiona	Total nitrogen load, in percent of total nitrogen load of Yakima River at Kiona
Section A. Yakima River at Umtanum (RM 140.4)				
1974	28	52	20	28
1977	28	134	51	37
1980	28	69	32	27
Section B. Yakima River at Umtanum (RM 140.4) plus Naches River near mouth (flows into Yakima RM 116.3)				
1974	48	87	35	40
1977	48	162	60	45
1980	48	111	44	36
Section C. Yakima River above Ahtanum Creek at Union Gap (RM 107.2)[1]/				
1974	62	91	105	75
1977	62	146	118	65
1980	62	96	82	54
Section D. Net increase from Yakima River at Umtanum (RM 140.4) to Yakima River above Ahtanum Creek at Union Gap (RM 107.2) excluding contributions from Naches River near mouth (C-B)				
1974	14	5	70	35
1977	14	-16	58	20
1980	14	-15	38	18
Section E. Estimated point-source effluent from Yakima Sewage Treatment Plant (at Yakima RM 111)				
1974	NA	<1	33	2
1977	NA	<1	174	7
1980	NA	<1	78	3
Section F. Estimated point-source effluent discharging into the basin upstream from Yakima River at Kiona				
1974	NA	1	52	14
1977	NA	4	238	30
1980	NA	2	108	13

[1]/Excludes flow and load that is passing Union Gap in Roza Canal.

for the increase in the annual phosphorus load observed in this reach. The environmental impact of this point-source loading to the Yakima River is reduced, because Wapato (Yakima RM 106.7) and Sunnyside (Yakima RM 103.8) canals divert more than 40 percent of the annual streamflow of the Yakima River near Union Gap. This diverted water along with its associated phosphorus loads is used for crop irrigation in the lower basin, where the phosphorus may be assimilated by crops, sorbed to the soils, or leached into the ground water. Consequently, the phosphorus loading from the Yakima STP may not be significantly contributing to the loading in the Yakima River at Kiona during irrigation season. Also, phosphorus fertilizer is extensively applied to crops, especially downstream from Union Gap. Estimates of phosphorus-fertilizer application indicate that, in Yakima County alone, more than 1,600 tons of phosphorus (as P) were applied in 1980 calendar year (fig. 46). This application is about 4 times the annual phosphorus load observed in the Yakima River at Kiona in 1980 WY (table 27). The point-source loading of nitrogen from the Yakima STP (section E) does not account for the net increase in the nitrogen load from Umtanum to Union Gap (section D). Several other potential sources in this reach in downstream order include: Umtanum Creek, Squaw Creek, Burbank Creek, Selah Creek, Wenas Creek, Wide Hollow Creek, and Moxee Drain.

Section F of table 28.--Estimates of the sum of major point-source loads of phosphorus and nitrogen in the Yakima River basin upstream from Kiona suggest that point-source loads are equivalent to more than 100 percent of the phosphorus load in the Yakima River at Kiona and about 13 percent of the nitrogen load. Point-source loads of nutrients, however, are small relative to applied amounts of nitrogen and phosphorus fertilizers. In 1980, point-source contributions in the basin were estimated to be about 25 percent of the applied phosphorus fertilizer and 5 percent of the applied nitrogen fertilizer in Yakima County (Richard Alexander, U.S. Geological Survey, Reston, Virginia, written commun., 1988).

Monthly streamflows and nutrient loads for 1980 WY (median-flow year) are shown in figure 50 for the Yakima River at Kiona (RM 29.9). Monthly load patterns for each of the phosphorus and nitrogen species closely follow the pattern shown for the monthly mean streamflow. A doubling of monthly streamflow from February to April coincides with an approximate doubling of the nutrient loads during the same time period. Largest loads occurred March through May during snowmelt along with the largest streamflows. The smallest loads and streamflows occurred July through October during irrigation after snowmelt. A winter rainstorm in December 1979 increased both streamflow and loads.

Instantaneous nutrient loads may be calculated to better define major sources and sinks of nutrients. In this report, instantaneous total phosphorus loads are shown during summer conditions when total phosphorus concentrations in the Yakima River often exceeded the recommended (0.1 mg/L as P) guideline for preventing aquatic-plant nuisances. Results from this evaluation may be used by water managers to help control eutrophic conditions during a critical time of the year, when stream temperatures are warm and when plant productivity is maximum.

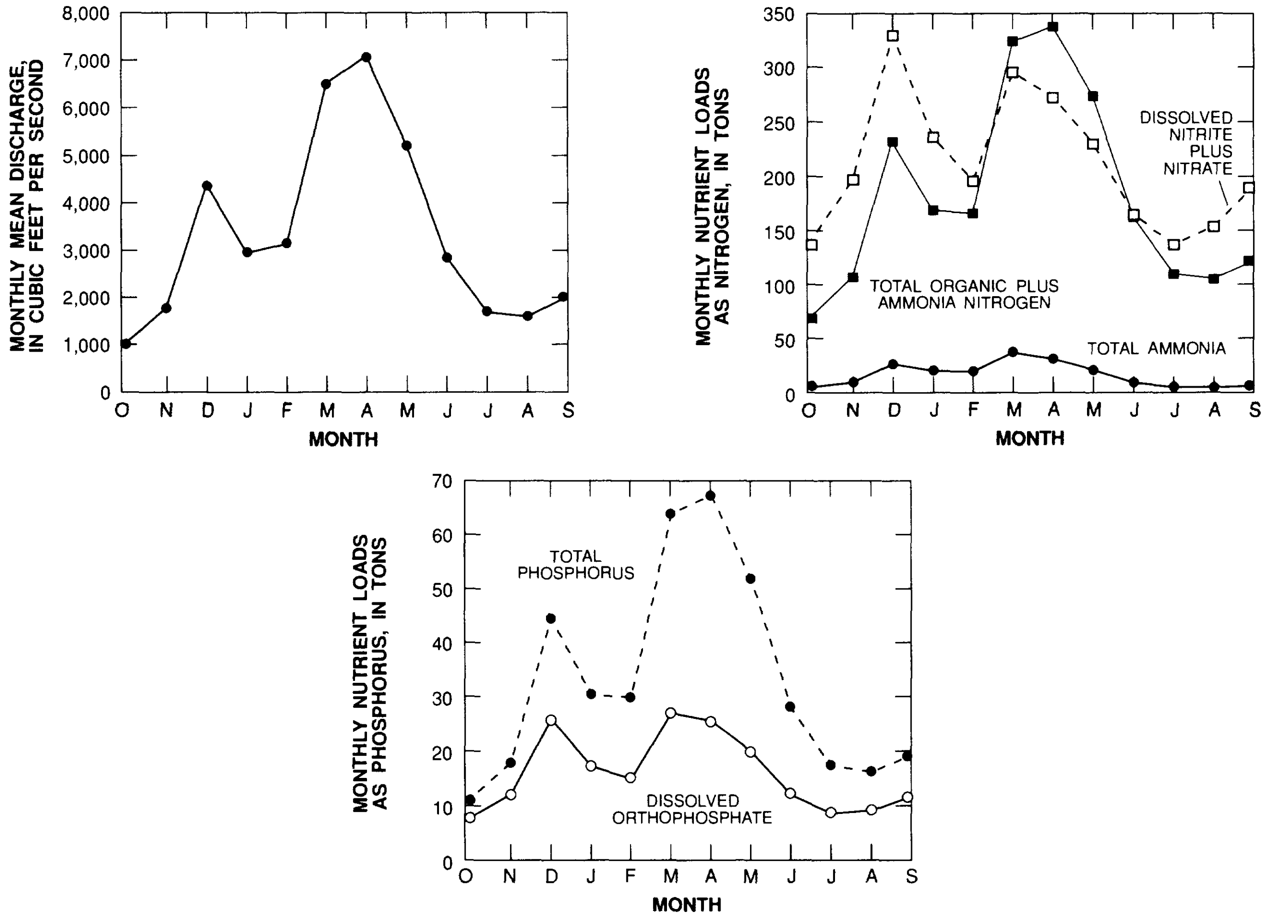


Figure 50.--Selected nutrient loads and monthly mean discharge in the Yakima River at Kiona, Washington, 1980 water year.

For quantifying major sources of total phosphorus during the summer, the only time period in the historical data with an adequate spatial coverage of phosphorus concentrations during a stable-flow period was September 1975. Instantaneous streamflows and phosphorus loads for this month are shown in figure 51 and table 29. These load estimates should be used only as a guide to identify potential major phosphorus sources during the summer months. Present sources (1990) of phosphorus could differ greatly from those observed in 1975; however, the quantity of streamflow and canal diversions in September 1975 are similar to 1988 flows and diversions.

The main-stem reach from Umtanum (RM 140.4) to Mabton (RM 59.8) was selected for calculation of these load estimates because downstream total-phosphorus concentrations were increasing rapidly in this reach (fig. 43). In September 1975, the background phosphorus concentration was small (near 0.02 mg/L) in the Yakima River at Umtanum and was nearly constant downstream to Terrace Heights Bridge (RM 113.2). Total phosphorus loads in the Yakima River from Umtanum (RM 140.4) to Terrace Heights Bridge showed large changes (table 29 and fig. 51) as a result of the Roza Canal diversion at RM 127.9, the Naches River contribution (RM 116.3), and the Roza Power Plant return (RM 113.3). Downstream from Terrace Heights Bridge (RM 113.2), the phosphorus load increased from about 300 to 1,100 lb/d (pounds per day) near Union Gap downstream from

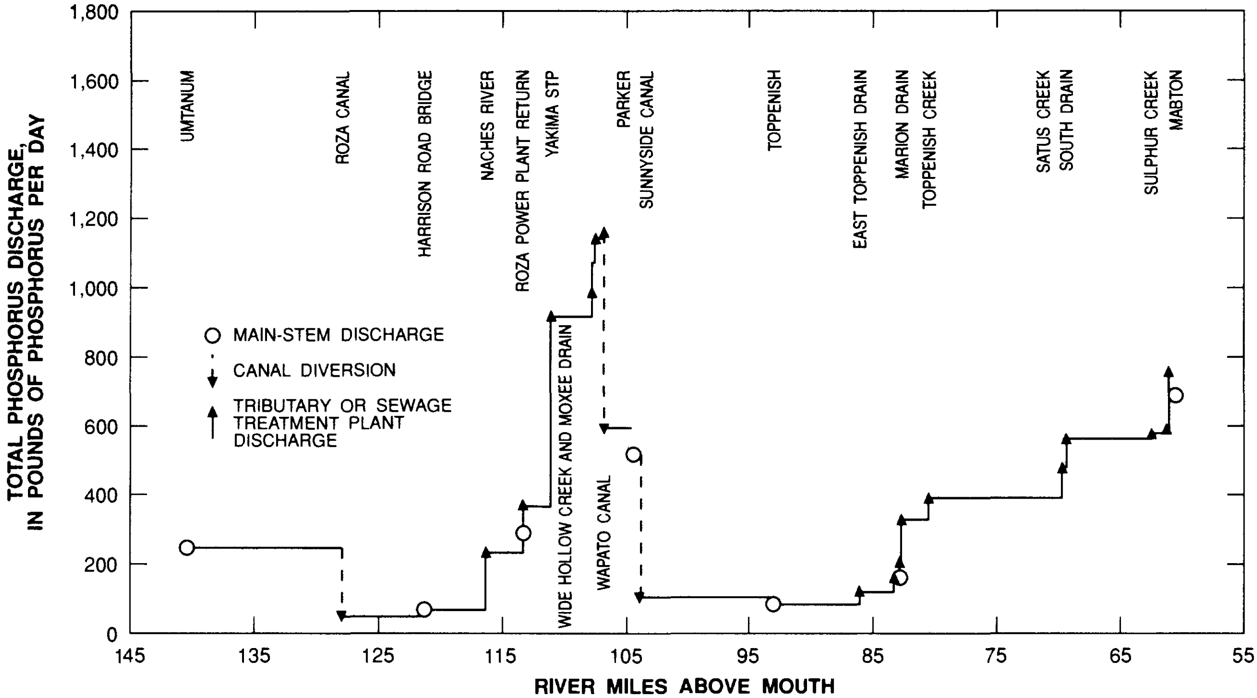


Figure 51.--Total phosphorus discharge in the Yakima River, Washington, in relation to tributary contributions and canal diversions, September 22-25, 1975. Phosphorus discharges are based on instantaneous measurements.

Table 29.--Instantaneous streamflows and total phosphorus discharges in the main stem, selected major tributaries, and canals in the Yakima River basin, Washington, September 22-25, 1975

[ft^3/s = cubic feet per second; lb/d = pounds per day; "Est." indicates estimated; RM = Yakima River Mile; "NA" = not applicable]

Site name	Yakima River Mile	Streamflow: Main stem (ft^3/s)	Streamflow: Tributary Inflowing (ft^3/s)	Streamflow: Canal Outflowing (ft^3/s)	Phosphorus load: Main stem (lb/d)	Phosphorus load: Tributary Inflowing (lb/d)	Phosphorus load: Canal Outflowing (lb/d)
Yakima River at Umtanum	140.4	2,300	NA	NA	248	NA	NA
Roza Canal at Roza diversion	127.9	NA	NA	1/-1,850 Est.	NA	NA	6/-199 Est.
Yakima River at Harrison Road bridge	121.2	450	NA	NA	73	NA	NA
Naches River near North Yakima	116.3	NA	990	NA	NA	160	NA
Roza Power Plant return	113.3	NA	2/1,260 Est.	NA	NA	7/136 Est.	NA
Yakima River at Terrace Heights	113.2	2,700	NA	NA	291	NA	NA
Yakima Sewage Treatment Plant	111.0	NA	3/15 Est.	NA	NA	8/550 Est.	NA
Wide Hollow Creek	107.4	NA	45	NA	NA	155	NA
Moxee Drain	107.3	NA	80	NA	NA	69	NA
Ahtanum Creek at mouth	106.9	NA	30	NA	NA	18	NA
Wapato Canal	106.7	NA	NA	4/-1,500 Est.	NA	NA	9/-566 Est.
Yakima River at Parker	104.6	1,370	NA	NA	517	NA	NA
Sunnyside Canal	103.8	NA	NA	5/-1,080 Est.	NA	NA	10/-407 Est.
Yakima River near Toppenish	93.0	290	NA	NA	78	NA	NA
East Toppenish Drain	86.0	NA	41	NA	NA	42	NA
Sub-Drain No. 35	83.2	NA	70	NA	NA	42	NA
Granger Drain	82.8	NA	37	NA	NA	44	NA
Yakima River at bridge near Granger	82.7	300	NA	NA	162	NA	NA
Marion Drain	82.6	NA	210	NA	NA	124	NA
Toppenish Creek	80.4	NA	103	NA	NA	61	NA
Satus Creek	69.6	NA	148	NA	NA	88	NA
South Drain	69.3	NA	96	NA	NA	83	NA
Satus Drain 302	62.4	NA	28	NA	NA	17	NA
Griffin Lake Outlet	61.6	NA	12	NA	NA	9	NA
Sulphur Creek	61.0	NA	265	NA	NA	171	NA
Yakima River at Mabton	59.8	1,600	NA	NA	690	NA	NA

1/ Flows at RM 121.2 minus RM 140.4.
2/ Flows at RM 113.2 minus Naches River minus RM 121.2.
3/ Flow is based on 1974 and 1977 average flow estimates.
4/ Flows at RM 104.6 minus Ahtanum Creek minus Wide Hollow Creek minus Moxee Drain minus Yakima Sewage Treatment plant minus RM 113.2.
5/ Flows at RM 93.0 minus RM 104.6.
6/ Assumes total phosphorus concentration at RM 140.4 equals total phosphorus concentration at Roza Canal diversion.
7/ Assumes total phosphorus concentration at Roza Canal diversion equals total phosphorus concentration at Roza Power Plant return.
8/ Assumes load from the Yakima Sewage Treatment Plant equals loads at RM 104.6 minus (Ahtanum Creek plus Wide Hollow Creek plus Moxee Drain plus RM 113.2 plus Wapato Canal).
9/ Assumes total phosphorus concentration in Wapato Canal equals total phosphorus concentration at RM 104.6.
10/ Assumes total phosphorus concentration in Sunnyside Canal equals total phosphorus concentration at RM 104.6.

Ahtanum Creek (RM 106.8). The instantaneous loads from Moxee Drain, Wide Hollow Creek, and Ahtanum Creek account for approximately 30 percent of this increase. Most of the remaining increase in the total-phosphorus load in this reach is probably due to Yakima STP. Although streamflow increases from Granger (RM 82.7) to Mabton (RM 59.8), the inflowing tributaries account for only 70 percent of the increase. Therefore, it might be expected that the load estimated from tributary and main-stem data at Mabton would be smaller than the measured load. On the contrary, the estimated load exceeds the measured load, indicating the possibility of phosphorus uptake by aquatic growth, suspended phosphorus deposition, or phosphorus sorption onto the bed sediment in the slow-moving productive reach.

Water Temperature

The main factors that control stream temperature are air temperature (which varies with altitude and latitude), rate of vertical mixing (which is controlled by velocity, depth, and roughness of stream channel), time of travel, and temperature of inflowing water. Because the upper Yakima River originates from precipitation, snowmelt, and ground-water seepage from the high Cascade Mountains, the initial stream temperature is cold, and warms as it flows to the lower basin. During the summer, water releases from the five major upstream reservoirs result in cold stream temperatures, because cold water is withdrawn from the lower levels of the reservoirs. As water flows through the stream reaches with a high rate of vertical mixing, water temperature quickly equilibrates near air temperature. Slow-moving water in shallow reaches also will increase in temperature owing to the long exposure time to warm air temperatures. Fast-flowing water (2-4 ft/s) in deep channels with minimal roughness, such as in canals, will increase in temperature the least. Terrestrial vegetation or deep canyons that shade the streams from sunlight will help the streams to maintain cooler temperatures.

State water-quality standards for the Yakima River basin allow maximum water temperatures of 16 °C for class AA streams (selected headwater streams) and 21 °C for class B streams (Sulphur Creek). Class A streams in the basin are located from the mouth of the Yakima River to its confluence with the Cle Elum River (Yakima RM 185.6). Class A streams have a special maximum water-temperature standard of 21 °C rather than the general statewide standard of 18 °C. Stream temperatures shall not exceed the standards due to human activities. When temperatures exceed standards under natural conditions, no temperature increase will be allowed that raises the receiving water temperature by greater than 0.3 °C.

Five percent of the 12,500 water-temperature measurements from about 400 sites from 1959-85 exceeded Washington State standards. Water-temperature measurements were above standards for 7 percent of the measurements at class AA streams, 5 percent at class A streams, and 2 percent at class B streams. About 86 percent of the measurements were made at class A streams, 9 percent at class AA streams, and 5 percent at class B streams. The occurrence of exceedances (listed above) may be biased high, because it is assumed that the high water temperatures occurred as a result of man's activities in the basin and not natural conditions. Under natural conditions without flow augmentation and canal diversions, summer streamflow might be smaller and result in higher stream temperatures; in accordance with State standards, these higher temperatures would be exceedances only if they were due to human activities.

The distribution of instantaneous water temperatures (monthly measurements from 1974-81 WY) in the Yakima River is shown in figure 52. Median-water temperatures are lowest upstream from Parker (RM 104.6) where the mean basin altitude is higher and results in cooler air and water temperatures. At RM 104.6, water has been diverted into Wapato Canal (RM 106.7) during irrigation season, and median temperatures begin to show an increase; another increase is shown downstream from RM 59.8

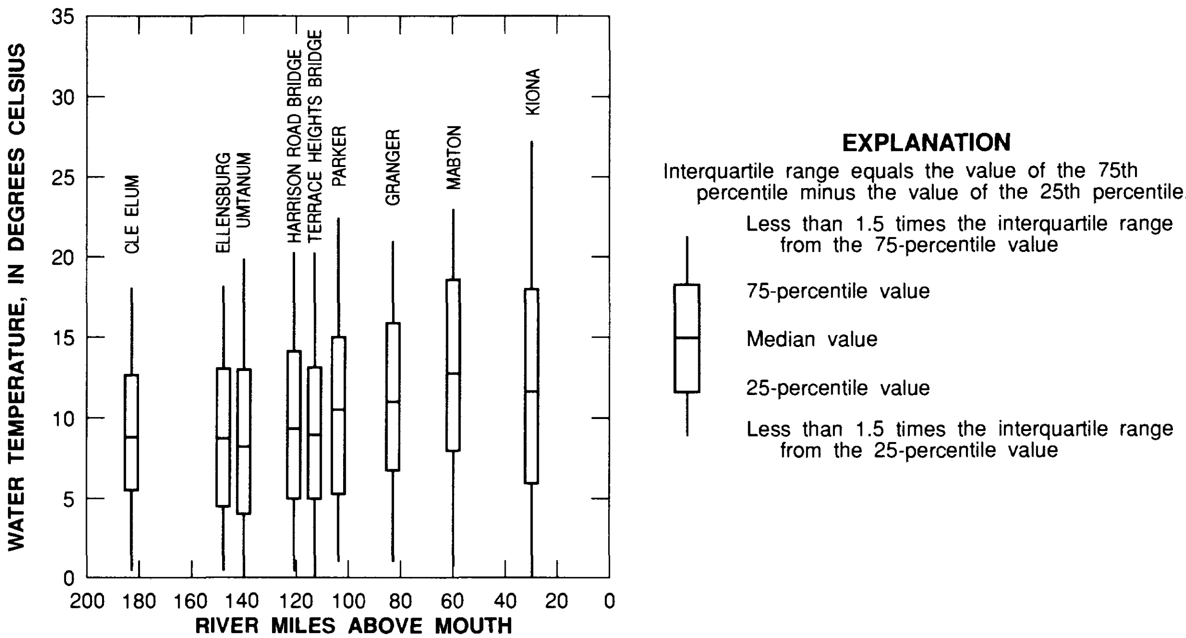


Figure 52.--Water temperature in the Yakima River, Washington, 1974-81 water years.

as quantities of agricultural-return flow increase. Much of the summer heating of the river water is associated with: (1) low flows downstream from the Wapato (RM 106.7) and Sunnyside (RM 103.8) Canal diversions, (2) slow stream velocities due to a small stream gradient between RM 69.6 and 47.1, and (3) low flows between Prosser Dam (RM 47.1) and Chandler Pumping Plant (RM 35.8).

Monthly distributions of instantaneous water temperatures for the Yakima River at Kiona and East Toppenish Drain from 1974-81 WY show the effect of ground-water contributions on water temperatures (fig. 53). Median streamflows at the Kiona site and the East Toppenish site are 2,400 and 20 ft^3/s, respectively. Stream temperatures in the East Toppenish Drain would be expected to more closely follow air temperatures, because the small water mass should rapidly equilibrate with air temperature. On the contrary, the distributions of monthly temperatures in the Yakima River at Kiona more closely follow air temperatures. The range of median values (difference between the minimum and maximum median values) at East Toppenish Drain and the

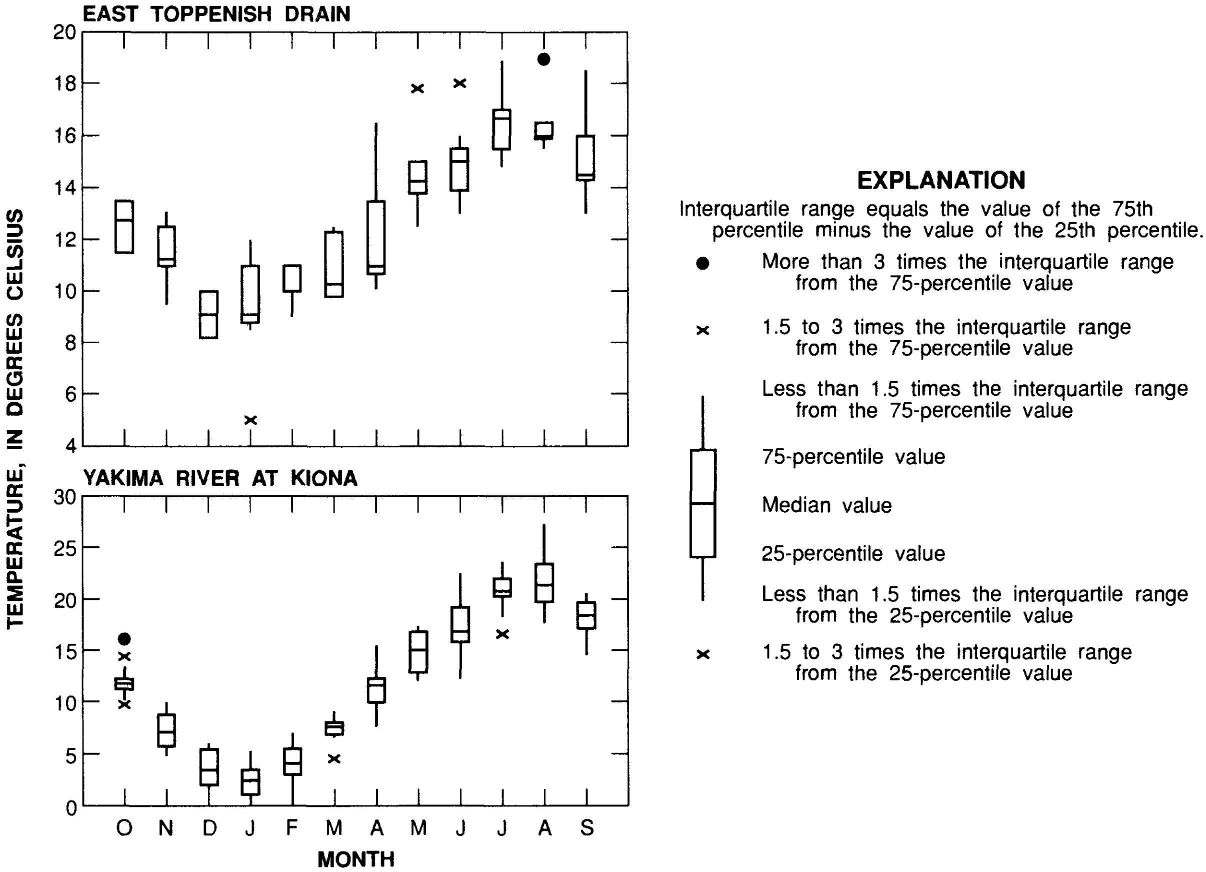


Figure 53.--Monthly water temperatures at East Toppenish Drain at Wilson Road, and Yakima River at Kiona, Washington, 1974-81 water years.

Yakima River at Kiona are 8 °C and 19 °C, respectively. The small range of temperatures at East Toppenish Drain may be caused by ground-water seepage that raises the minimum and lowers the maximum.

Vaccaro (1986) modeled streamflow and water temperature in the main stem for the period, April to October 1981. Vaccaro (1986) demonstrated that a 4 °C increase in temperatures from the upper Yakima reservoirs resulted in a 1.0 °C increase in mean irrigation-season water temperature at Umtanum (RM 140.4), but less than a 0.1 °C increase at Prosser (RM 47.4) in the lower basin. He also showed that a 4 °C increase in air temperature over the basin increased water temperature by 1.5 °C at Umtanum and a 2.3 °C increase at Prosser. The 4 °C increase corresponds to maximum error in interpolated air temperatures used for calibrating the model. These model simulations show that the effect of reservoir-outflow temperatures diminished in a downstream direction, and that the influence of air temperature on water temperature is dominant in the lower basin. In addition, ground-water contributions also are controlling water temperatures in the main stem.

Vaccaro (1986) also modeled water temperatures for three flow conditions (fig. 54): (1) August 1981 operating conditions with reservoir releases and diversions (observed regulated flows), (2) August 1981 reservoir releases and no diversions, and (3) August 1981 conditions with no reservoir storage and no diversions (natural-- unregulated flows). The differences between August mean-water temperatures for observed 1981

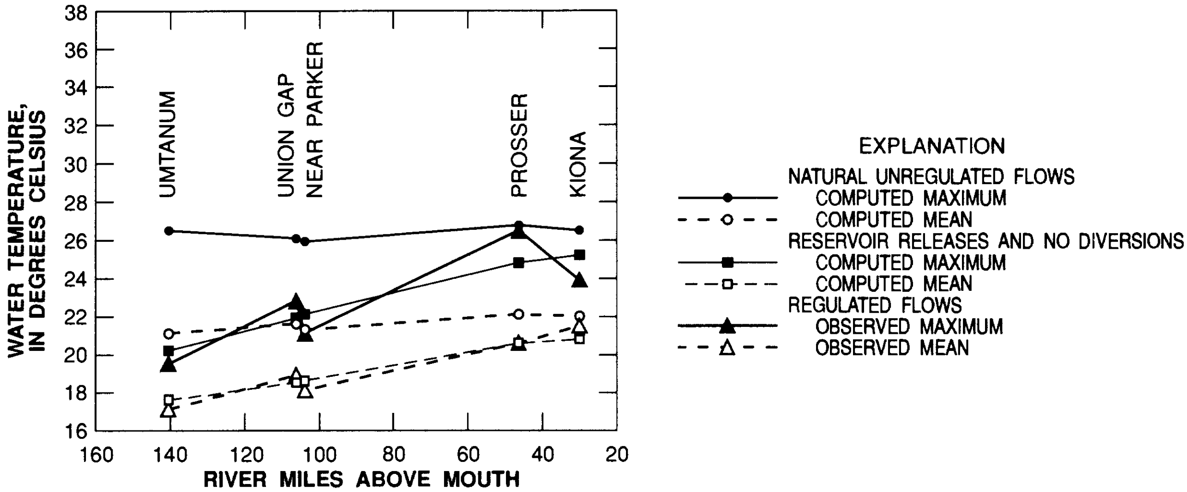


Figure 54.--Computed and observed mean and maximum water temperatures for three streamflow conditions in the Yakima River, Washington, August 1981.

operating conditions and 1981 reservoir conditions with no diversions are small, while the computed mean for natural conditions are significantly higher. For natural conditions, the computed-mean water temperature is above the 21 °C class A standard at all five of the sites. At the three upstream sites, the natural computed-mean August temperatures are 2-4 °C higher than the other two mean-temperature conditions. At Prosser (RM 47.4) and Kiona (RM 29.9), the computed-mean temperatures for the three conditions are within 1-2 °C, showing the significance of air- and water-temperature equilibration in the slower moving water in the lower river. These computation also show that maximum stream temperatures at and downstream from Union Gap (RM 107.2) exceed the 21 °C State standard for all three flow conditions.

About 25 percent of the sites had significant ($\rho \leq 0.1$) increasing-temperature trends before and after flow adjusting the temperature values (table 51 at the back of report and summary in table 30). Increasing-temperature trends occur as far upstream as Wilson Creek at Thrall Road (confluence at Yakima RM 147), a major drain carrying agricultural-return flow from the Kittitas Valley. Non-flow-adjusted stream-temperature trends for main-stem and canal sites and tributaries (including agricultural-return flows) range from +0.17 to +0.36 °C per year.

From 1974-81 water years, the median non-flow-adjusted change in temperature is 0.30 °C per year for main-stem and canal sites and 0.20 °C per year for agricultural-return flows (fig. 55). If these increases were constant, they would correspond to an increase of about 2.4 °C for main-stem and canal sites and 1.6 °C for agricultural-return flows during the 8-year period. The similarity in the trends at the main-stem sites and agricultural-return flows is expected, because water temperature in the main stem is directly affected by water temperatures of the inflowing drains. For example, the largest main-stem trend occurred in the Yakima River at Mabton where most of the streamflow may be attributed to agricultural-return flow during irrigation season.

Table 30.--Summary of significant (probability level less than or equal to 0.1) trends for stream temperature and streamflow, Yakima River basin, Washington, 1974-81 water years

[Site types listed as: "M" = main stem, "C" = canal, and "D" = agriculturally or point-source-affected tributary; "NT" = no significant trend]

Site type	Site number and name	Water years of record	Stream temperature, Non-flow adjusted: Trend, degrees Celsius per year	Stream temperature, Non-flow adjusted: Trend, percent of median per year	Stream temperature, Non-flow adjusted: Median, degrees Celsius	Stream temperature, Flow adjusted: Trend, percent change per year	Streamflow: Trend, percent of median per year
M	320 Yakima River at Harrison Rd Bridge	1974-81	0.31	3.3	9.3	3.3	NT
M	322 Yakima River-Terrace Heights Bridge	1974-81	.17	1.9	9.0	4.5	-6.7
M	337 Yakima River at bridge near Granger	1974-81	.30	2.7	11.0	NT	-8.2
M	338 Yakima River at bridge near Mabton	1974-81	.36	2.8	12.8	NT	NT
M	100 Yakima River at Kiona	1974-81	.20	1.7	11.6	-1.7	-9.2
C	307 Chandler Canal--mile 0.6 nr Prosser	1974-81	.30	2.2	13.7	2.2	-2.7
C	308 Chandler Canal--mile 2.8 nr Prosser	1974-81	.29	2.1	14.0	2.1	-3.0
D	350 Wilson Creek at Sanders Road	1974-77	NT	NT	9.5	-1.4	NT
D	353 Wilson Creek at Thrall Road	1974-81	.20	2.0	9.8	NT	NT
D	339 East Toppenish Drain at Wilson Road	1974-81	NT	NT	12.8	2.2	-10.0
D	340 Sub-Drain 35 at Parton Road	1974-81	.18	1.4	12.5	1.6	NT
D	346 Granger Drain--Hwy 223 abv Granger	1974-81	.36	3.0	12.0	NT	11.0
D	341 Marion Drain at Highway 97	1974-81	NT	NT	12.0	2.4	-8.0
D	334 Sulphur Cr Wasteway at McGee Road	1974-81	.25	2.0	12.7	2.8	NT
D	347 Spring Creek at Hess Road	1974-81	.17	1.3	13.0	NT	NT

Monthly mean air temperatures, measured at the City of Yakima Airport (1974-81) in the central part of the Yakima River basin, were analyzed using the seasonal-Kendall-trends test to examine the effects of ambient air temperature on the water temperature in the Yakima River at Terrace Heights Bridge (RM 113.2). The Yakima River at Terrace Heights Bridge had the largest flow-adjusted stream-temperature trend (+4.5 percent per year) in the main stem. Trends for air temperature were found to be nonsignificant ($\rho = 0.57$); consequently, mechanisms other than air temperature and streamflow (for example, ground-water contributions) may be affecting the water temperature.

Dissolved Oxygen

Most aquatic organisms require oxygen to produce energy for their existence; conditions favorable for their growth and reproduction require that adequate dissolved-oxygen (DO) concentrations be maintained at all times. Presently (1990), most of the streams in the Yakima River basin are class A, where DO concentrations should exceed 8.0 mg/L. Dissolved oxygen in class AA streams (headwater streams) should exceed 9.5 mg/L. Sulphur Creek is the only stream that is currently designated as class B in the basin, where DO should exceed 6.5 mg/L. Prior to January 6, 1988, the Yakima River from its mouth to the Sunnyside Dam also was designated as class B.

The solubility of oxygen is directly proportional to the partial pressure of oxygen above the water. The amount of oxygen that is soluble in water decreases as barometric pressure decreases (altitude increases) and (or) as temperature increases. In addition, solubility decreases as the dissolved-solids content increases. The solubility of oxygen at saturation in the Yakima River basin varies greatly over the annual range of stream temperatures. At an altitude of 340 feet

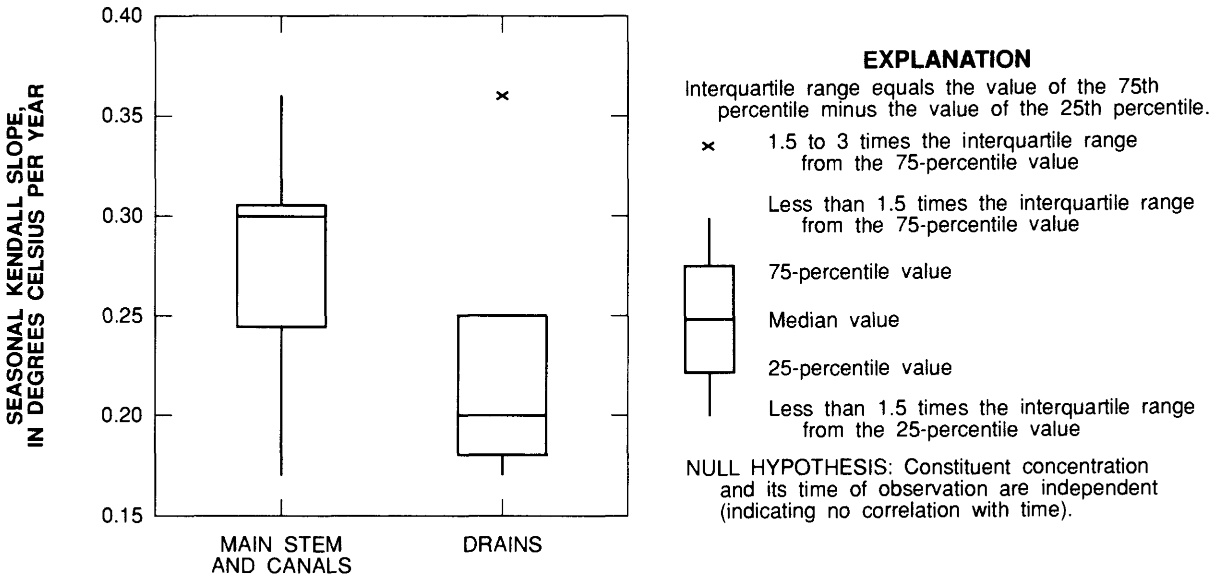


Figure 55.--Distribution of significant (probability level less than or equal to 0.1) seasonal Kendall slope estimators for non-flow-adjusted temperature trends, Yakima River basin, Washington, 1974-81 water years.

(barometric pressure = 750 mm of mercury) near the mouth of the Yakima River, DO solubility at 100-percent saturation ranges from 14.4 mg/L at 0 °C to 8.8 mg/L at 21 °C (class A temperature standard); at an altitude of 3,426 feet (barometric pressure = 670 mm of mercury) at the spillway of Bumping Lake Dam, the solubility at 100-percent saturation ranges from 12.8 mg/L at 0 °C to 8.7 mg/L at 16 °C (class AA temperature standard).

DO concentrations in the basin are generally similar to those in many rivers in the United States (Smith and others, 1987; median DO for rivers in the United States is 9.8 mg/L from 1974-81 WY compared to a median DO of 10.2 mg/L for the Yakima River basin from 1959-85 WY). The historical data set 1959-85 WY for the Yakima River basin contains 6,165 determinations of DO at 185 sites. Most of these data were collected during daylight periods, when photosynthetic activity increases DO in the streams and when warmer stream temperatures decrease in solubility of DO. Accordingly, the data represent stream conditions when DO concentrations and percent saturations were near maximum, if the controlling effect on daytime DO was photosynthesis; or near minimum, if the controlling effect was stream temperature. In stream reaches containing abundant aquatic plant growth, the collection of nighttime data would result in smaller DO concentrations due to respiration and the absence of photosynthesis, and would increase the number of determinations not meeting State standards in the historical data. Based on present Washington State DO standards (1990), 715 determinations (12 percent of the determinations) from 103 sites (56 percent of the sites) were less than the standards. Summaries of data that were less than the DO standards are shown by stream class in table 31 and by site in table 53 at the back of report. About 30 percent of the historical determinations were made in the main stem, and less than 3 percent of these determinations were less than the standards. The largest percentage of determinations less than the standards (25 percent) occurred in the class AA waterbodies, while the class A and B waterbodies had 10 and 1 percent, respectively.

Table 31.--Summary of dissolved-oxygen determinations that were less than State standards for the Yakima River basin, Washington, 1959-85 water years

Stream class	Number of sites with determinations	Number of sites with determinations less than standards	Percent of sites with determinations less than standards	Number of determinations	Number of determinations in each stream class less than standards	Percent of determinations in each stream class less than standards
AA	53	26	49	661	165	25
A	122	75	61	5180	547	10
B	10	2	20	324	3	1

The class AA sites are located in subbasins which are higher in altitude with minimal influences from man's activities. More than 50 percent of the class AA concentrations, not meeting standards (less than or equal to 9.5 mg/L), occurred in the large headwater lakes (Cle Elum and Rim Rock Reservoirs, and Keechelus Lake) that release water into class AA streams, and probably are associated with DO depletion in the hypolimnion. The class AA standard of 9.5 mg/L may be naturally unattainable for some of the headwater streams, due to altitude and temperature effects (fig. 56). For example, the site on the Little Naches River near Cliffdell is located at about 2,500 feet in altitude. Stream temperature at this site has been observed as high as 19.7 °C which corresponds to 8.3 mg/L of DO at 100-percent saturation. Even though the stream is 100-percent saturated, its DO would violate the State standard by 1.2 mg/L. An issue that needs to be further evaluated is to determine whether the stream temperature in the Little Naches River was as high as 19.7 °C as a result of natural conditions or some activity by man, such as timber harvesting.

Many of the DO concentrations not meeting State standards are from class A streams that are tributaries to the Yakima River in the lower basin. Subbasins with the largest number of determinations less than the class-A standard (8.0 mg/L) are the Sulphur Creek, Toppenish Creek, and Satus Creek subbasins with 184, 111, and 46, respectively. Most of the streams in these subbasins receive agricultural-return flow, urban runoff, and (or) point-source discharges. Sulphur Creek had only three determinations that did not meet the class-B standard (6.5 mg/L).

Sites in the Yakima River basin with 25 percent of their DO determinations less than or equal to 8.0 mg/L are shown in table 32. The class AA sites may be reflecting the influences of altitude (atmospheric pressure) and stream temperature on DO saturation (as mentioned earlier). Most of the class A sites listed in table 32, are agricultural-return flows. STP's upstream from the sites on East Toppenish Drain (map reference number 339) and Sunnyside STP outfall

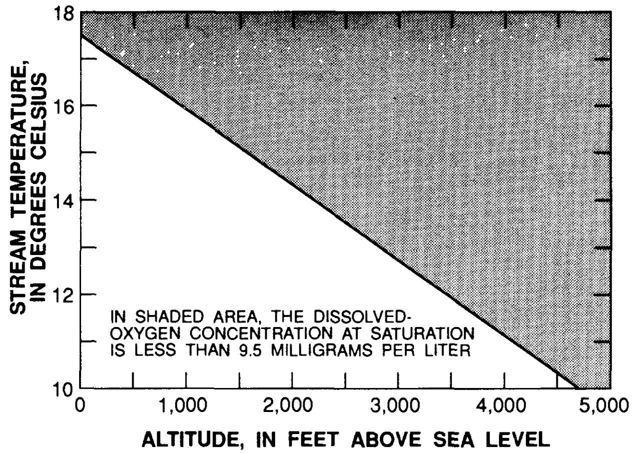


Figure 56.--Relation between altitude and stream temperature for dissolved-oxygen concentrations that are 100 percent saturated at 9.5 milligrams per liter. Relation is based on assumption that atmospheric pressure is 760 millimeters of mercury at sea level.

into Drainage Irrigation District (DID) 3 (map reference number 516) are probably significant contributors to the small DO concentrations in those drains. The Nequist Drain (map reference number 310) is an underground tile outfall and reflects influences of subsurface drainage from the agricultural activities.

The distributions of DO concentrations (instantaneous, daytime determinations) in the Yakima River from 1974-81 WY are shown in figure 57 and listed in table 49 (at back of report). Daytime DO concentrations at all Yakima River sites were greater than 8.0 mg/L more than 75 percent of the time. At several sites (fig. 57), DO concentrations dropped below the 8.0 mg/L standard for class A streams. Generally, DO concentrations at sites upstream from Granger (RM 82.7) were larger than concentrations at downstream sites. Relatively large point-source loads of oxygen-demanding effluent (having a large biochemical chemical demand or containing a large ammonia concentration) historically occurred at Ellensburg, Selah, Yakima, Union Gap, Toppenish, and Prosser (in downstream order, see point-source loading table 8). Largest sources were the Yakima STP (RM 111) and Prosser STP (domestic and industrial source just upstream from RM 47.1); however, these loads did not create a sustained depletion in daytime DO concentrations, as indicated by measurements at Parker (RM 104.6) and Kiona (RM 29.9).

Most of the DO concentrations not meeting standards for class AA, A, and B streams in the Yakima River basin occurred during the warmer stream temperatures in the summer, June through September (fig. 58). Potential causes of these occurrences include: higher water temperatures that result in lower DO concentrations at saturation (all stream classes); higher water temperatures that increase metabolic rates of oxygen consumption by aquatic organisms; increased water-use activities by man, such as irrigation, harvesting, cattle and dairy production, and oxygen-demanding effluent from the processing of fruits and vegetables (class A and B streams); and, minimal streamflows for dilution of point and nonpoint sources (class A and B streams).

Table 32.--Sites in the Yakima River basin, Washington, with 25 percent of the dissolved-oxygen determinations less than or equal to 8.0 mg/L (milligrams per liter), 1959-85 water years

Class	Map reference number	Site name	Number of observations	Dissolved-oxygen concentrations, in mg/L: Minimum	Dissolved-oxygen concentrations, in mg/L: 25-percentile value
		Class AA standard is 9.5 milligrams per liter			
AA	236	Crow Creek	8	8.0	8.0
AA	243	Little Naches, Lower	3	7.0	7.0
AA	246	Naches River	10	2.0	2.8
AA	247	Milk Creek	1	7.0	7.0
AA	251	Clear Creek	18	8.0	8.0
AA	252	Oak Creek at mouth	7	6.0	7.0
		Class A standard is 8.0 milligrams per liter			
A	292	DID No. 25 at State Highway No. 12	44	5.5	7.4
A	293	Mile 28 Drain at State Highway	43	4.8	7.4
A	294	DID 2 East Branch at Mile 28 Drain	43	5.3	7.2
A	295	Drain 27.2 at Knowles Road	26	6.0	7.4
A	296	26.6 Drain at Kirk Rd crossing	30	0.8	6.8
A	299	Kid Hover Wasteway near bottom	11	5.4	6.5
A	301	KID Main Canal near head at gage	27	6.0	7.5
A	305	Below Drop No 3--WID Main Canal	12	4.8	7.4
A	306	WID Main Canal nr Canal Intake	20	3.2	7.8
A	309	Satus 2 Canal, NW1/4 S17 9N 21E	16	7.3	7.7
A	310	Nequist Dr NW1/4 S 25 9N 21E	22	2.5	3.5
A	324	Wide Hollow Creek near Gromore	30	4.8	7.3
A	330	Drain DID #3 at South Hill Road	33	5.7	8.0
A	331	Drain DID #3 at Duffy Road	33	5.8	7.3
A	335	Griffin Lake Inlet	47	6.0	8.0
A	336	Griffin Lake Outlet	43	2.4	5.7
A	339	East Toppenish Drain at Wilson Road	57	1.4	5.0
A	340	Sub Drain 35 at Parton Road	57	6.4	7.6
A	346	Granger Drain--Hwy 223 abv Granger	63	6.2	8.0
A	356	Drain DID #3 abv Rendering Plant	25	5.5	7.9
A	357	Drain at Elks Golf Course	30	2.0	5.7
A	362	Manastash at Brown Road Bridge	10	7.1	8.0
A	376	Yakima River near Horlick	14	7.1	7.6
A	378	Squaw Cr--0.3 mi above U.S. Hwy 97 Bridge	18	1.7	7.6
A	505	DID 3 Drain on Needham Feedlot property	15	6.3	7.6
A	516	Outfall of Sunnyside STP into DID 3	1	5.6	5.6

Monthly distributions of DO concentrations at a site indicate the complexity of factors that influence DO concentrations. Daytime, DO concentrations in the Yakima River at Kiona (RM 29.9) suggest that DO concentrations are controlled primarily by stream temperature relative to (1) DO saturation (DO concentrations at saturation decrease as water warms from the winter to the summer months), and (2) oxygen consumption by aquatic organisms (rates of DO consumption--respiration and biochemical oxygen demand--increase with increasing stream temperatures) [fig. 59]. In contrast, minimum DO in East Toppenish Drain occurred during the winter, when the temperatures were low (fig. 59). The predominant source of water during the winter low flows was probably ground water and effluent from the Toppenish STP, which may account for the smaller winter DO concentrations. During the summer in East Toppenish Drain, photosynthetic activity from an abundance of aquatic plants probably controlled DO, causing increased daytime concentrations.

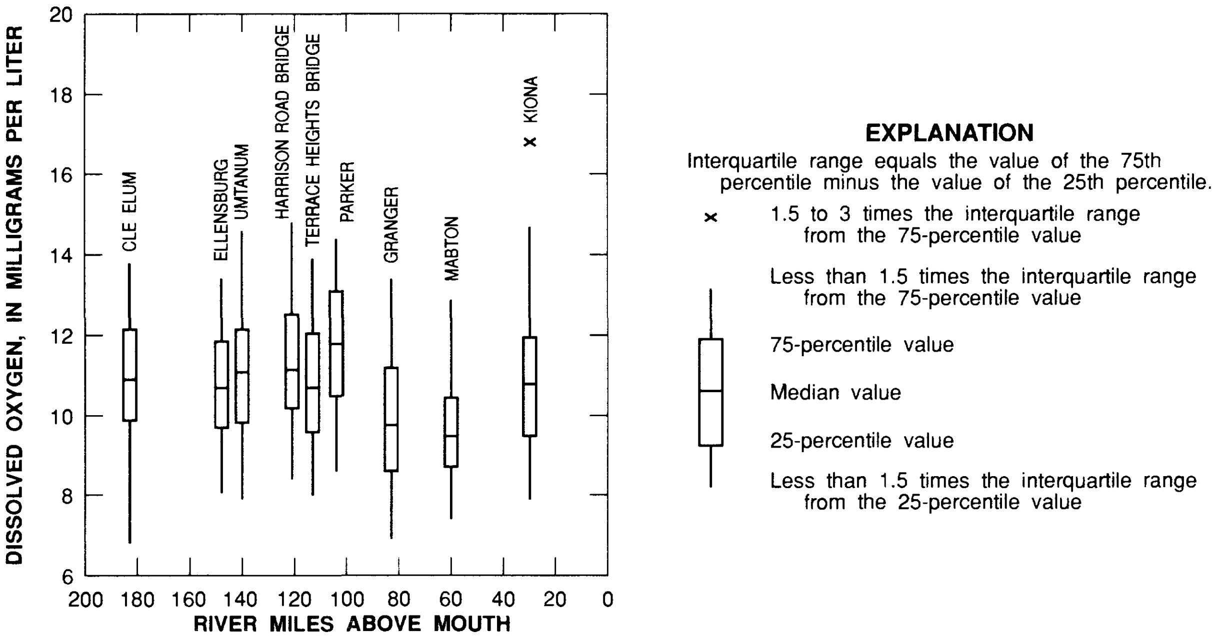


Figure 57.--Concentrations of dissolved oxygen in the Yakima River, Washington, 1974-81 water years.

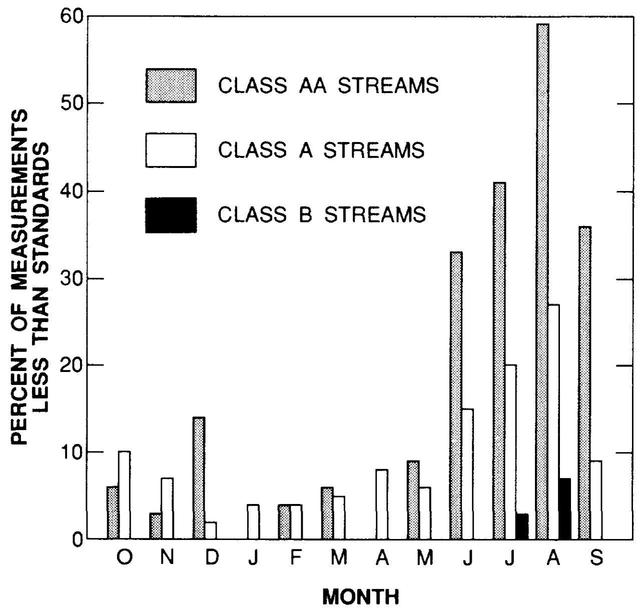


Figure 58.--Frequency of monthly dissolved-oxygen concentrations less than State standards by stream class, Yakima River basin, Washington, 1959-85 water years.

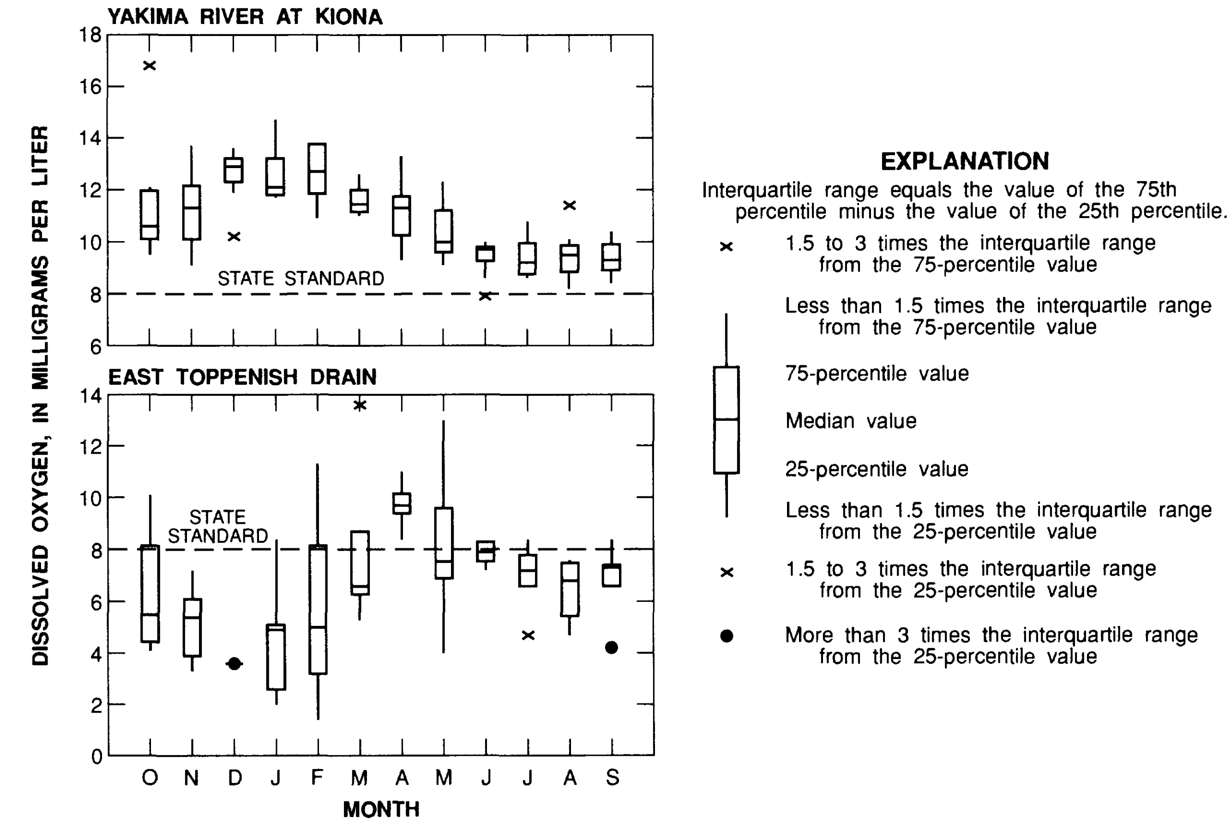


Figure 59.--Monthly concentrations of dissolved oxygen for the Yakima River at Kiona and East Toppenish Drain at Wilson Road, Washington, 1974-81 water years.

Additional data need to be collected to better understand the spatial and temporal (long- and short-term) variability of DO in the Yakima River basin. The historical data only represent instantaneous daytime values when conditions are influenced by photosynthetic activity. Consequently, minimum DO concentrations in Yakima River basin have not been defined. A synoptic sampling of DO at or near dawn (a likely period of minimum daily DO concentrations; Fretwell, 1979) in the basin during the warm summer conditions would be helpful to determine the extent of DO concerns.

Organic Carbon and Related Measures

Organic compounds contain carbon and are derived from natural, synthetic, and microorganism-degradation processes. Organic compounds are used in our everyday lives and may flow into streams and ground water from precipitation runoff, domestic and industrial effluent, and accidental spills and leaks. Some organic compounds are removed by waste-water treatment; however, many persistent compounds still reach the aquatic environment. Natural and synthetic organic compounds may impact stream-water quality by affecting color, taste, odors, health of the aquatic system, and dissolved-oxygen concentrations. In addition, some organic compounds are toxic if consumed in drinking water at sufficiently large concentrations.

Three measurements of organic carbon have been used in the Yakima River basin to estimate organic-compound concentrations and loads in streams or point-source effluent. These measurements include biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC) which equals suspended organic carbon plus dissolved organic carbon. BOD measures the oxygen uptake of rapidly decomposable organic and inorganic substances by either chemical or biological activity usually over a 5-day period (Thurman, 1985). COD is a measure of the biochemical oxygen demand plus the oxygen demand of decomposable organic and inorganic substances by a strong chemical oxidant (potassium dichromate; Thurman, 1985). At best, both BOD and COD determinations provide a qualitative measure of organic carbon content.

TOC data are limited for the basin, both temporally and spatially. Based on only 193 determinations of TOC from 26 sites in the basin from 1969-81 water years, concentrations range from 0.1 mg/L in the Yakima River at Prosser (RM 47.4) to 17 mg/L at Toppenish Creek near Satus with a median concentration of 4.4. These few data are similar to levels observed in selected rivers in the United States whose average concentrations range from 3.3 to 32.0 mg/L for dissolved organic carbon (DOC) and 1.6 to 20.0 mg/L for suspended organic carbon (SOC) [Thurman, 1985, p. 43]. In addition, the range of TOC concentrations observed in the basin are remarkably similar to DOC concentrations in (1) snow (0.1 to 6 mg/L) in North America, and (2) tree-canopy drip (5 to 10 mg/L), indicating that most of the TOC in the Yakima River basin may be in the DOC phase (Thurman, 1985). Monthly data from the Yakima River at Kiona from 1975-81 WY suggest that median TOC concentrations are relatively constant throughout the year. On the basis of 20 samples from the Yakima River at Union Gap (RM 107.2) and at Kiona (29.9), the DOC generally constitutes more than 80 percent of the TOC, which is typical of many rivers in the United States. Relatively few agricultural drains have organic-carbon data, and the proportion of DOC to TOC may be much different in the sediment-ladened water containing agricultural soils.

Historical concentrations of COD (3,966 determinations) provide the best spatial and temporal constituent coverage for estimating organic carbon concentrations. Monthly COD concentrations in the main stem from 1974-81 water years are shown in table 49 (at the back of the report) and in figure 60. Median values of COD more than double in the main stem from 4.0 mg/L at Cle Elum (RM 183.1) to 10 mg/L at Mabton (RM 59.8). Median concentrations from 2 to 7 mg/L occur in the headwater tributaries and canals that receive minimal influences from man's activities. Increases in COD concentrations in the lower basin downstream from Union Gap reflect organic inputs from domestic, industrial, and agricultural sources. On the basis of data from 1968-85 WY, sites with median COD concentrations greater than or equal to 10 mg/L are listed in table 33. Many of these sites are agricultural-return flows that also receive point-source discharges. Some of the largest COD concentrations occurred in the Sunnyside subbasin and also may be associated with runoff from dairies and livestock.

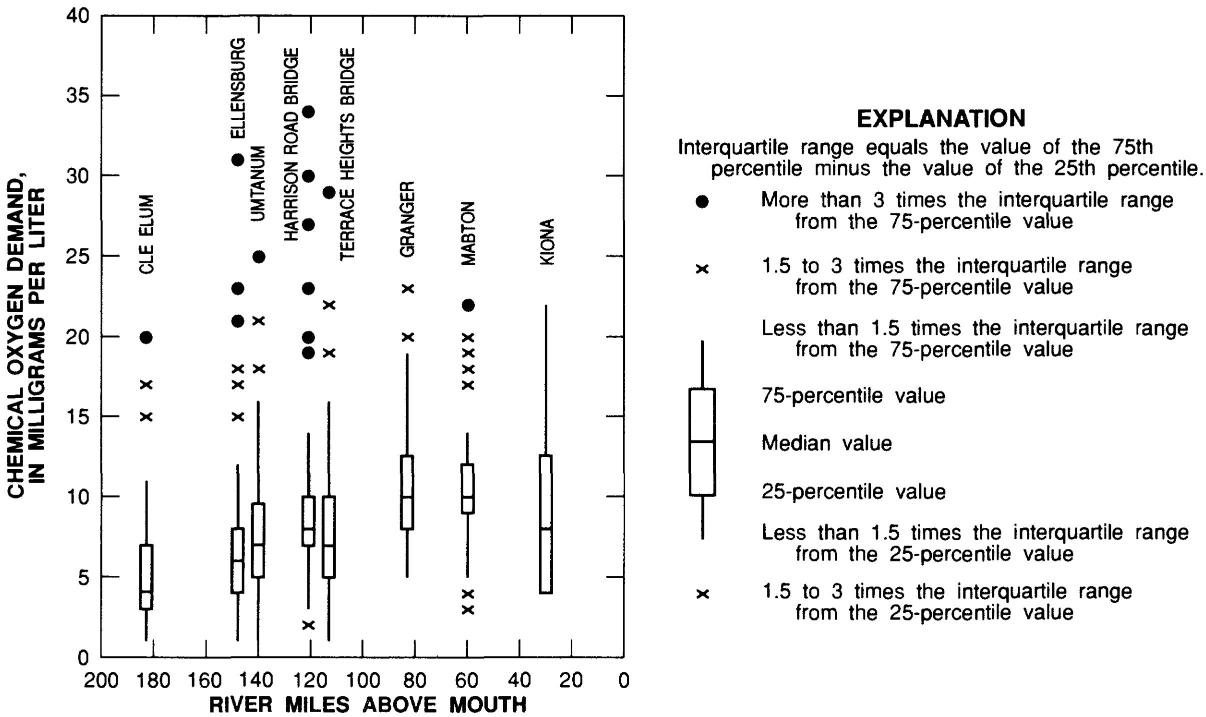


Figure 60.--Chemical oxygen demand in the Yakima River, Washington 1974-81 water years (data at river mile 29.9 collected from 1979-85 water years).

In streams, bacteria consume dissolved oxygen in the process of decomposing organic matter as a food source. If BOD tests are performed under conditions that are similar to those that occur in streams, the test provides a quantitative measure of DO consumption. In the Yakima River basin, BOD is positively correlated with COD (fig. 61; relation shown for all sites with concurrent measurements of BOD and COD). From this relation, BOD concentrations are about 20 percent of the COD concentrations, indicating that up to 80 percent of the COD may be biologically resistant organic matter during a 5 day BOD test. However, the positive correlation between COD and BOD indicates that COD should relate to bacterial DO consumption. Comparison of concurrently collected COD and DO concentrations (tables 32 and 33) shows that 18 of the 26 class A sites with small DO concentrations also had large COD concentrations. Many of the sites with large COD concentrations (listed in table 33) also may have DO problems, especially during the night when photosynthetic activity is not occurring.

Major Metals and Trace Elements

Concern about major metals and trace elements in the aquatic environment has been increasing over the last several decades, because these elements: (1) are widely distributed throughout the environment, (2) are persistent for long periods of time, (3) are toxic to plants, humans, and other animals at small concentrations, and (4) bioaccumulate in plants and animals and move up the food chain into edible fish. Trace elements commonly occur in concentrations less than 1 mg/L in water and have atomic weights greater than that of calcium. Major metals generally occur in larger concentrations. Trace elements are less abundant than the heavier-weight elements (trace metals) in both

Table 33.--Chemical-oxygen-demand concentrations at sites with median concentrations greater than or equal to 10 milligrams per liter, Yakima River basin, Washington, 1968-85 water years

[mg/L - milligrams per liter; listed in order of increasing median concentrations]

Map reference number	Station name	Water-year period	Number of observations	Chemical oxygen demand Median mg/L	Chemical oxygen demand Maximum mg/L
337	Yakima River at bridge near Granger	1974-81	71	10	23
338	Yakima River at bridge near Mabton	1971-81	72	10	22
299	KID Hover Wasteway near bottom	1968-71	9	10	17
307	Chandler Canal--mi 0.6 nr Prosser	1970-81	83	10	49
342	Wanity Slough at Myers Road	1974-81	67	10	29
524	Trib. to DID 5 Drain at Factory Road	1974-74	1	10	10
504	Sulphur Creek at Sunnyside Canal	1974-75	6	10	26
327	Ahtanum Creek at mouth	1974-81	72	10	53
156	Hyak Creek--head of Lake Keechelus	1968-75	21	11	78
308	Chandler Canal Mile 2.8 nr Prosser	1970-81	82	11	32
318	Cowiche Creek SE1/4 S 9 13N 18E	1971-74	21	11	28
339	East Toppenish Drain at Wilson Road	1974-81	67	11	19
529	Roza Main Canal at District Line Road	1974-74	1	11	11
344	Satus Cr East of North Satus Road	1974-74	2	12	12
506	DID 9 Drain at Sunnyside-Mabton Hwy	1974-75	9	12	18
310	Nequist Drain NW1/4 S 25 9N 21E	1971-74	23	12	17
325	Wide Hollow Cr at W. Washington Ave	1974-77	37	12	17
335	Griffin Lake Inlet	1974-79	51	12	38
521	Trib to DID 9, 500 yd N. Stover Rd	1974-74	2	12	14
500	Sulphur Creek at Green Valley Road	1974-75	9	12	16
348	Snipes Cr at Old Inland Empire Road	1974-81	62	12	35
319	Cottonwood Canal Drain SE1/4 S 28	1971-77	58	13	52
328	Sulphur Cr at North above Sunnyside	1974-79	53	13	105
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	13	164
350	Wilson Creek at Sanders Road	1974-77	37	13	35
351	Wilson Creek at Dammon Road	1974-77	37	13	33
353	Wilson Creek at Thrall Road	1974-81	58	13	38
501	Sulphur Creek at Duffy Road	1974-75	9	13	22
509	DID 18 Drain at Vernita Highway	1974-75	9	14	36
147	Domerie Creek above Rosyln Intake	1975-75	1	14	14
293	Mile 28 Drain at State Highway	1968-74	41	14	50
300	KID Coyote Canyon Drain near bottom	1968-79	60	14	44
313	Coleman Cr NW1/4 S 20 17N 19E	1971-79	75	14	104
315	Cascade Canal NE1/4 S 31 18N 19E	1971-74	15	14	70
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	14	187
352	Wipple Wasteway at Thrall Road	1974-79	54	14	26
512	DID 3 Drain at Duffy Road	1974-74	2	15	16
292	DID No. 25 at State Highway No. 12	1968-83	43	15	100
312	Cherry Cr SE 1/4 S 29 17N 19E	1971-79	72	15	72
508	Washout Drain at Allen Road	1974-75	9	16	51
324	Wide Hollow Creek near Gromore	1974-77	35	16	36
334	Sulphur Cr Wasteway at McGee Road	1974-81	71	16	172
345	South Drain at Highway 22 nr Satus	1974-81	66	16	50
347	Spring Creek at Hess Road	1974-81	65	16	37
536	Sunnyside Canal, 0.9 miles from dam	1974-74	1	16	16
520	Trib. to DID 9 at Euclid Road	1974-74	2	16	18
515	DID 3 Drain at South Hill Road	1974-74	2	17	22
311	Satus Drn 302 NW1/4 S34 9N 22E	1971-81	82	17	132
323	Drain at Birchfield Road	1974-81	72	17	125
333	Sulphur Cr Wasteway at Morse Road	1974-79	51	18	146
343	Toppenish Creek at Cook Road	1974-74	2	18	19
507	DID 5 Drain along Tear Road	1974-75	9	18	37
525	Washout Drain at Van Belle/Washout Rd	1974-74	2	19	25
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	19	222
522	Trib. to DID 5 Drain at Allen Road	1974-74	2	19	25
294	DID 2 East Branch at Mile 28 Drain	1968-74	42	20	65
523	Trib. to DID 5 at Alexander Road	1974-74	2	21	22
357	Drain at Elks Golf Course	1978-81	35	21	269
336	Griffin Lake Outlet	1974-79	46	22	35
514	Tributary to DID 3 at Midvale Road	1974-74	2	23	32
505	DID 3 Drain on Needham Feedlot	1974-75	9	23	48
513	DID 3 Drain adj Yakima Rendering Plant	1974-74	2	23	34
519	Trib. to DID 3 Drain at Reeves Road	1974-74	2	25	27
296	26.6 Drain at Kirk Road crossing	1968-74	29	26	650
527	Trib. to DID 18 at Van Belle Road	1974-74	2	28	36
510	DID 3 at E. 1st St in Sunnyside	1974-74	3	30	31
511	DID 3 trib. from Snipes Mt. Lateral	1974-74	1	31	31
356	Drain DID #3 abv Rendering Plant	1975-77	25	32	134
295	Drain 27.2 at Knowles Road	1968-73	24	32	304
330	Drain DID #3 at South Hill Road	1974-77	36	35	187
518	DID 3 Drain at Outlook Road	1974-74	2	37	37
517	DID 3 Drain at Highway 12	1974-74	2	37	39
331	Drain DID #3 at Duffy Road	1974-77	37	39	128
326	Wide Hollow Cr at Union Gap STP	1974-81	73	43	246
516	Outfall of Sunnyside STP into DID 3	1974-74	3	111	131

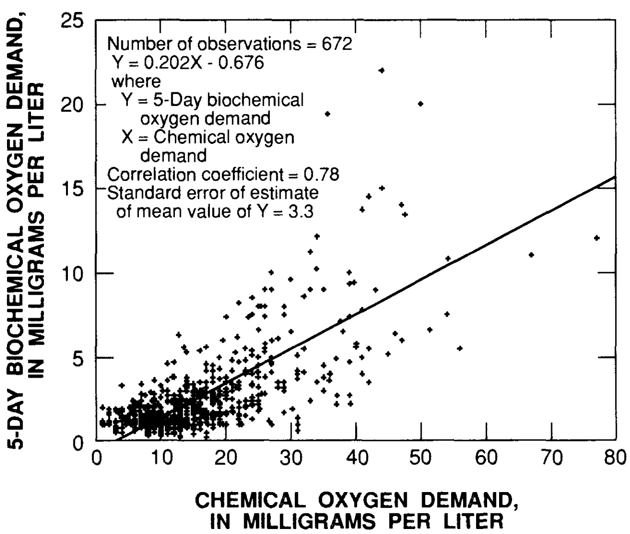


Figure 61.--Relation between chemical oxygen demand and 5-day biochemical oxygen demand at selected surface-water sites in the Yakima River basin, Washington, 1974-81 water years (some large values are not shown).

the lithosphere and biosphere; however, the spectrum of effects from trace elements should not be underestimated. Trace elements are essential nutrients for aquatic-life growth, may have no deleterious effect in many aquatic environments, and may be toxic at enriched concentrations.

Sources of major metals and trace elements in the aquatic environment in the Yakima River basin include: natural weathering or erosion of volcanic rocks and soils of the High Cascades, decomposition of plant and animal matter, atmospheric deposition affected by natural activities (ash fallout from the volcanic eruption of Mount St. Helens), man's activities (combustion of fossil fuels and air emissions from industrial processes), transportation, municipal and industrial wastewater, urban stormwater runoff, paints, fertilizers, and pesticides.

Dissolved major metals and trace elements may precipitate out of solution and may sorb onto suspended sediment and bed sediment, providing a historical integration of water-column conditions. Consequently, suspended sediment and the top few centimeters of bed sediment may act as a reservoir and contain many times the concentration of those same dissolved elements in the water column. Trace elements like boron, zinc, and cadmium generally have ratios of dissolved species to particulate species of between 2:1 and 1:1; copper, mercury, chromium, and lead have ratios between 1:2 and 1:4; iron, aluminum, and manganese (under normal oxygenated conditions in rivers) are almost totally associated with sediment (Forstner and Wittmann, 1979, p. 63).

Major metals evaluated in this study include: barium (Ba), iron (Fe), and manganese (Mn); trace elements, many of which are EPA priority pollutants (Chapman and others, 1982), include: arsenic (As), boron (B), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), and zinc (Zn).

Median concentrations of dissolved major metals and trace elements in the Yakima River basin are similar to background element concentrations in inland water that has been minimally affected by man's activities (table 34). Enriched dissolved-element concentrations (75- and 90-percentile values) in the basin are several times larger than the background concentrations; however, they are well within the range of concentrations detected in United States rivers (rivers that have been affected by man's activities; Kopp and Kroner, 1969; Smith and others, 1987).

Analysis of bed-sediment samples collected from the upstream mountainous regions of the Yakima River basin indicates that median concentrations of major metals and trace elements fall within the expected 95-percent range for uncontaminated soils in the Western United States (R.C. Severson, U.S. Geological Survey, written commun., 1987, based on data in Shacklette and Boerngen, 1984). Few water samples were collected from these upstream bed-sediment sampling sites; consequently, dissolved-element concentrations could not be related directly to element concentrations in bed sediment. The few trace elements (discussed later in this section) that had enriched concentrations in several of the bed-sediment samples did not show enrichment in filtered-water samples collected at downstream locations in the basin.

Analyses of 6-12 whole-fish samples from the Yakima River basin for As, Cd, Cr, Cu, Hg, Pb, and Zn indicate that the median concentrations generally are similar to national baseline concentrations (geometric mean concentrations) collected by U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (table 35). The 85-percentile concentrations for As, Pb, and Zn for Yakima whole-fish samples are elevated (more than one and one-half times larger) in relation to the 85-percentile national-baseline values; however, the significance of this relation will require additional data from the Yakima River basin for comparison with national-baseline data for the same species.

Water

Statistical summaries of major metals and trace elements were made for sites with five or more chemical determinations from 1953-85 WY (tables 54 to 57 at the back of the report). Sites with less than five determinations are listed if one or more constituent concentrations exceeded State water-quality standards (tables 55 and 57 at the back of the report). Censored data (constituent concentration less than the reporting level) were assumed to be smaller than the water-quality standard, even when analytical reporting levels were above State standards. This assumption may reduce the number of exceedances of standards shown in this report. Summaries are shown for dissolved constituents in tables 54 and 55 (at the back of the report) and for total recoverable or total constituents in tables 56 and 57 (at the back of the report). The relatively few data used in these summaries are not necessarily representative of spatial and temporal variability of element concentrations in streams throughout the basin. As a result, the data should be used for identifying sites with element enrichment and not for intersite and intrasite comparisons. The classification "dissolved" is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that

Table 34.--Summary of dissolved-trace-element concentrations in surface water in the United States and in the Yakima River basin, Washington, 1953-85 water years

[Yakima River basin data are not representative of the spatial and temporal variability of element concentrations in streams throughout the basin; "--" = no data or not calculated; NASQAN = U.S. Geological Survey's National Stream Quality Accounting Network based on data from about 300 sites; concentrations in micrograms per liter]

Dissolved element	Background concentrations in inland water, minimally affected by man's activities 1/	Rivers of the United States (1962-67) 2/			NASQAN 1974-81 4/ Percentiles of station-mean concentration			Yakima River basin (1953-85 water years)				
		Minimum	Mean	Maximum	25th	50th	75th	Number of samples	Percentiles 25th	50th	75th	90th
Alkali metals												
Lithium	1	--	3/ 1.1	--	--	--	--	102	<4	<4	5	7
Alkaline-earth metals												
Beryllium	.01	0.01	.19	1.2	--	--	--	69	<.5	<1	<1	<1
Barium	10	2	43	340	--	--	--	120	10	20	20	40
Strontium	50	3	217	5,000	--	--	--	80	39	54	80	120
Transitional metals												
Iron	< 30	1	52	4,600	36	63	157	180	30	48	100	200
Manganese	< 5	.3	58	3,230	11	24	51	165	<10	10	20	30
Vanadium	.9	2	40	300	--	--	--	69	<6	<6	<6	8
Chromium	.5	1	9.7	112	9	10	10	387	0	0	10	10
Cobalt	.05	1	17	48	--	--	--	132	<3	<3	<3	<3
Nickel	.3	1	19	130	--	--	--	139	1	1	2	4
Other metals												
Aluminum	< 30	1	74	2,760	--	--	--	127	10	20	50	90
Copper	1.8	1	15	280	--	--	--	491	2	3	10	20
Silver	.3	.1	2.6	38	--	--	--	121	<1	<1	1	1
Zinc	10	2	64	1,183	12	15	21	465	<3	11	20	50
Cadmium	.07	1	9.5	120	<2	<2	<2	133	<1	<1	<1	2
Mercury	.01	--	3/ <.3	--	.2	.2	.3	167	<.1	<.1	.2	.5
Lead	.2	2	23	140	3	4	6	372	<2	4	10	18
Nonmetals												
Arsenic	2	5	64	336	<1	1	3	218	<5	<5	5	5
Antimony	.1	--	3/ .5	--	--	--	--	24	0	0	0	0
Selenium	.1	--	3/ <1	--	<1	<1	1	133	0	0	<1	<1
Boron	10	1	101	5,000	--	--	--	1,164	10	10	40	70

1/ Forstner and Wittman, 1979.
2/ Kopp and Kroner, 1968.
3/ Hem, 1985.
4/ Smith and others, 1987.

Table 35.--Summary of trace-element concentrations in selected fish-tissue samples from U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program and from the Yakima River basin, Washington, 1976-84

[All concentrations in micrograms per kilogram, wet weight; "--" indicates no data]

Trace element	Yakima River basin, Washington: Summary of whole, gill, liver, edible, tissue analyses — Number of samples	Percentile: Minimum 0	10	25	Median 50	75	85	90	Maximum 100	Whole fish: Number of samples	Percentile 50	85	National Contaminant Biomonitoring Program--whole-fish analyses 1/ National baseline concentrations: Collection period	Geometric mean	85th percentile
Arsenic	35	10	15	15	40	200	230	282	610	10	220	460	1978-79	160	230
													1980-81	140	220
Cadmium	37	5	10	10	17	41	63	84	140	12	50	112	1978-79	40	90
													1980-81	30	60
Chromium	31	15	15	15	110	260	324	484	800	6	270	595	1978-79	--	--
													1980-81	--	--
Copper	37	480	498	770	1,300	2,250	2,940	4,120	7,400	12	870	1,330	1978-79	860	1,140
													1980-81	680	900
Mercury	33	13	13	24	71	166	247	288	780	12	90	219	1978-79	110	180
													1980-81	110	180
Lead	37	15	15	50	320	645	756	1,280	3,300	12	165	1,260	1978-79	190	320
													1980-81	170	250
Zinc	37	6,900	13,700	16,200	20,800	27,900	31,400	43,600	112,000	12	23,000	77,900	1978-79	25,600	46,300
													1980-81	23,800	40,100

1/ Aggregate of fish species that include species not sampled from the Yakima River basin.

passes through a 0.45 μm (micrometer) filter. *Total recoverable and total* are used to refer to chemical analyses of whole-water samples (suspended sediment and water mixtures) but differ from one another in terms of analytical recoveries. A chemical determination is classified *total recoverable* if analytical procedures recover typically less than 95 percent of an element's concentration in a standard reference sample. Analytical procedures with recoveries typically greater than or equal to 95 percent provide *total* element concentrations.

The number of determinations and number of sites (listed in tables 54 and 56 at the back of the report) with element data in the basin is variable and ranges from as few as 96 for total recoverable Ba at only 6 sites to as many as 1,117 at 46 sites for dissolved B. Also, element coverage varies at many sites; for example, major-metal and trace-element data for sites with five or more determinations are available at seven or fewer sites for dissolved Ba, Cd, Fe, Mn, Hg, Ni, Se, and Ag in comparison to 46 sites for dissolved B. The period of record for most sites is small, often 2 to 5 years; in addition, the frequency and duration of sample collection for major metals and trace elements generally is not adequate for calculating annual element loads.

For many trace elements including Cd, Cr^{+3}, Cu, Pb, Ni, Ag, and Zn, toxicity is related to the hardness of the water and increases as hardness decreases (U.S. Environmental Protection Agency, 1986). For example, EPA (1986) criteria for chronic Pb toxicity range from 1.3 to 7.7 μg/L, as hardness ranges from 50 to 200 mg/L (as $CaCO_3$).

Dissolved concentrations of Fe, Mn, Pb, and Hg equaled or exceeded Washington State standards and EPA National Primary or Secondary Drinking-Water Regulations at one or more sites in the Yakima River basin from 1953-85 WY (table 55 at the back of the report); dissolved concentrations of Cd, Cr, Cu, Pb, Hg, Ag, and Zn equaled or exceeded Washington State standards and EPA criteria established for the protection of freshwater aquatic life. Dissolved elements with the largest percentage of drinking-water exceedances (relative to the total number of determinations) are Fe (7 percent), Mn and Pb (each 2 percent), and Hg (less than 1 percent). Similarly, percentages of aquatic-life exceedances are Pb (56 percent), Hg (43 percent), Cu (23 percent), Cd (12 percent), Zn (3 percent), Cr (1 percent), and Ag (less than 1 percent). Even though EPA criteria (adopted as Washington State standards) actually are based on total-recoverable analysis, the dissolved constituent concentrations were large enough to equal or exceed criteria. Note that Cr criteria vary depending on the valence of Cr. For example, assuming a water hardness of 50 mg/L, chronic-toxicity, water-quality criteria for $Cr^{+6}$and Cr^{+3} range from 11 μg/L to 120 μg/L, respectively (assuming a water hardness of 50 mg/L as $CaCO_3$). Because of limitations in earlier analytical methods, Cr concentrations were reported as the sum of the Cr^{+6} and Cr^{+3}concentrations. As a result, historical Cr data are not directly comparable to water-quality criteria; however, as a conservative measure, all Cr concentrations were evaluated against the more stringent criteria established for Cr^{+6}.

In 1969, large concentrations of dissolved Pb were detected by EPA in the Yakima River at Kiona (RM 29.9) and again during the early 1970s when USGS began monitoring (fig. 62); the two agencies show a similar range of concentrations, which reduces the likelihood of erroneous results because of sample-contamination and analytical errors. Monthly Pb concentrations during this time period were highly variable, with the largest concentrations occurring during the winter months and during the irrigation season. The decreasing Pb concentration from 1969-85 could be associated with large declines in the use of leaded gasoline in vehicles since 1974.

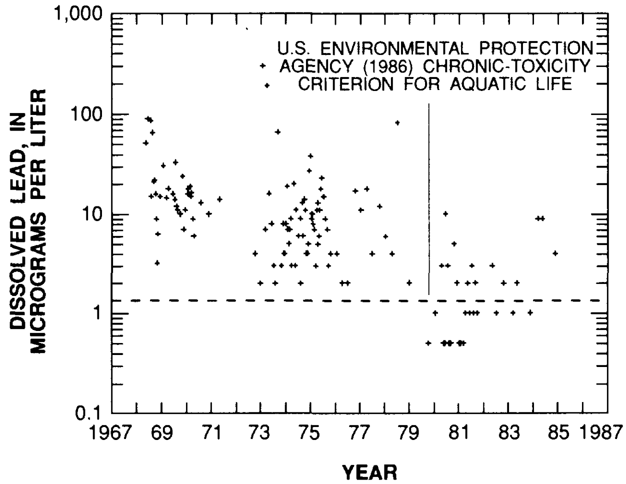


Figure 62.--Concentrations of dissolved lead in the Yakima River at Kiona, Washington, 1968-85 water years (the criterion is based on a hardness of 50 milligrams per liter; water hardness varies seasonally at Kiona, so that exceedances of criterion typically occur at different lead concentrations).

The occurrence of large concentrations of dissolved Cu that exceed EPA (1986), chronic-toxicity, criteria for aquatic life is somewhat problematic from 1962 to 1969, a period when brass water-quality samplers were used and could have caused Cu contamination. Copper sulfate also was used during 1962 to 1969, and currently is being used, by some irrigation districts to minimize nuisance plant growth in canals (Lee Henderson, Kittitas Reclamation District, oral commun., 1989). The amount of copper sulfate used is about one-half pound per cubic foot of capacity. Typical of several other irrigation districts in the basin, the Sunnyside Irrigation District discontinued copper sulfate use for economic reasons in the late 1970's (Jim Trull, Sunnyside Irrigation District, oral commun., 1989); acrolein, which is very toxic to benthic invertebrates, has since been used as an economical substitute for copper sulfate. The decreasing use of copper sulfate may be reflected in the decreasing occurrence of exceedances of Cu criteria from 1962-75 water years (fig. 63). Sixty-three percent of the Cu determinations, made prior to 1970, exceeded Cu criterion compared to 10 percent from 1970-85. Most of the exceedances occurred during irrigation season, which coincides with the application of copper sulfate in irrigation canals. Natural sources of Cu also occur in the Cascade-Range geology (Pre-Tertiary volcanic rocks and Paleocene-Cretaceous nonmarine rocks) of headwater streams and could result in the downstream transport of Cu throughout the basin. For example, copper ore occurs at Copper City upstream from Bumping Lake, and an old abandoned copper claim is located in the headwaters of the Kachess River (Onni Perala, U.S. Bureau of Reclamation, written commun., November 1989).

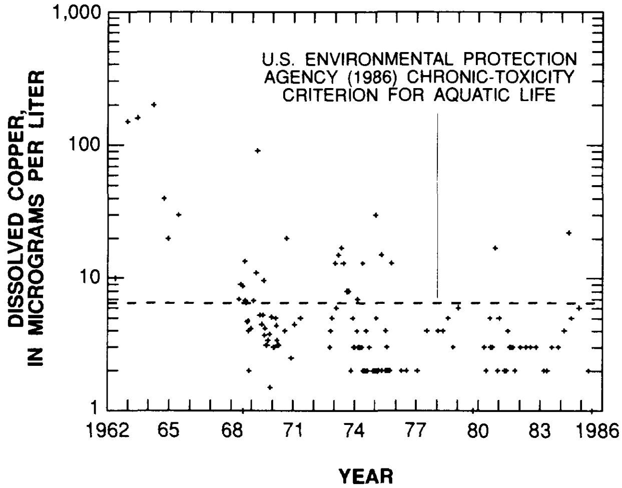


Figure 63.--Concentrations of dissolved copper in the Yakima River at Kiona, Washington, 1962-85 water years (the criterion is based on a hardness of 50 milligrams per liter; water hardness varies seasonally at Kiona, so that exceedances of criterion typically occur at different lead concentrations).

Total and total-recoverable major metals and trace elements exceeded EPA (1986) criteria (that have been adopted as State standards) at one or more sites in the Yakima River basin from 1953-85 WY: Cd, Cr, Cu, Fe, Pb, Hg, Mn, Ni, Ag, and Zn (table 57 at the back of the report). Percentages of drinking-water exceedances (relative to the total number of determinations) are Mn (33 percent), Fe (6 percent), and Pb (2 percent). Similarly, percentages of aquatic-life exceedances are Pb (75 percent), Cu (44 percent), Hg (32 percent), Cd (14 percent), Cr (13 percent), Ag (7 percent), Fe (6 percent), Zn (5 percent), and Ni (less than 1 percent). The order of these exceedances--though the percentages are slightly larger--is similar to the order of exceedances for dissolved major metals and trace elements (table 55 at the back of the report).

Estimates of iron and selected trace-element sources in the Yakima River basin are summarized in table 36. Gianessi's (1986) estimates indicate that point sources are contributing less than 10 percent of the annual element loads to the surface water in the Yakima River basin. Nonpoint source loads include natural and man-caused contributions from forested, rural, urban, and livestock runoff. Gianessi attributed most of the point-source, element loadings to sewage-treatment-plant discharges in the Yakima River basin.

Table 36.--Summary of selected element loads discharged to surface water from point and nonpoint sources in the Yakima River basin, Washington, 1977-81 (Gianessi, 1986)

[Loads in 1,000 pounds per year]

Element	Constituent loads		Total
	Point sources	Nonpoint sources	
Arsenic	<1	<1	1
Cadmium	<1	<1	1
Chromium	13	126	139
Copper	4	58	62
Iron	30	3,968	3,998
Lead	2	51	53
Mercury	<1	<1	<1
Zinc	12	206	218

Bed Sediment

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By T.L. Fries[1] and J.L. Ryder[2]

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Bed-sediment studies in the Yakima River basin have been mineral-resource investigations focused in the mountainous regions. Sediment studies conducted in the more populous agricultural area apparently have focused on water-quality issues without regard to trace-element contributions from bed sediment. A search of existing data bases and literature indicates that no comprehensive study of trace-element geochemistry in bed sediment has been done in the Yakima River basin. Included in this report are data from (1) the mineral-resource study in the Goat Rocks Wilderness area (Church and others, 1983) done by the Geologic Division of the U.S. Geological Survey and (2) the mineral assessment study in the headwaters of the Yakima and Naches Rivers (Moen, 1969) done by the Washington Department of Natural Resources (fig. 64).

The primary goal of the Goat Rocks study was mineral exploration. Data for 48 stream samples (Church and others, 1983) in the Yakima River basin were retrieved from the U.S. Geological Survey's Rock Analysis Storage System (RASS). Church's study was conducted in the area of Old Snowy Mountain, southwest of Rimrock Lake (fig. 64). The collection and analysis of these data were complicated, because the area had received recent deposits of volcanic debris (pyroclastic and air-fallen deposits) from the May 18, 1980, eruption of Mount St. Helens.

A summary of analytical results of sieved streambed samples containing particles finer than 177 µm in diameter are shown in table 37. Analyses were performed using six-step semiquantitative direct-current emission spectrography. Concentrations of Sb, As, Bi, Cd, Au, Mo, Sn, and W were not detected at any of the 48 sites.

In 1969, Moen published the results of trace-element analyses for 182 bed-sediment samples collected from eight subbasins: Cle Elum Lake, Easton, Upper Naches, Tieton, Teanaway Creek, Elk Heights and Taneum Creek, Manastash Creek and Thorp, and Swauk Creek in the northwest part of the Yakima River basin (fig. 64). Summary results for total concentrations of Cu, Pb, Mo, and Zn are shown in table 38. The determinations were performed using atomic absorption spectrophotometry and colorimetry.

1/ Chemist with the U.S. Geological Survey, Branch of Geochemistry, Menlo Park, California.

2/ Physical Science Technician, U.S. Geological Survey, Branch of Geochemistry, Denver, Colorado.

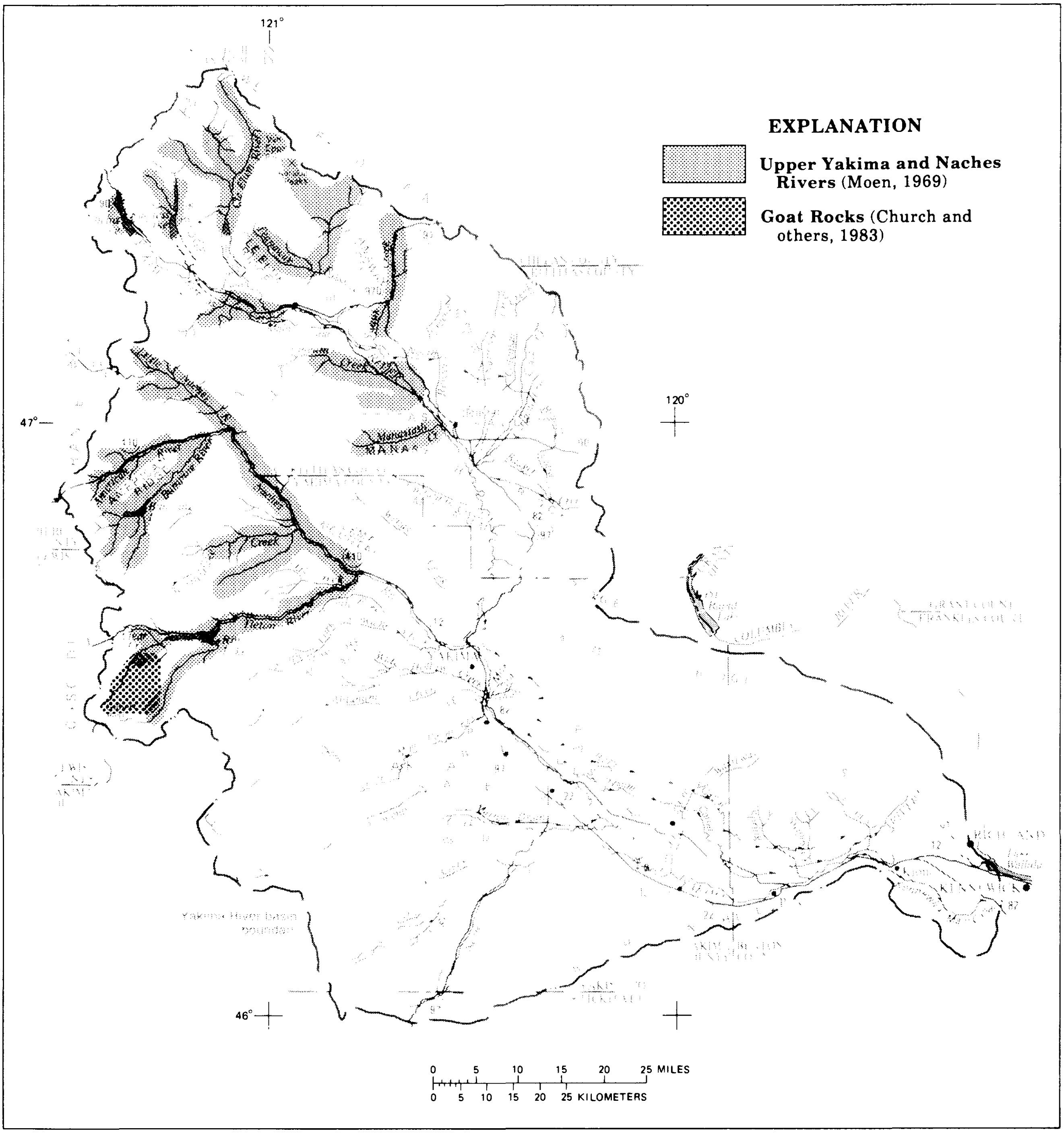

Figure 64.--Sampling locations for trace elements in bed sediment in the Yakima River basin, Washington, 1965-68 (Upper Yakima and Naches Rivers) and 1981 (Goat Rocks area).

Table 37.--Summary statistics for selected element concentrations in bed-sediment samples (finer than 177 micrometers in diameter) from the Goat Rocks Wilderness area in the Yakima River River basin, Washington (Church and others, 1983)

[* indicates observed range, "--" indicates no data]

Element	Number of determin- ations	Minimum	Percentile 10	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Maximum	Expected 95-percent range for soils in the Western United States (Shacklette and Boerngen, 1984)
Element, in percent									
Calcium	48	1	1.8	1.8	2	2	3	3	0.19 - 17
Iron	48	2	5	5	7	10	10	10	.55 - 8.0
Magnesium	48	.5	1	1	1.5	2	2	2	.15 - 3.6
Titanium	48	.1	.5	.5	.7	1	>1	>1	.069 - .70
Element, in micrograms per gram									
Antimony	48	<100	<100	<100	<100	<100	<100	<100	--
Arsenic	48	<200	<200	<200	<200	<200	<200	<200	1.2 - 22
Barium	48	150	300	300	400	500	600	1,000	200 - 1,700
Beryllium	48	<1	<1	1	1	1	1.5	2	.13 - 3.6
Bismuth	48	<10	<10	<10	<10	<10	<10	<10	--
Boron	48	<10	<10	10	10	20	50	100	5.8 - 91
Cadmium	48	<20	<20	<20	<20	<20	<20	<20	--
Chromium	48	10	30	50	100	150	150	200	8.5 - 200
Cobalt	48	5	20	20	30	50	50	50	1.8 - 28
Copper	48	7	20	30	50	50	70	100	4.9 - 90
Gold	48	<10	<10	<10	<10	<10	<10	<10	--
Lanthanum	48	<20	<20	<20	<20	<20	<20	<20	8.4 - 110
Lead	48	<10	<10	<10	<10	10	10	20	5.2 - 55
Manganese	48	300	700	1,000	1,000	1,500	1,500	2,000	97 - 1,500
Molybdenum	48	<5	<5	<5	<5	<5	<5	<5	.18 - 4.0
Nickel	48	<5	30	30	40	50	50	100	3.4 - 66
Niobium	48	<20	<20	<20	<20	<20	<20	<20	<10* - 100*
Scandium	48	5	10	15	20	20	20	30	2.7 - 25
Silver	48	<.5	<.5	<.5	<.5	<.5	<.5	<.5	--
Strontium	48	100	250	300	300	500	500	500	43 - 930
Tin	48	<10	<10	<10	<10	<10	<10	<10	--
Tungsten	48	<50	<50	<50	<50	<50	<50	<50	--
Vanadium	48	20	150	150	200	200	300	500	18 - 270
Yttrium	48	10	15	15	15	20	20	30	8.0 - 60
Zinc	48	<200	<200	<200	<200	<200	200	300	17 - 180
Zirconium	48	70	100	100	150	250	300	500	<20* - 1,500*

In tables 37 and 38, trace-element concentrations in bed sediment from the Yakima River basin are compared with element concentrations in uncontaminated soil samples collected west of the 97th meridian within the conterminous United States (Shacklette and Boerngen, 1984). For this report, element concentrations in bed sediment are defined as common or unenriched levels when they fall within the expected 95-percent range shown for the western United States soils. Those values larger than the expected 95-percent range are defined as uncommonly large levels. Due to the lack of particle-size data, this comparison ignores the effects of particle-size differences among the soil and the bed-sediment samples. These size differences may affect the comparisons for several elements including B, Cr, Cu, Ni, V, and Zn (Ronald C. Severson, U.S. Geological Survey, California, written commun., May 1987). Consequently, results from this comparison only should be used to indicate a potential for element enrichment in bed sediment.

Most of the trace-element concentrations measured in the mountainous regions of the Yakima River basin fell within the expected 95-percent range for Western United States soils. Four of the nine subbasins listed in tables 37 and 38 had uncommonly large levels of some trace elements (table 39). Concentrations of Mo at 5 $\mu g/g$ (micrograms

Table 38.--Summary of copper, lead, molybdenum, and zinc concentrations in bed-sediment samples from the Upper Yakima River basin, Washington (Moen, 1978)

["na" means not applicable; "--" means not available; location of subbasins shown in figure 13]

Subbasin or area	Number of determinations	Minimum	Percentile 10	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Maximum	Expected 95-percent range for soils in the Western United States (Shacklette and Boerngen, 1984)
				Copper, in micrograms per gram					
Cle Elum River	22	5	8	11	17	28	84	88	na
Teanaway River	23	5	8	11	14	18	27	30	na
Easton	15	15	16	20	22	34	206	208	na
Upper Naches River	76	5	8	19	20	31	70	385	na
Tieton River	31	10	11	14	17	26	45	50	na
Swauk Creek	9	5	na	na	na	na	na	10	na
Manastash Creek and Thorp	2	10	na	na	na	na	na	15	na
Elk Heights and Taneum Creek	4	5	na	na	na	na	na	20	na
Goat Rocks area	48	7	20	30	50	50	70	100	na
Soils in Western United States	--	2	--	--	--	--	--	300	4.9-90
				Lead, in micrograms per gram					
Cle Elum River	22	<25	<25	<25	<25	<25	<25	29	na
Teanaway River	23	<25	<25	<25	<25	<25	<25	37	na
Easton	15	<25	<25	<25	<25	<25	<25	50	na
Upper Naches River	76	<25	<25	<25	<25	26	49	150	na
Tieton River	31	<25	<25	<25	<25	<25	<25	<25	na
Swauk Creek	9	<25	na	na	na	na	na	<25	na
Manastash Creek and Thorp	2	<25	na	na	na	na	na	<25	na
Elk Heights and Taneum Creek	4	<25	na	na	na	na	na	<25	na
Goat Rocks area	48	<10	<10	<10	<10	10	10	20	na
Soils in Western United States	--	<10	--	--	--	--	--	700	5.2-55
				Molybdenum, in micrograms per gram					
Cle Elum River	22	<5	<5	<5	<5	<5	<5	5	na
Teanaway River	23	<5	<5	<5	<5	<5	<5	<5	na
Easton	15	<5	<5	<5	<5	<5	<5	5	na
Upper Naches River	76	<5	<5	<5	<5	<5	<5	5	na
Tieton River	31	<5	<5	<5	<5	<5	<5	<5	na
Swauk Creek	9	<5	na	na	na	na	na	<5	na
Manastash Creek and Thorp	2	<5	na	na	na	na	na	<5	na
Elk Heights and Taneum Creek	4	<5	na	na	na	na	na	<5	na
Goat Rocks area	48	<5	<5	<5	<5	<5	<5	<5	na
Soils in Western United States	--	<3	--	--	--	--	--	7	0.18-4.0
				Zinc, in micrograms per gram					
Cle Elum River	22	20	26	36	48	62	90	110	na
Teanaway River	23	30	41	49	59	69	98	110	na
Easton	15	45	50	56	69	82	98	101	na
Upper Naches River	76	20	45	62	78	97	330	1,000	na
Tieton River	31	45	52	59	68	84	120	125	na
Swauk Creek	9	40	na	na	na	na	na	65	na
Manastash Creek and Thorp	2	50	na	na	na	na	na	65	na
Taneum Creek and Elk Heights	4	40	na	na	na	na	na	75	na
Goat Rocks	48	<200	<200	<200	<200	<200	200	300	na
Soils in Western United States	--	10	--	--	--	--	--	2,100	17-180

Table 39.--Subbasins in the Yakima River basin, Washington, with uncommonly large element concentrations in bed sediment compared to those concentrations in Western United States soils

Subbasin	Elements with uncommonly large 50-percentile concentrations
Tieton (Goat Rocks)	Cobalt
	Elements with uncommonly large 90-percentile concentrations
Easton	Copper
Tieton (Goat Rocks)	Cobalt, iron, titanium, vanadium, zinc
Upper Naches River	Zinc
	Elements with uncommonly large maximum concentrations
Cle Elum	Molybdenum
Easton	Copper, molybdenum
Tieton (Goat Rocks)	Boron, cobalt, copper, iron, manganese, nickel, scandium, titanium, vanadium, zinc
Upper Naches River	Copper, lead, molybdenum, zinc

per gram) were measured in three of the four basins, but this concentration is at the minimum analytical reporting level, which adds uncertainty to its actual concentration.

Ten elements were identified with uncommonly large levels in the Tieton subbasin (Goat Rocks area), and four elements were identified in the upper Naches River subbasin. The rock types in these basins that may be contributing to the uncommonly large levels include the andesitic and rhyolitic volcanics, and the granitic- and ultramafic-intrusive units; these units generally are not present in the lower Yakima River basin which is mostly underlain by basalt, glaciolacustrine, and alluvium deposits. The increased occurrence of uncommonly large concentrations in the Tieton and Upper Naches subbasins also may be due to the large number of samples collected in each of these subbasins--larger number of samples may increase the range of concentrations.

The bed-sediment analyses by Church and others (1983) and Moen (1969) represent the total trace-element concentrations in the sediment, and the results do not necessarily represent the actual concentrations of the trace element that are bioavailable to the biota.

Fish Tissue

Results of fish-tissue analyses for selected trace elements are shown in table 40. Spatial- and temporal-data coverages are limited, and trace-element concentrations vary widely at a site and from site to site. As shown in table 35, 85-percentile concentrations for As, Pb, and Zn in whole-fish tissues from the Yakima River basin are elevated (more than one and one-half times) when compared with national baseline data (85-percentile concentrations) from U.S. Fish and Wildlife Service's (USFWS) National Contaminant Biomonitoring Program. Arsenic and Zn concentrations in whole-fish tissues were elevated (more than one and one-half times compared with USFWS 85-percentile concentrations) in the two samples collected from the Yakima River near Granger (table 40). Elevated As concentrations occurred in two species (largescale sucker and black crappie); enriched Zn occurred in one species (carp), which may be characteristic of that species.

Table 40.--Trace-element concentrations in fish-tissue and bed-sediment samples from selected sites in the Yakima River basin, Washington, 1976-84

[Data from Hopkins and others (1985) and U.S. Environmental Protection Agency's computer storage and retrieval system; concentrations in tissues in micrograms per kilogram, wet weight; concentration in bed sediment in micrograms per kilogram, dry weight; "na" = not analyzed; "*" = largest concentration in edible tissue samples for species collected from 10 locations throughout Washington in 1984; "--" = not available]

Site	Date month/year	Tissue or medium	Organism	Arsenic	Cadmium	Chromium	Copper	Mercury	Lead	Zinc
Yakima River at Ellensburg (river mile 161)	04/78	Unknown	Largescale sucker	<300	<10	200	490	60	3,300	96,000
Naches River at municipal water intake (river mile 9.7)	07/80	Unknown	Unknown	<90	25	200	480	13	320	6,900
Naches River near mouth	07/80	Unknown	Unknown	<100	17	420	620	41	400	14,000
Yakima River downstream of Moxee Drain (river mile 107.2)	09/83	Gill	Bridgelip sucker	20	10	50	1,300	13	570	16,000
	09/83	Gill	Mountain whitefish	40	10	90	1,100	74	690	23,000
	09/83	Gill	Northern squawfish	40	10	110	1,700	191	770	30,000
	09/84	Edible	Bridgelip sucker	<30	30	<30	1,500	250*	<30	26,800
	09/84	Liver	do. do.	100	100	100	7,400	na	<100	30,700
	09/84	Gills	do. do.	<30	20	800	1,700	33	170	35,500
	09/84	Edible	Northern squawfish	<100	10	<30	2,700*	780*	170*	12,600
	09/84	Gills	do. do.	<30	10	<30	2,200	300	<30	27,000
	09/84	Edible	Mountain whitefish	200	10	<30	1,700	640	<30	14,700
	09/84	Liver	do. do.	<30	<30	200	5,800	na	600	20,800
	09/84	Gills	do. do.	<30	20	<30	2,100	140	<30	24,600
	09/84	Sediment		1000	600	16,700	600	18	700	54,300
Yakima River near Granger (river mile 82.7)	10/76	Whole	Black crappie	<500	140	230	490	50	190	19,600
	10/76	Whole	Largescale sucker	610	<50	270	550	90	<100	14,400
	10/78	Whole	Carp	157	51	na	1,100	216	140	112,000
	10/78	Whole	Carp	184	48	na	1,300	208	<100	76,100
	10/78	Whole	White crappie	221	<10	na	567	71	1,370	28,800
	--/80	Whole	Black crappie	380	20	na	500	270	100	33,000
	--/80	Whole	Largescale sucker	220	10	na	800	90	100	21,600
	--/80	Whole	Largescale sucker	230	10	na	800	100	100	24,300
Yakima River at Kiona (river mile 29.9)	09/80	Whole	Smallmouth bass	na	110˙	260	940	< 29	1,260	20,300
	09/80	Whole	Bridgelip sucker	na	55	270	1,200	< 27	660	14,300
Yakima River mile 19.9	09/82	Whole	Bridgelip sucker	38	80	500	1,900	95	670	25,400
	09/82	Gill	do. do.	28	<20	<100	1,500	35	520	15,900
	09/83	Gill	do. do.	<20	10	110	870	20	510	16,400
	09/82	Whole	Mountain whitefish	32	60	600	1,100	23	480	21,200
	09/82	Gill	do. do.	34	20	100	1,100	48	750	16,700
	09/83	Gill	Channel catfish	<20	10	200	740	16	630	19,300
	09/84	Edible	Bridgelip sucker	30	20	<30	2,300*	100	2,000	23,200
	09/84	Liver	do. do.	330	<30	200	3,500	na	<100	18,600
	09/84	Gills	do. do.	230	10	<30	3,700	24	370	17,700
	09/84	Edible	Northern squawfish	30	10	<30	2,300	120	<30	16,300
	09/84	Liver	do. do.	<30	<30	100	7,400	na	<100	16,500
	09/84	Gills	do. do.	<30	70	<30	2,600	24	200	29,300
	09/84	Sediment		2,800	1,400	35,800	< 100	38	4,200	82,500
Yakima River at Highway 224 near Richland (river mile 9.3)	07/80	Unknown	Unknown	90	34	300	570	30	340	11,000

When compared with data from other sites in the basin, As concentrations generally were 10 times larger in all of the samples from the Yakima River near Granger (RM 82.7). A potential source for arsenic may be acid lead-arsenate sprays that were used prior to 1947 for controlling codling moths in apple orchards (Peryea, 1989). Peryea (1989) found that high application rates of phosphate (PO_4) fertilizer may increase dissolution of As (PO_4 and As compete for surface-exchange sites on soil particles). Consequently, a potential exists for As contamination in the shallow aquifers which feed the agricultural-return flows.

Elevated Pb concentrations occurred in whole-fish samples of several fish species downstream from Yakima RM 107.2 (table 40). About 50 percent or more of the total-recoverable and dissolved Pb concentrations in water samples from Yakima River at Union Gap (RM 107.2) and Kiona (RM 29.9) exceeded EPA (1986), chronic-toxicity, aquatic-life, criterion (table 55 and 57 at the back of the report and fig. 62). Sources of lead in the basin include urban runoff (combustion of leaded gasoline) and historical usage of acid-lead-arsenate insecticide sprays; however, dissolved Pb transport in agricultural soils is perceived to be restricted to the top 60 centimeters of soil (Peryea, 1989).

Four of the fish samples shown in table 40 have element data for edible, liver, and gill tissue samples. The data suggest that the liver and gill samples contain the largest element concentrations. Mercury was a notable exception with largest concentrations occurring in the edible fish tissues (no data were available for livers). Overall, element concentrations varied widely in the fish samples throughout the basin and were dependent on fish species and tissue type.

In 1984, the Washington State Department of Ecology collected fish-tissue samples for trace element analyses from 10 streams throughout Washington (table 40; Hopkins and others, 1985). Fish from the Yakima River basin had the largest concentrations of Cu, Hg, and Pb in edible tissues. A comparison of EPA, Food and Drug Administration (FDA), and World Health Organization (WHO) human-consumption guidelines with trace-element concentrations in Yakima River fish is shown in table 41. The 6.5 g/d (grams per day) fish-ingestion rate is EPA's estimate of the national average consumption of freshwater and estuarine fish and shellfish; the 20 g/d rate was estimated by U.S. Department of Agriculture for freshwater-, estuarine-, and marine-fish consumption; the 165 g/d rate is the amount consumed by 0.1 percent of the population in the nation (Johnson, and others, 1986). The small number of samples from the basin indicate that Cd, Cr, Cu, Pb, and Zn concentrations in tissue samples do not exceed recommended EPA, FDA, and WHO recommended dietary allowances. Assuming a fish ingestion rate of 165 g/day for 0.1 percent of the population in the nation, the recommended dietary allowance for Hg for Yakima fish would be exceeded in the main stem for several species (table 40); however, all samples from the basin had Hg concentrations less than FDA's action level of 1,000 $\mu g/kg$ (micrograms per kilograms, wet weight).

Radionuclides

Radionuclides occur in water either naturally as a result of the disintegration of high-atomic-weight isotopic elements or artificially as nuclear-fission products. Naturally occurring forms like uranium (^{238}U),

Table 41.--Comparison of U.S. Environmental Protection Agency, Food and Drug Administration, and World Health Organization dietary guidelines with maximum trace-element concentrations in Yakima River fish, Washington, 1976-84

[EPA = Environmental Protection Agency; FDA = Food and Drug Administration; WHO = World Health Organization; Recommended dietary allowance from Johnson and others (1986), Hopkins and others (1985), and Irene Murphy, Office of Policy Analysis, Washington, D.C., and Michael Harthill, Minerals Management Service, Washington, D.C.]

Element	Recommended dietary allowance, in micrograms per day	Maximum recommended concentration of trace element in edible fish tissue based on EPA, FDA, or WHO recommended dietary allowance, assuming fish ingestion of: 6.5 grams per day (in micrograms per kilogram)	20 grams per day	165 grams per day	Largest concentration in edible fish tissue from the Yakima River basin, in micrograms per kilogram
Cadmium 1/	30	4,600	1,500	180	30
Chromium 2/	125	19,000	6,200	760	<30
Copper 2/	2,000-3,000	310,000-460,000	100,000-150,000	12,000-18,000	2,700
Lead 3/	350	54,000	18,000	2,100	2,000
Mercury 1/	20	3,100	1,000	120	780
Zinc 4/	10,000	1,500,000	500,000	61,000	27,000

1/ U.S. Environmental Protection Agency maximum contaminant level criterion; 500 µg/Kg (micrograms per kilogram) of cadmium--unofficial FDA guidelines in other food types; 1,000 µg/Kg of mercury, wet weight--FDA action level in edible fish; 500 µg/Kg of mercury, wet weight, total body burden--EPA standard to protect fish and predatory aquatic organisms.

2/ Food and Drug Administration recommended dietary allowance for adults.

3/ World Health Organization recommended dietary allowance for 70 Kg person; 7,000 µg/Kg of lead--unofficial Food and Drug Administration guidelines in other food types.

4/ Food and Drug Administration recommended dietary allowance for children.

^{235}U, and thorium (^{232}Th) spontaneously decay, producing primarily alpha-emitting substances like radium (Ra) and radon (Rn). Artificially produced forms like strontium (^{90}Sr), ^{89}Sr, iodine (^{131}I), potassium (^{32}K), and cobalt (^{60}Co) are strong beta and gamma emitters (Hem, 1985).

Radioactive chemicals are similar in many respects to other chemical contaminants. When ionizing radiation is absorbed into aquatic biota and human tissues above natural background levels, it may be injurious to the health of the organisms. Radionuclides are probable human carcinogens. In the aquatic environment, radioactive chemicals may (1) remain in the water column (dissolved or suspended), (2) reside in the bed sediment, or (3) be taken up by the aquatic biota. These chemicals may accumulate in the biota and move up the food chain. Humans can receive unacceptable doses of the radiation by drinking contaminated water or eating contaminated fish.

The Yakima River basin lacks baseline-radionuclide data, with the exception of a limited amount of ^{40}K data. The data, however, are of little environmental value, because ^{40}K is a non-toxic stable nuclide that occurs naturally in the earth's crust. The absence of baseline data prohibits any evaluation of radionuclides relative to spatial and temporal variability as well as comparison to water-quality standards. Because of the basin's close proximity to the Hanford Nuclear Facility (operated by the U.S. Department of Energy) in addition to any natural-nuclide sources in the basin, radionuclides should be addressed in two phases (Al Yang, U.S. Geological Survey, oral commun., 1988). The first phase would be a gross screening for nuclides by measuring gross alpha, beta, and gamma emissions, with no attempt to differentiate between natural and artificial radionuclides. In the second phase, if gross measurements exceed water-quality standards, samples would be collected to identify specific nuclides that pose risks to human health. Nuclide determinations should include: ^{89}Sr, ^{90}Sr, ^{131}I, ^{239}Pu, ^{137}Cs, ^{3}H, ^{60}Co, and ^{99}Tc.

Pesticides and Other Synthetic Organic Compounds

About a million organic (containing carbon) compounds have been identified by man (Sawyer and McCarty, 1967). Major sources of organic compounds are natural occurrences in plants and animals, degradation and alteration of organic matter by microorganisms that feed on the organic compounds as a food source, atmospheric deposition, sources from man's activities including industrial and domestic emissions, and synthetic organic compounds made for a variety of household, industrial, and agricultural uses.

When used properly, synthetic organic compounds are beneficial and often invaluable in human activities. One such use is the application of pesticides to control insects and weeds that are damaging to agriculture. Some of these pesticides sorb onto soil particles and others are soluble in water. In areas of pesticide application and irrigation, some of the soluble compounds will percolate down to ground-water supplies and seep to surface water as subsurface drainage. During periods of high precipitation and surface runoff, erosion causes sediment-sorbed pesticides to be transported from fields to surface water.

In small concentrations in the water column and bed sediment, many of these pesticides can be harmful and even toxic to aquatic organisms. Some pesticide compounds bioaccumulate (concentrate in tissues of aquatic plants and animals) to concentrations that are orders of magnitude larger than those that occur in the water and sediment in which the organisms live. A few of these pesticides are resistant to biological degradation and may persist in sediment and water for many months or years.

Even though the application of pesticides is extensive on irrigated land in the Yakima River basin, few samples have been collected to determine the spatial and seasonal distributions of the concentrations of these compounds in the aquatic environment. Trace organic analyses were completed on 145 samples collected from 13 locations in the Yakima River basin from 1968-83 water years (table 42; WATSTORE and STORET computer data retrieved in 1986 WY). About 50 percent of the 3,761 trace organic determinations, available in the WATSTORE and STORET data bases for the Yakima River basin, were made on samples collected from the Yakima River at Kiona (RM 29.9).

In 1985, WDOE collected fish, water, and sediment samples for analyses of DDT (dichlorodiphenyltrichloroethane) compounds and other contaminants (Johnson and others, 1986; these data were not computer accessible from WATSTORE and STORET in 1986 WY). In contrast to previous samplings in the basin, this WDOE study targeted 11 large tributaries that receive substantial agricultural-return flow during the summer months. In addition, three main-stem sites were chosen to represent water quality: in the headwater at Cle Elum (RM 183.1), mid-basin at Parker (RM 104.6), and the lower basin at Kiona (RM 29.9). Fish-tissue samples were collected from six main-stem sites: at Cle Elum, Wymer (RM 135), Roza Dam (RM

127.9), Buena (RM 94), Prosser (RM 46), and Kiona. Bed-sediment samples were collected at selected major diversion dams. All samples were analyzed for organochlorine pesticides and PCB (polychlorinated biphenyl) compounds, and a limited number of samples were analyzed for organophosphorus

Table 42.--Sampling sites and numbers of samples and determinations for trace-organic compounds in water, sediment, and tissues of aquatic organisms in the Yakima River basin, Washington, 1968-83 water years

[A sample may have been analyzed for one or more compound determinations. Site locations are shown on plate 1; data retrieved from U.S. Environmental Protection Agency's Computer Storage and Retrieval System and U.S. Geological Survey's computer system in 1986 water year]

Map reference number	Site name	Number of samples	Number of determinations
32	Yakima River at Union Gap	1	1
39	Main Canal near Parker	4	48
42	Sunnyside Canal at Maple Grove Road	1	23
86	DID 18 Drain at Sunnyside	1	45
91	Sulphur Creek Wasteway nr Sunnyside	1	45
100	Yakima River at Kiona (USGS site)	68	1,648
386	Yakima River at Ellensburg Water Intake	2	222
387	Yakima River at Hwy 224 nr Richland	3	334
388	Naches River at Yakima Water Intake	3	334
389	Naches River at mouth near Yakima	3	335
399	Yakima River at Kiona (EPA site)	18	178
424	Yakima River at Granger	33	394
464	Yakima River near Birchfield Drain	7	154
	Total	145	3,761

pesticides, carbamates/phenylurea pesticides, herbicides, acid/base-neutral organic compounds, volatile organic compounds, and selected metals. The Yakima River basin was selected for study by WDOE in 1985, because previous monitoring in 1984 by WDOE (Hopkins and others, 1985) revealed that Yakima River fish livers had among the largest concentrations of DDT, dichlorodiphenyldichloroethylene (DDE), DDD (dichlorodiphenyldichloroethane), , and PCB in Washington State.

About 85 percent of the organic-compound determinations (STORET and WATSTORE data) from 1968-83 water years were reported as concentrations less than minimum analytical reporting levels. (Note that historical reporting levels are 1-2 orders of magnitude larger than those that are currently (1990) available.) A summary of concentrations larger than minimum reporting levels is presented in table 58 at the back of report. Many constituent concentrations listed in table 58 exceeded the minimum reporting level only once at a given sampling site, partially because few samples were collected at each site. The small number of determinations at a site makes it difficult to accurately define spatial, seasonal, and long-term variations in compound concentrations.

On the basis of data from 1968-83 and 1985 water years, the compounds that consistently occurred in the water column, bed sediment, or fish tissues were: dieldrin, DDT, DDE, DDD, and PCB. PCB compounds occurred in fish tissue, but data were not available to support their occurrence in bed sediment, except for one sample from Sulphur Creek near Sunnyside. Largest organochlorine concentrations in water were found in agricultural-return flows: 0.15 and 0.07 μg/L for DDT+DDD+DDE at Drainage Irrigation District (DID) 18 and Moxee Drain at Birchfield Road near Union Gap, respectively; and 0.16 μg/L for endosulfan at Moxee Drain. The concentrations of these compounds were below State standards for acute toxicity to aquatic life, but a number of the determinations exceeded State standards for chronic toxicity. Except for samplings in the Yakima River at Kiona, exceedances of chronic toxicity standards did not occur in the main stem. The increased number of exceedances at Kiona may be partially due to the relatively large number of samples collected at the site, since the late 1960's. Other compounds that were consistently observed in water samples from Yakima River at Kiona (RM 29.9) include aldrin, endrin, lindane, heptachlor, heptachlor epoxide, diazinon, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T).

Trace organic compounds that exceeded Washington State standards for chronic toxicity are listed in table 43. None of the compounds exceeded the freshwater standards for acute toxicity. All of the compounds listed in table 43, except endosulfan, exceeded standards in the Yakima River at Kiona (RM 29.9).

Major sources (tributaries listed in table 43) of DDT+DDE+DDD and dieldrin to the Yakima River are located throughout the basin from Yakima RM 147 (Wilson Creek) to RM 41.8 (Spring and Snipes Creeks), suggesting that DDT and dieldrin were used on a diversity of crop types. The Kittitas Irrigation District is drained by Wilson Creek, and major crops include cereals (barley, corn, oats, and wheat) and forage (pasture, hay, and silage). Roza and Sunnyside Irrigation District are

Table 43.--Summary of sites in the Yakima River basin, Washington, where trace-organic compounds exceeded Washington State standards for aquatic life, 1968-85 water years

[DDT = dichlorodiphenyltrichloroethane; DDD = dichlorodiphenyldichloroethane; DDE = dichlorodiphenyldichloroethene; PCB = polychlorinated biphenyls; map reference numbers shown in parenthesis; data retrieved from U.S. Environmental Protection Agency's Computer Storage and Retrieval System, and U.S. Geological Survey's computer system (summary shown in fig. 58), and from Johnson and others (1986)]

Compound	Freshwater aquatic-life standards, in micrograms per liter		Site where standards for chronic toxicity were exceeded
	Acute	Chronic	
Aldrin/dieldrin[1]	2.5	0.0019	Wilson Creek at Thrall (7) Granger Drain at Granger (51) Toppenish Creek near Satus (62) Satus Creek at Satus (70) Drainage Irrigation District 18 Drain at Sunnyside (86) Sulphur Creek Wasteway near Sunnyside (91) Spring/Snipes Creeks (97 and 98) Yakima River at Kiona (100)
DDT + DDD + DDE	1.1	.001	Moxee Drain at Birchfield Road near Union Gap (28) Granger Drain at Granger (51) Drainage Irrigation District 18 Drain at Sunnyside (86) Sulphur Creek Wasteway near Sunnyside (91) Spring/Snipes Creeks (97 and 98) Yakima River at Kiona (100)
Endosulfan	.22	.056	Moxee Drain at Birchfield Road near Union Gap (28)
Endrin	.18	.0023	Yakima River at Kiona (100)
Parathion	.065	.013	Yakima River at Kiona (100)
PCB	2.0	.014	Yakima River at Kiona (100)

[1] Aldrin is metabolically converted to dieldrin, so the sum of the aldrin and dieldrin concentrations should be compared to the Washington State dieldrin standard.

drained by several of the creeks listed in table 43 (Granger and Drainage Irrigation District 18 Drains; Sulphur, Spring, and Snipes Creeks), and major crops include orchards, row crops (hops, mint, vegetables), forage, and cereals.

In 1985 water year, the largest concentrations of DDT+DDE+DDD and dieldrin occurred at sites that also had the largest suspended-sediment concentrations (Johnson and others, 1986). These compounds tend to sorb to sediment (see relation in fig. 65) and are transported into streams by erosion. This pesticide-sediment relation suggests that DDT+DDE+DDD and dieldrin concentrations may be reduced in the streams by controlling sediment erosion from agricultural land. For example, a 50-percent reduction in suspended-sediment concentrations would result in about a 50-percent reduction in DDT+DDD+DDE and dieldrin concentrations. All data shown in figure 65 were collected during irrigation season from June through August when suspended-sediment concentrations are large from increased agricultural erosion. In October 1985 after irrigation, streamflows and suspended-sediment concentrations were decreased, and DDT+DDE+DDD and dieldrin concentrations at all sites (three main-stem and 11 tributary sites) were less than the reporting levels (<0.006 μg/L for DDT+DDE+DDD and <0.003 for dieldrin). Dieldrin and DDT+DDE+DDD also were detected in bed sediment in the main stem and tributaries. The maximum concentration for DDT+DDE+DDD was 234 μg/kg and for dieldrin 14.9 μg/kg, both occurring at Sulphur Creek. In addition, a large concentration (1,065 μg/kg) of aldrin was detected in bed sediment at Spring and Snipes Creeks. Interim bed-sediment criteria for nonpolar, hydrophobic, organic contaminants indicate that the DDT and dieldrin concentrations in the basin could affect consumers of the aquatic biota (U.S. Environmental Protection Agency, 1988).

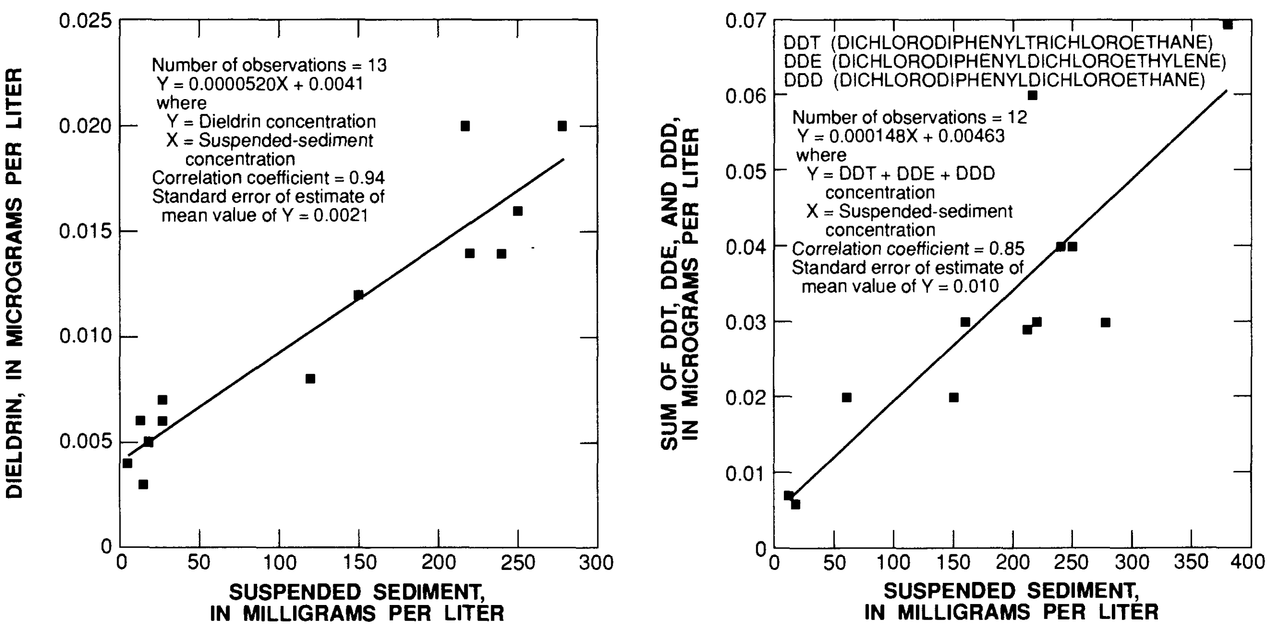

Figure 65.--Relation between concentrations of selected insecticides and concentrations of suspended sediment at selected surface-water sites in the Yakima River basin, Washington, 1985.

Data from the Yakima River at Kiona (RM 29.9) are adequate to examine long-term time trends for dieldrin, DDT, DDD, and DDE. These organochlorine insecticides and metabolites are carcinogenic and have been monitored in the Yakima River at Kiona from 1968 through 1980 (fig. 66). Concentrations stored in STORET and WATSTORE as zero values or "less than" values are plotted at one-half of the analyzing agency's minimum reporting level; those data that fall on the reporting-level line indicate the presence of the contaminant at the minimum reporting level concentration (fig. 66). From 1968-82, USGS had a minimum reporting level of 0.01 μg/L, which was about 10 times larger than the EPA's chronic-toxicity criteria for the protection of freshwater aquatic life. In general, USGS data show measurable decreases in DDT, DDE, DDD, and dieldrin concentrations from 1968-74, which coincide with EPA decisions (1) in December 1972 to ban further use of DDT due to health and environmental-hazard considerations and (2) in 1974 to prohibit the manufacture of dieldrin in the United States. Decreases of DDT, DDE, and DDD concentrations in Yakima River water at Kiona preceded the decreases of those compounds in Yakima River fish from Granger by 2-4 years (fig. 67). Note that DDT plus metabolite concentrations in whole fish decreased for each fish species from 1970-80.

Concentrations of DDT, DDE, DDD, and dieldrin determined by EPA from 1969-73 are smaller than those concentrations reported by USGS for the the same years (fig. 66). Examination of the monthly sampling frequency of these compounds reveal a likely reason for the bias. USGS data were available for each of the 12 months in a year, whereas most of the EPA data were collected from January through April and September through December. As shown in figure 68, the largest DDT concentrations occurred during the peak irrigation season (May-August), when EPA collected a limited number of samples. Eroding sediment from agricultural areas, where these persistent pesticides are applied, are a likely source of the hydrophobic insecticides. The largest DDT, DDE, and DDD concentrations that occurred in the EPA data were observed in the few samples collected from May to August. A seasonal pattern for dieldrin was not evident; consequently, a likely explanation could not be identified for the bias between agencies in the dieldrin concentrations. The additional cause for this bias could be the result of one or more of the following:

(1) Differences in collection procedures between agencies--for example, USGS probably collected depth- and stream-width integrated samples, whereas EPA samples probably were point samples collected near the water surface; as a result, the USGS samples may have contained more sediment and larger concentrations of the hydrophobic contaminants (DDT, DDE, DDD, and dieldrin).

(2) Samples may have been preserved differently by the agencies prior to analysis.

(3) Analytical techniques at one or both of the laboratories could have resulted in a bias.

State standards for the protection of freshwater life from chronic toxicity are: 0.0019 μg/L for dieldrin and 0.001 μg/L for DDT+DDE+DDD. The minimum analytical reporting levels for dieldrin and DDT+DDE+DDD

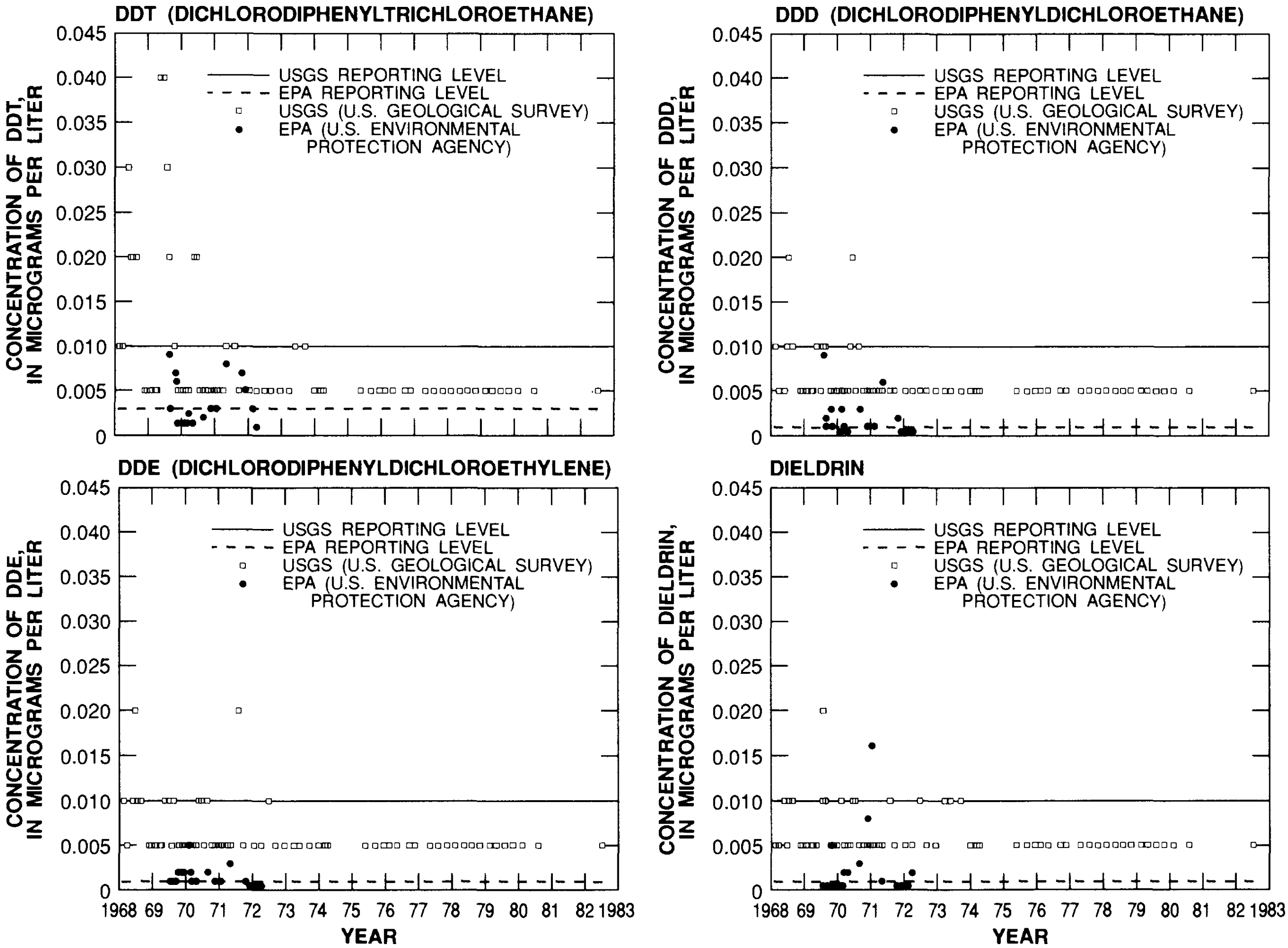

Figure 66.--Concentrations of selected insecticides in whole- water samples from the Yakima River at Kiona, Washington, 1968-82. Concentrations reported less than the analytical reporting level were divided by two for presentation in this figure.

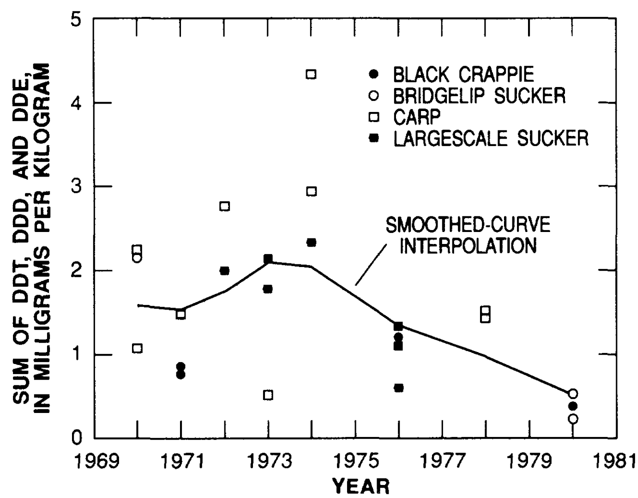

Figure 67.--Combined concentrations of dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyl-dichloroethane (DDD), and dichlorodiphenyldichloroethylene (DDE) in whole-fish tissue (wet weight) from the Yakima River at Granger, Washington, 1970-80.

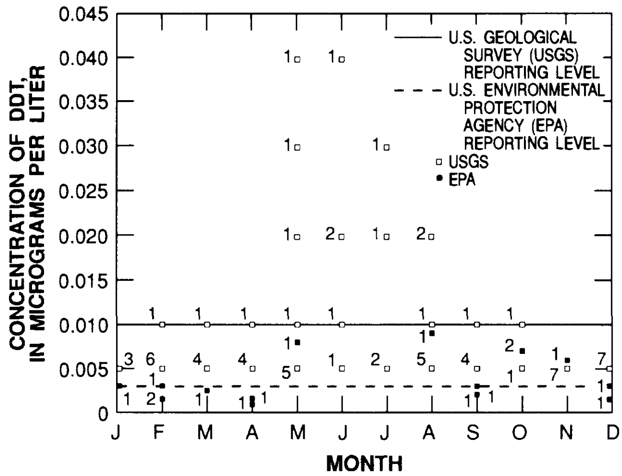

Figure 68.--Monthly concentrations of dichlorodiphenyltrichloroethane (DDT), in whole-water samples from the Yakima River at Kiona, Washington, 1968-82.

exceeded the State standards for chronic exposure (fig. 66); thus the data reported as less than the minimum reporting level cannot be used to determine whether the standards for chronic exposure were being exceeded. Using lower reporting levels, a 1985 sampling for organochlorine compounds in the Yakima River at Kiona indicated that the DDE and dieldrin concentrations exceeded chronic exposure standards by factors of 6 to 7 and 2 to 3, respectively, on June 24, 1985 (Johnson and others, 1986).

From 1968-85 water years, dieldrin, DDT, DDE, DDD, and PCB were the predominant organochlorine compounds found in fish throughout the Yakima River basin; largest concentrations were detected in the lower basin downstream from the City of Yakima. A few fish samples also contained endosulfan and endrin. Salmonids generally had smaller concentrations than resident species. In 1985, concentrations of DDT+DDE+DDD in resident, adult, whole fish from the Yakima River at Kiona ranged from 1,100 to 3,000 μg/kg (wet weight; largescale sucker and northern squawfish, respectively), exceeding the maximum recommended concentration (1,000 μg/kg) by the National Academy of Science for the protection of fish predators (such as fish-eating birds). PCB ranged from <100 to 300 μg/kg in whole fish (resident species) from the main-stem sites (Johnson and others, 1986).

In 1985, concentrations of DDT+DDE+DDD, dieldrin, and PCB in edible Yakima fish tissue were below the Food and Drug Administration action levels. The EPA methodology for assessing risks to humans was used by WDOE to show that carcinogenic risks from ingestion of dieldrin and PCB in Yakima fish were similar to or greater than those risks associated with ingestion of DDT compounds in Yakima fish (Johnson and others, 1986). Assuming EPA's national average consumption of freshwater and estuarine fish and shellfish (6.5 g/d), the average lifetime (70 years) cancer risks for consumption of fish by humans from the lower Yakima River are $3x10^{-5}$, $8x10^{-5}$, $9x10^{-7}$, $2x10^{-6}$, and $1x10^{-5}$ for PCB, dieldrin, DDD, DDT, and DDE, respectively (a risk of $1x10^{-6}$ is 1 person in 1,000,000 people).

Fecal-coliform Bacteria

The transmission of pathogenic microorganisms in water can be associated with fecal contamination from warm-blooded animals including man (U.S. Environmental Protection Agency, 1976). Fecal-coliform bacteria are one of the indicators of fecal contamination in water. These bacteria are found in the gut of warm-blooded animals, but they may be associated with soils, vegetation, and insects. Thus, the occurrence of fecal-coliform bacteria does not conclusively indicate the presence of fecal contamination, because of the possibility of nonfecal-bacteria sources. Unless the source of the indicator bacteria has been determined to be nonfecal by species identification, the presence of fecal-coliform bacteria, as used in this report, indicates a potential health hazard.

Presently (1990), most of the surface-water streams in the Yakima River basin are class A, where fecal-coliform concentrations shall not exceed a geometric mean value of 100 colonies per 100 mL, with not more than 10 percent of the samples exceeding 200 colonies per 100 mL. Class AA streams shall not exceed a geometric mean value of 50 colonies per 100 mL, with not more than 10 percent of the samples exceeding 100 colonies per 100 mL. Class B streams (Sulphur Creek) shall not exceed a geometric mean concentration of 200 colonies per 100 mL, with not more than 10 percent of the samples exceeding 400 colonies per 100 mL.

The historical data set from 1968-85 WY for the Yakima River basin contains 2,235 determinations of fecal-coliform bacteria from 200 sites. Most of the determinations (87 percent) were made using the 0.45-micrometer, membrane-filter method with M-FC media (STORET parameter code 31616). The remaining determinations were made using the 0.70-micrometer, membrane-filter method with M-FC media (7 percent; STORET parameter code 31625), and the most-probable number method with the EC-broth (6 percent; STORET parameter code 31615).

State standards do not specify a time period or minimum number of determinations required for calculating a geometric mean value; however, fecal-coliform-bacteria criteria from EPA (1976) and other bacteria criteria (specifically E. coli and enterococci; U.S. Environmental Protection Agency, 1986) suggest a 30-day period with not less than 5 samples equally spaced over the 30 days. All of the Yakima sites have fewer than five determinations in a month (30-day period), resulting in a data set that is inadequate to determine whether State standards were exceeded. Nonetheless, to evaluate sanitary-quality conditions at a site with fewer than five determinations in a month, instantaneous data (one sample from a site in a month) were assumed to be representative of the monthly geometric-mean value and were compared to the State standards. Apparent exceedances of standards at a site will serve to guide future bacteria samplings.

About 12 percent of the Yakima-River-basin data were coded with "remarks," such as "non-ideal colony count," "actual value is less than the value shown," "estimated," and others. Remarked data usually add some uncertainty to the data values, sometimes making the data inappropriate for statistical analysis. With two exceptions, the remarked codes were ignored, and the data were included in the analysis. The first exception involved data (fewer than 3 percent of the determinations) which were remarked as "actual value is less than the value shown;" most of these data were reported less than one or two colonies per 100 mL, and their values were divided by two for the statistical analysis. The second exception involved data (less than 0.5 percent of the determinations) which were remarked as "presence of material verified but not quantified." These data were stored with zero concentrations and were not included in the analysis.

On the basis of present Washington State standards (1990), 1,088 determinations (49 percent) from 128 sites (64 percent of the sites) exceeded the standards. Summaries of data that exceeded the fecal-coliform-bacteria standards are shown by stream class in table 44 and by site in table 59 at the back of report. About 32 percent of the determinations were made in the main stem, and about 40 percent of these determinations exceeded the standards. Most of the exceedances of standards in the main stem occurred at sites downstream from Union Gap (RM 107.2). Distributions of fecal-coliform-bacteria concentrations for each of the sites reveal that many of the sites, including all of the class B sites, had median values that exceed 1990 State standards.

Table 44.--Summary of historical fecal-coliform-bacteria concentrations relative to 1990 State standards for the Yakima River basin, Washington, 1968-85 water years

[Summary based on a comparison of State standards to each determination made at a site; State standards indicate that the geometric mean shall not exceed 50 for class AA, 100 for class A, and 200 colonies per 100 milliliters for class B streams]

Stream class	Number of sites sampled	Percent of sampled sites in each stream class with exceedances of standards	Number of determin-ations	Percent of determin-ations in each stream class that exceed standards
AA	70	24	519	14
A	120	84	1499	54
B	10	100	217	93

Sites in the Yakima River basin that are minimally influenced by man's activities typically have the smallest fecal-coliform-bacteria concentrations and the fewest exceedances of State standards. Sites with median concentrations less than State standards include: (1) class AA sites in the national forest, where concentrations are generally less than 5 colonies per 100 mL, (2) class A sites upstream from Kittitas Valley (RM 155), (3) class AA and class A sites in the Naches River basin, and (4) throughout the basin upstream from man's activities.

Prior to the 1970's, the principal source of fecal-coliform bacteria in the Yakima River basin was untreated and (or) improperly treated effluent from STPs (Sylvester and others, 1951); however, since the 1970's, most of these discharges were and are being treated with chlorine, substantially reducing the bacteria concentrations in the effluent (Jim Milton, Washington Department of Ecology, oral commun., August 24, 1989). Data collected since 1970 suggest that other land- and water-use activities are controlling the bacterial quality of streams. Most of the class A and B tributary sites with bacteria concentrations exceeding standards are downstream from agricultural-return flows or areas with large numbers of dairies. These tributaries account for the large fecal-coliform-bacteria concentrations in the Yakima River downstream from Toppenish (RM 93).

Fecal-coliform-bacteria concentrations in the Sunnyside subbasin were among the largest observed in the Yakima River basin. Concentrations larger than 1,000 colonies per 100 mL occurred at 31 of the 39 sites (79 percent). Concentrations larger than 10,000 colonies/100 mL occurred at 16 of those sites. Sunnyside and Granger Drain subbasins also have the largest number of dairies in the Yakima River basin; many of them are located within a 12 mile radius of the City of Sunnyside, and most drain into Sulphur Creek (Jim Corliss, South Yakima Conservation District, oral commun., August 28, 1989). Few dairies were treating their runoff prior to the early 1980's; thus, they are likely contributors to the increased fecal-coliform-bacteria concentrations observed in the lower Yakima River.

The distributions of fecal-coliform-bacteria concentrations in the Yakima River, shown in figure 69, are based on two samples collected monthly from each site in 1975 WY. Data from 1975 WY were selected for analysis, because

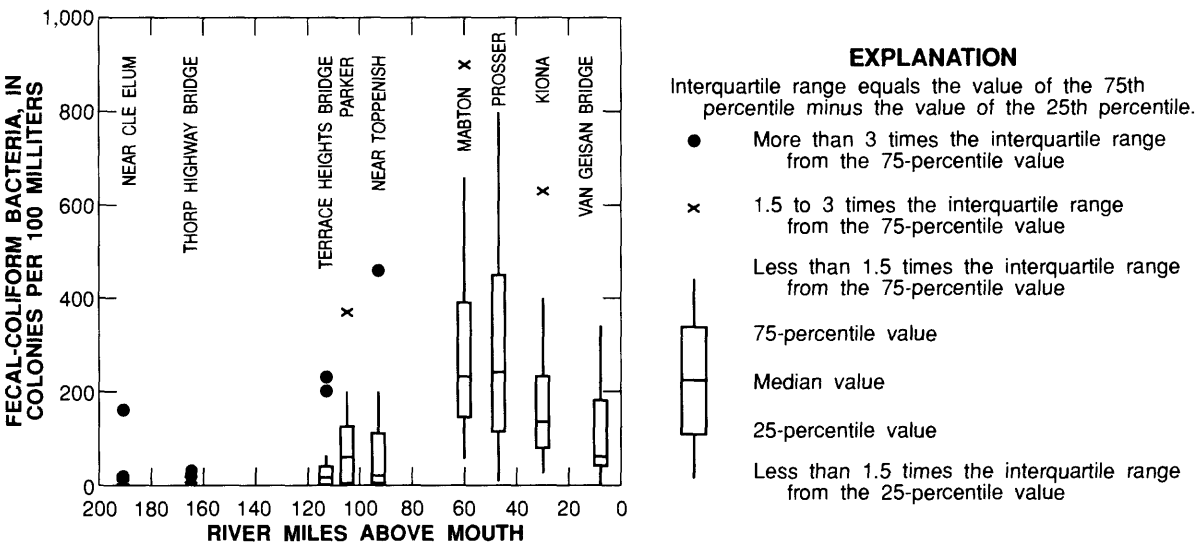

Figure 69.--Concentrations of fecal-coliform bacteria in the Yakima River, Washington, 1975 water year (some large values are not shown).

it is the only year with adequate monthly and spatial coverage for intersite comparisons. Bacteria concentrations at sites upstream from Terrace Heights Bridge (RM 113.2) were typically well below State standards. The Naches River flows into the Yakima at RM 116.3 and helps dilute the bacteria concentrations to below standards at Terrace Heights. Bacteria loads from Wide Hollow Creek and Moxee Drain contribute to the slight increase in concentration observed at Parker (RM 104.6), where more than 25 percent of the monthly fecal-coliform-bacteria determinations exceeded the 1990 State standards. A large increase in bacteria concentrations occurred at Mabton (RM 59.8), and can be attributed to several of the agricultural return flows that are listed in table 59 at the back of report. More than 75 percent of samples from the Yakima River at Mabton (RM 59.8) and Prosser (RM 47.4) had concentrations that exceeded State standards. Downstream from Prosser, median fecal-coliform-bacteria concentrations decreased by a factor of about two or more. This decrease probably was due to a natural die-off of the fecal-coliform bacteria; nevertheless, standards were still exceeded for more than 50 percent of the determinations in the Yakima River at Kiona (RM 29.9) and for more than 25 percent of the determinations at Van Giesan Bridge in Richland (RM 8.4).

The long-term, monthly coverage of fecal-coliform-bacteria data is poor for most of the sites in the basin, except Yakima River at Parker (RM 104.6) and at Kiona (RM 29.9) [fig. 70]. At Parker, the largest concentrations occurred during irrigation season, and about 50 percent of the determinations from June through October exceeded the Class A standard of 100 colonies per 100 mL. The monthly fecal-coliform-bacteria concentrations for several major agricultural return flows that enter the Yakima River between Parker and Kiona (Granger and Marion Drains; and Toppenish, Satus, and Sulphur Creeks) indicate that standards are exceeded year round (fig. 71); however, concentrations are noticeably smaller during the low flows from September through December. Monthly concentrations in the Yakima River at Parker and Kiona are almost an order of magnitude smaller than those observed in the agricultural-return flows, probably due to dilution and natural die-off. Concentrations in the Yakima River at Kiona do not exhibit a pronounced seasonal pattern. Except for April, more than 25 percent of each month's determinations exceeded the class A standard.

Fecal-coliform-bacteria data were available at only two sites in the Yakima River basin for determining long-term temporal trends: Yakima River at Parker (RM 104.6) and Yakima River at Kiona (RM 29.9). Both sites had monthly data available from 1977-85 water years. The non-flow-adjusted, time-trend results indicate significant ($\rho \leq 0.1$) increases in fecal-coliform-bacteria concentrations at both sites, 6 percent per year at Parker and 14 percent per year at Kiona. Flow-adjusted results reveal similar increases, indicating that the trends were not associated with the increasing streamflows. These trends may be associated with increases in numbers of livestock in the basin. For example, the number of dairy cattle have notably increased in the South Yakima Conservation District from 1984 to 1989 (Jim W. Corliss, Sunnyside, Washington, written commun., August 1989); however, historical fecal-coliform-bacteria data for streams in the basin are not available to quantify major sources.

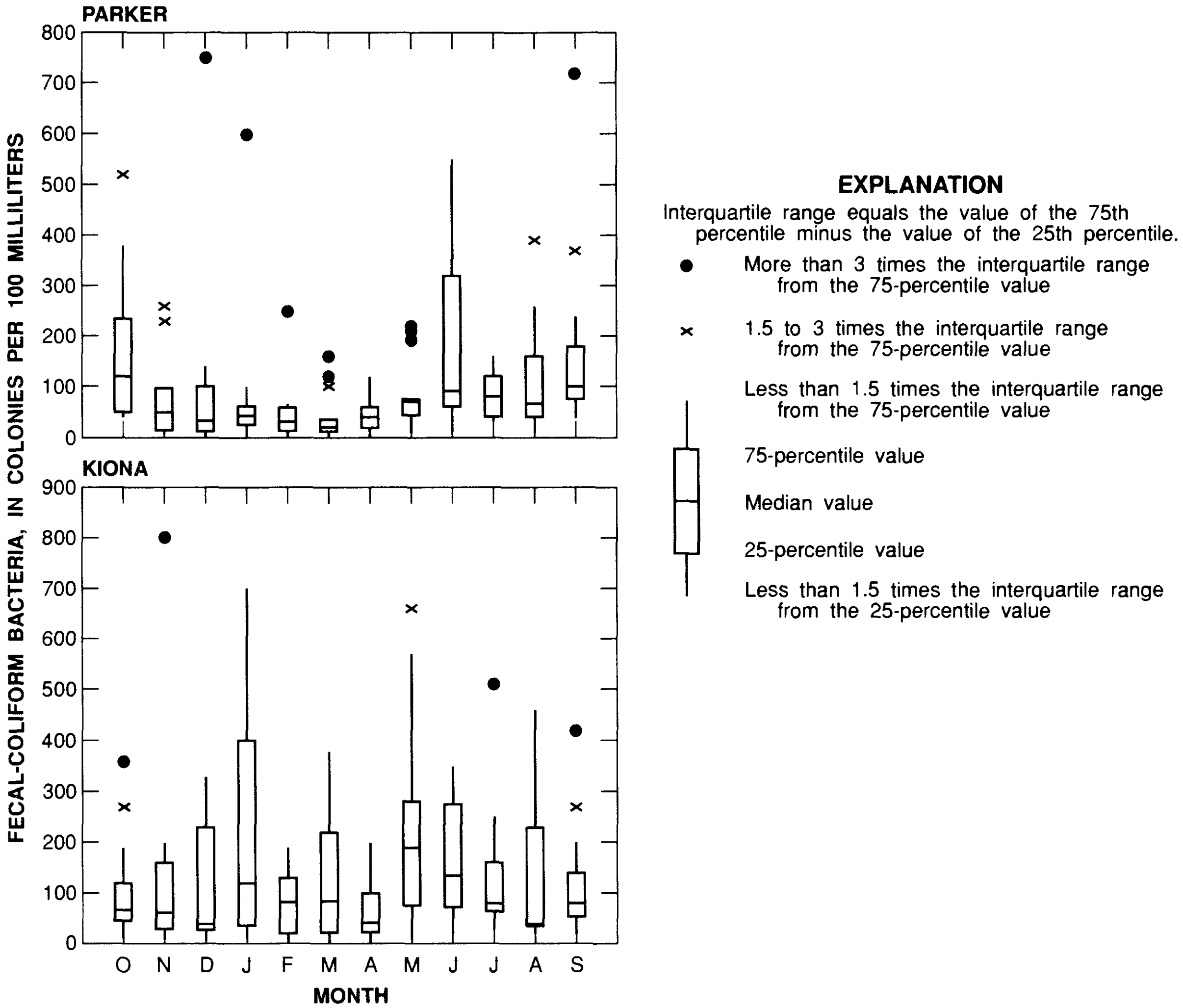

Figure 70.--Monthly concentrations of fecal-coliform bacteria in the Yakima River at Parker and Kiona, Washington, 1971-85 water years (some large values are not shown).

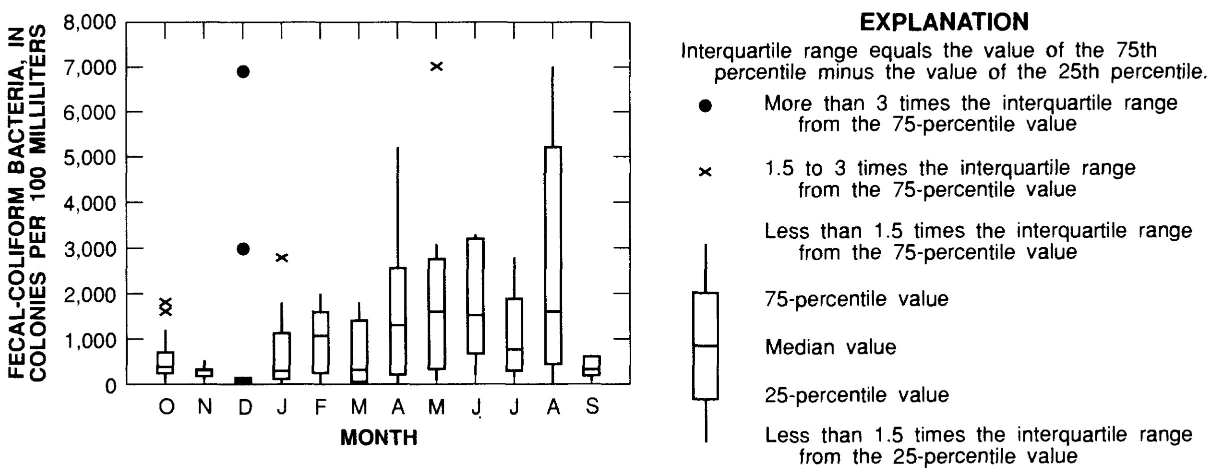

Figure 71.--Monthly concentrations of fecal-coliform bacteria in selected agricultural-return flows in the Yakima River basin, Washington, 1970-84 water years (some large values are not shown).

Fish and Other Aquatic Biological Communities

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By S. S. Embrey[1/] and B.D. Watson[2/]

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Beginning in about 1935 and continuing through 1990, several biological studies have been completed in the Yakima River basin. Because of the commercial and recreational value of anadromous fish, the emphasis of published biological investigations has been on the description, protection, and enhancement of salmon and trout populations. However, some data also are available for macroinvertebrates and algae. Major impacts on stream biology, particularly fish populations, in the basin include agricultural development and associated irrigation projects; overfishing in the ocean, Columbia River, and Yakima River; and Columbia River hydropower development.

Historical Perspective

Prior to 1880, anadromous fish runs were estimated to be more than one-half million fish (Davidson, 1965; Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990) in the Yakima River basin. Timelines for selected water-resource developments that may have affected Yakima River basin fishery are listed in table 45.

By 1900, all of the low-water summer flow in the Yakima River basin had been appropriated and diverted by private interests for irrigation, and a serious water shortage had developed. Construction of large storage reservoirs and the completion of several diversion dams prior to 1905 had seriously affected fish migrations in the Yakima River. The annual number of anadromous fish returning to the Yakima system declined to about 60,000 (90-percent decline) in 1905 as a result of these construction activities (Davidson, 1965). The total number of fish caught by fishermen declined about 90 percent from about 160,000 to 20,000 (Davidson, 1965), and between 1905 and 1930, the catch further declined to 1,000 fish (Washington State Departments of Fisheries and Game, 1961). Overfishing had an additional impact on the already diminished numbers of fish that returned to the Yakima system (U.S. Army Corps of Engineers, 1978b). In the 1960's and 1970's, harvest rates in the ocean and Columbia River exceeded 90 percent and effectively wiped out the natural upper-Columbia-River stocks of coho salmon (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990).

Programs were started in 1930 to install screening devices at diversion dams to prevent the loss of fish to irrigation canals. These screens probably saved the runs of chinook salmon, and steelhead trout from extinction (Davidson, 1965). Currently (1990), sockeye salmon are absent from the system since their access to lakes in the upper Yakima and

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1/ Hydrologist with the U.S. Geological Survey, Water Resources Division, Tacoma, Washington

2/ Fishery biologist with the Yakima Indian Nation, Fisheries Resources Management, Toppenish, Washington

Naches River basins was blocked by dams, 1904-10. Summer chinook salmon are absent, probably because of (1) low flows and high temperatures in the lower basin during the fish-migration period and (2) mortalities in the Columbia River associated with fish passage and hydropower development (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990).

Distribution, Abundance, and Productivity of Fish

A study conducted in 1957 and 1958 (Patten and others, 1970) provides a comprehensive discussion of native and introduced-fish species utilizing various habitats in the Yakima River. A total of 33 species, 10 of which were introduced, and 3 hybrids were identified. Four new species--kokanee, lake trout, tui chub, and burbot--were added to Patten's list by the U.S. Bureau of Reclamation in 1979 (table 46). The nine dominant species in the basin by decreasing order of numbers found were: chiselmouth, redside shiner, northern squawfish, largescale sucker, speckled dace, mountain whitefish, torrent sculpin, salmon (chinook and coho), and carp.

Patten and others (1970) found that the largest number of fish were concentrated from the mouth of the Yakima River to Whitstran (Yakima RM 40) and from near Satus Creek (RM 75) to City of Yakima (RM 110). The fewest fish were found from Prosser (RM 47.4) to Mabton (RM 59.8). Juvenile salmon were abundant from Toppenish (RM 95) to Thorp (RM 175). The distribution and abundance of some fish species were related to water temperature, stream velocity, and (or) bed substrate (Patten and others, 1970). Only carp were found in a sparsely populated reach between Prosser (RM 47.4) and Mabton (RM 59.8) where the current is slow, the water is relatively warm and turbid from agricultural-return flow, and the stream bottom is silt and clay. Few warm-water species were found in the canyon reaches.

Anadromous fish

In 1969, salmon comprised 22 percent of the total catch in pounds; however, this amounted to 44 percent of the total dollar value of the catch (Ward and others, 1969). In 1982, salmon comprised 27 percent of the total catch and 55 percent of the total value (Ward and Hoines, 1982). Chinook salmon (*Oncorhynchus tshawytscha*) has long been the most important species in value to the commercial and sport fisheries (Fulton, 1968). This species also has important cultural and religious value to the native American. In 1978, the Yakima spring Chinook run represented about 14 percent of the total Columbia spring chinook run (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990). Fishery experts indicate that the spawning grounds in the Yakima River basin have the greatest potential for increasing anadromous fish populations in the Columbia River basin (Bonneville Power Administration, 1985).

Table 45.--Timelines associated with anadromous fishery conditions and water-resource developments in the Yakima River basin, Washington, 1850-1990

[Modified from Confederated Tribes and Bands of the Yakima Indian Nation, Washington Department of Fisheries, and Washington Department of Wildlife, 1990]

Year	Fishery condition or water-resource development
1850s	Anadromous fish runs were as follows: Spring chinook 200,000 Summer/fall chinook 200,000 Summer steelhead 80,000 Early coho 110,000 Sockeye 200,000 Estimated total 790,000 fish
Prior to 1880	Indians annually caught about 160,000 anadromous fish for personal consumption and trade.
1850 (pristine) to 1900 (early water-resource development)	90-percent decline in anadromous fish runs. Decline attributed to: (1) Overfishing in the lower Columbia River and ocean. (2) In-basin features: -- Unladdered dams (Pomona Dam circa 1880; Sunnyside Dam in 1893; Erwin Ditch in 1897) that blocked spawning; -- Entrainment of fry and smolts in newly constructed diversion canal; few were screened prior to 1934; -- Destruction of spawning beds by driving logs downstream with sudden reservoir releases -- Intense local fishery; -- Habitat elimination (diking and channelization that eliminated braided channels); and -- Loss of natural storage and rearing habitat due to reduction of beavers and their ponds.
1890	Anadromous fish population dropped to 515,000.
1900-1941	Period can be characterized by the following: (1) Construction of major water-resource features of the current irrigation system, (2) Lack of controls on ocean fishery, (3) Dewatering of spawning and rearing habitat, and (4) Further construction of stream barriers for migrating fish and major dam construction in the Columbia River.
1900	All natural summer flows in the Yakima River were appropriated and diverted for irrigation, leaving the lower Yakima River with increasing temperatures in stagnant pools.
1904-06	Unladdered temporary dams were completed at Lake Kachess, Lake Keechelus, and Lake Cle Elum; permanent dams were finished in 1912, 1914, and 1922, respectively. Primary source of water in the lower Yakima River in August was irrigation return flow, which degraded water quality in the main stem. Anadromous fish population dropped to 60,000.
1910	Bumping Lake dam was completed without a fishway, resulting in the extinction of the sockeye run in the basin.

Table 45.--Timelines associated with anadromous fishery conditions and water-resource developments in the Yakima River basin, Washington, 1850-1990--Continued

Year	Fishery condition or water-resource development
1920	Anadromous fish runs declined to 12,000 fish. Summer chinook ceased to exist in any significant numbers.
1925-29	Unladdered Rimrock Lake and ineffectively laddered Easton Dam were completed; geographic distribution of fish reduced roughly to its present extent (1990).
1930	Washington State and Federal Bureau of Fisheries began screening of canals and irrigation ditches.
1936	Screening program was accelerated when Works Progress Administration became involved.
1941	Most larger diversion canals were screened.
1940-80	Logging and road building increased. Anadromous fish.runs declined.
1960	Anadromous fish runs peaked at 19,000.
Mid-1960s	Spring chinook sport fishing was phased out.
Early 1970s	Small number of summer chinook continued to spawn near Sunnyside Dam as late as the early 1970s. Monitoring since 1980 indicates that summer chinook are now extinct in the basin.
1977	Commercial fishing of spring and summer chinook in the Columbia River has been contingent on achieving minimal runs at Bonneville Dam.
Late 1970s	Low-flow years resulted in a court order for the Yakima Indian Nation to refrain from fishing entirely in 1979 and to institute males-only fishing in 1980. Yakima Indian Nation has restricted harvesting rather severely since 1980.
1980s	Kittitas Decision (by Judge Quackenbush) ordered that spring chinook redds in the Yakima River be protected with adequate streamflow from Easton to the confluence with the Teanaway River; court order led to immediate improvement in the reproduction in upper Yakima River salmon.
	Most significant factor limiting fish runs was perceived to be inadequate, obsolete, and deteriorating ladders and juvenile-screening systems in the main stem. Facilities were rebuilt between 1984-89.
	Anadromous fish runs were as follows ("--" indicates no data; summer chinook and sockeye runs extinct)

Fish	Number of fish				
	Year				
	1983	1984	1985	1986	1987
Fall chinook	1,267	4,440	943	4,047	1,813
Coho chinook	--	--	229	94	--
Spring chinook	1,324	2,667	4,527	9,452	4,390
Summer steelhead	918	1,140	2,194	2,227	2,491

Table 46.--Taxonomic list and common names of fish species in the Yakima River basin, Washington

[from U.S. Bureau of Reclamation, 1979]

Species classification	Common name
CLASS AGNATHA	
Order Petromyzontiformes	
Family Petromyzontidae--	Lampreys--
Lampetra richardsoni	western brook lamprey
Entosphenus tridentatus or *Lampetra tridentata* (Patten, 1970)	Pacific lamprey
CLASS OSTEICHTYES	
Order Acipenseriformes	
Family Acipenseridae--	Sturgeons
Acipenser transmontanus	white sturgeon
Order Salmoniformes	
Family Salmonidae - Trouts	
Oncorhynchus kisutch	coho salmon
Oncorhynchus tshawytscha	chinook salmon
Oncorhynchus nerka	kokanee (nonanadromous sockeye or blueback)
Salmo clarki	cutthroat trout
Salmo gairdneri	rainbow trout, or steelhead
Salmo trutta (introduced)	brown trout
Salvelinus fontinales (introduced)	brook trout
Salvelinus malma	dolly varden
Prosopium williamsoni	mountain whitefish
Salvelinus namaycush	lake trout
Order Cypriniformes	
Family Cyprinidae - Minnows, Carp	
Cyprinus carpio (introduced)	common carp
Mylocheilus caurinus	peamouth
Rhinichthys cataractae	longnose dace
Rhinichthys falcatus	leopard dace
Rhinichthys osculus	speckled dace
Richardsonius balteatus	redside shiner
Ptychocheilus oregonensis	northern squawfish
Acrocheilus alutaceus	chiselmouth
Gila bicolor	tui chub
Family Catostomidae - Suckers	
Catostomus columbianus	bridgelip sucker
Catostomus macrocheilus	largescale sucker
Catostomus platyrhynchus or *Pantosteus platyrhynchus*	mountain sucker
Order Gadiformes	
Family Gadidae - Codfishes	
Lota lota	burbot
Order Perciformes	
Family Centrarchidae - Sunfishes	
Lepomis gibbosus (introduced)	pumpkinseed
Lepomis macrochirus (introduced)	bluegill
Micropterus dolomieui (introduced)	smallmouth bass
Micropterus salmoides (introduced)	largemouth bass
Pomoxis nigromaculatus (introduced)	black crappie
Family Cottidae - Sculpins	
Cottus asper	prickly sculpin
Cottus bairdi	mottled sculpin
Cottus confusus	shorthead sculpin
Cottus beldingi	piute sculpin
Cottus rhotheus	torrent sculpin
Family Percidae - Perch	
Perca flavescens (introduced)	yellow perch
Order Siluriformes	
Family Ictaluridae - Catfishes	
Ictalurus melas (introduced)	black bullhead
Order Percopsiformes	
Family Percopsidae - Trout Perches	
Columbia transmontanus or *Percopsis transmontanus*	sand roller

Fulton (1968) summarized information on pre-1965 and 1966 spawning areas and abundance of chinook salmon in the Columbia River basin. A subsequent report (Fulton, 1970) similarly summarized information on steelhead trout, and coho, sockeye, and chum salmon. Spring and summer-run chinook salmon were noted by Fulton to be spawning in the upper Yakima and Naches Rivers; their former spawning areas included Satus, Toppenish, Ahtanum, Wenas, Manastash, and Taneum Creeks, and Teanaway River. Summer-run chinook were not present in the basin by the late 1970's (U.S. Bureau of Reclamation, 1979). The extent of the former spawning area for fall-run chinook salmon was not known to Fulton (1970), but the salmon have utilized the lower part of the Yakima River, primarily downstream from Benton City (U.S. Bureau of Reclamation, 1979). The Confederated Tribes and Bands of the Yakima Indian Nation and others (1990) indicate that fall chinook also spawn as far upstream as the Yakima River at Granger and in Marion Drain, the agricultural-return flow for the Wapato Irrigation District. Coho salmon (O. kisutch), prior to 1969, were spawning in the upper Yakima and Naches, Cle Elum and Kachess Rivers, Umtanum and Taneum Creeks, and other areas (Fulton, 1970). In 1969, coho salmon were restricted to the Yakima River upstream from Cle Elum River. Spawning has since resumed in Cle Elum River and in the Naches River basin, and generally coincides with areas used by steelhead trout (Salmo gairdneri) [Stemple, 1985]. A small number of spawning coho, however, have been observed in the lower Naches River, and in Ahtanum, Wide Hollow, and Cowiche Creeks. These fish are undoubtedly the result of large outplants (about 600,000) of coho smolts made at various locations (Nile Pond on the Naches River, Wide Hollow Creek, Ahtanum Creek, Toppenish Creek, Simcoe Creek, and Wanity Slough) since 1985. The outplanted smolts were reared at the Cascade Hatchery and were early-run, lower Columbia stock. Steelhead trout, in 1969, spawned in the upper Yakima River, parts of Naches River including American and Bumping Rivers (U.S. Bureau of Reclamation, 1979), and Satus and Toppenish Creeks (Fulton, 1970). Stemple (1985) lists additional spawning areas presently available in Cle Elum, Teanaway, Little Naches, and Tieton Rivers, and in Rattlesnake Creek. Presently (1990), the distribution of steelhead production is believed to be approximately as follows: 50 percent in Satus Creek, 20 percent in the Yakima River from Wapato Dam (RM 106.6) to Satus Creek (RM 69.6), 10 percent in the Naches River basin, and 20 percent in the remaining basin. Spawning upstream from Roza Dam (RM 127.9) is minimal at present; no more than 85 adults have been counted over Roza Dam in the past few years. The current lack of steelhead production upstream from Roza Dam is attributable to the old fish ladder (1940-87), which was operable only when the reservoir was at full pool. The U.S. Bureau of Reclamation was forced to lower Roza pool whenever ice was present, thus cutting off the winter and early spring portions of the run.

Sockeye salmon (O. nerka), also known as blueback salmon, require a lake to complete the freshwater phase of its life cycle, and were known to use all four lakes in the Upper Yakima Basin prior to 1904 (Davidson, 1965; Fulton, 1970). Construction of crib dams without fishways at Kachess and Cle Elum Lakes during 1904 and 1905 eliminated 90 percent of the original sockeye salmon spawning areas and left only Bumping Lake in the Naches River basin with an estimated annual run of 1,000 sockeye salmon (Davidson, 1965). The sockeye salmon run was completely eliminated following completion of Bumping Lake Dam in 1910. This species of salmon presently (1990) survives in the lakes as kokanee, the nonanadromous variety of O. nerka (Fulton, 1970; Mongillo and Faulconer, 1980).

Size, age, and fecundity were determined for fish in the upper Yakima and Naches Rivers, using an equation originally developed by Galbreath and Ridenhour (1964) for Columbia River chinook salmon. The estimated total number of eggs deposited in the Yakima River basin declined between 1957 and 1961 from 8.7 million to 1.5 million. Counts of seaward migrants at Prosser was used to determine that the survival of spring chinook salmon from egg to smolt averaged 11 percent and ranged from 5 to 16 percent. Low survival in 1957 (5 percent) was attributed to an artificially lowered water level in the upper Yakima River during October and November, causing exposure of 30 to 50 percent of the eggs deposited. Migration was maximum between April 14 and May 19, 1957 and occurred mostly at night.

The average egg-to-smolt survival rates shown in table 47 are low and are probably due to high levels of predation, particularly downstream from the major diversions (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990). For example, during a low-flow year, smolts and predators are concentrated in smaller areas, and the loss of near-shore refuges increases smolt vulnerability to predators. Based on literature data (Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990), these smolt losses could be entirely attributed to predation by a large population (9,300) of northern squawfish in the basin. Predatory birds (gulls and herons) also have been observed feeding heavily on smolts in a few locations in the basin.

Estimates concerning fecundity and survival for spring chinook salmon (table 47) have been generated subsequent to the work by Major and Mighell (1969). Stemple (1985), in his description of a habitat-area-fish-production model, used survival and fecundity estimates reported by various researchers.

Table 47.--Estimated number of deposited eggs and average survival for several life stages of spring chinook salmon, fall chinook salmon, coho salmon, and steelhead trout, Yakima River basin, Washington, 1957-86

["--" indicates not available; IFFPO = Instream Flow and Fish Production Objectives Work Group; YIN = Confederated Tribes and Bands of the Yakima Indian Nation]

Species	Investigators	Estimated number of eggs deposited (x 1,000)	Life stages	Average survival (percent)	Range of survival (percent)	Years
Spring chinook salmon	Major and Mighell, 1969	4,300	Egg to smolt	10.7	5.4 to 16.4	1957 to 1961
Spring chinook salmon	Stemple, 1985	4,870	Egg to smolt	5.6	--	--
Spring chinook salmon	Fast and others, 1986	4,590	Egg to smolt	5.1	4.5 to 6.2	1981 to 1984
Spring chinook salmon	Fast and others, 1986	--	Egg to fry	59.6	20.6 to 62.5	1981 to 1986
Spring chinook salmon	Fast and others, 1986	--	Fry to smolt	8.2	7.1 to 10.3	1981 to 1984
Spring chinook salmon1/	Fast and others, 1986	--	Smolt to adult	4.4	--	1983
Spring chinook salmon1/	Fast and others, 1986	--	Smolt to adult	4.5	--	1984
Spring chinook salmon	IFFPO Work Group, 1987	4,500	Egg to smolt	6.2	--	--
Fall chinook salmon	YIN and others, 1990	546	Egg to smolt	8.2	--	1983
Fall chinook salmon	YIN and others, 1990	--	Smolt to adult	1.3	--	1983
Fall/summer chinook salmon	Stemple, 1985	5,700	Egg to smolt	15.0	--	--
Summer steelhead	YIN and others, 1990	1,099	Egg to smolt	8.0	--	1983
Summer steelhead	YIN and others, 1990	--	Smolt to adult	1.4	--	1983
Steelhead trout	Stemple, 1985	4,350	Egg to smolt	.7	--	--

1/ Figures based on smolts counted at the Prosser juvenile facility. About 50 percent of the wild spring chinook smolts may be lost between Sunnyside and Prosser Dams; consequently, the actual smolt-to-adult survival rates may be about one-half of the figures listed above.

Historically, Yakima River basin productivity has been viewed in terms of numbers of fish migrating out of the basin and numbers of adult fish returning to the basin to spawn. In 1920, the total salmon run to the Yakima River was about 11,000 fish. After installation of screening devices on the diversion dams in the 1930's, the catch of chinook salmon leveled off at about 1,000 to 1,500 fish per year. Adult-return productivity from 1950 to 1960 was estimated to average 9,600 spring chinook, 800 fall chinook, and about 1,800 coho salmon (Washington State Departments of Fisheries and Game, 1961). Spawning escapement was computed with the assumption that contributions of fish from the Naches River basin were equivalent to those from the Yakima River basin. In 1960, the total salmon run was about 19,000, but it decreased to about 10,000 fish by 1979 (U.S. Bureau of Reclamation, 1979). National Marine Fisheries Service (cited by U.S. Bureau of Reclamation, 1979) estimated that in 1975 about 3,000 spring chinook salmon, 1,000 fall chinook salmon, 1,000 coho salmon, and 6,000 steelhead trout entered the Yakima River. In 1986, the return of 9,400 spring chinook salmon alone to the Yakima River was the largest return in 29 years (Fast and others, 1986; see table 45 for fish runs in the 1980's).

Stemple (1985) described relations used to estimate potential fish production based on numbers of fish per unit of habitat area under various streamflow regimes. He concluded that fish production, on the basis of the fry- or juvenile-rearing life stage, generally is limited by high flows during the irrigation season. In addition, the Washington State Department of Fisheries asserts that the construction of several miles of flood protection dikes (adjacent to the Naches and Yakima Rivers) has exacerbated the loss of available rearing habitat by effectively removing, or restricting access to, large areas of important low-energy habitat.

The Yakima Indian Nation's Fisheries Program working in cooperation with the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program plans to improve salmon and steelhead trout production by planning at the subbasin level (tributaries to the Columbia River) and the system level (Instream Flow and Fish Production Objectives Work Group, 1987). Some of the work done in 1987 included estimating the carrying capacity of the Yakima River basin. Numbers of fish that potentially could be supported in reaches of the Yakima and Naches Rivers and their tributaries are computed from total stream area, estimated fish densities, and percentage of fish use of the stream reach of interest (table 48) [Brad Caldwell, Washington Department of Ecology, written commun., 1987]. The total estimated anadromous fish capacity of the Yakima River basin is about 9.7 million, compared with the 1987 anadromous fish run of 8,694 (< 0.09 percent; table 45). This small run along with the relatively small number of deposited eggs (about 18,000 annually; table 47) for anadromous fish indicates that the Yakima River basin has the potential to sustain a large increase in fish production. In the 1850s, the estimated fish run of 790,000 was only 8 percent of the total carrying capacity, suggesting that environmental factors other than water development, also may have been affecting the fish runs.

Goodwin and Westley (1967) evaluated Kachess, Keechelus, and Cle Elum Reservoirs as part of a feasibility study to restore the sockeye salmon fishery in the basin. Although these reservoirs were considered to be oligotrophic, Goodwin and Westley (1967) concluded that a successful fishery could occur on the basis of comparisons with similar lakes in Alaska that are known to be major producers of sockeye salmon. Plankton abundances were determined in order to assess the production potential for sockeye salmon. Zooplankton were most abundant during April and May; Cyclops spp. were most abundant in all reservoirs and Limnocalanus spp. were the least abundant. Phytoplankton standing crops (chlorophyll a concentrations) reflected the intensity of zooplankton grazing during certain months of the year. Kachess Reservoir had the largest zooplankton abundance and Keechelus had the largest phytoplankton abundance. Cle Elum Reservoir is probably the least productive of the Yakima Basin impoundments in terms of primary producers and the support of a fishery (Mongillo and Faulconer, 1980). Fertilization of Cle Elum Reservoir may be one method of improving the fishery as suggested by Mongillo and Faulconer (1980). The rationale for artificial fertilization is based on the cycling and replenishment of nitrogen and phosphorus to lakes from the carcasses of sockeye salmon following completion of spawning. These carcasses are no longer available to the system (Lavier, 1976; Allen, 1976).

Table 48.--Estimated carrying capacity of anadromous fish in the Yakima River basin, Washington, 1987

[from Brad Caldwell, Washington Department of Ecology, written commun., 1987]

Species	Carrying capacity (thousands of fish)			
	Lower Yakima River (mouth to Naches River)	Upper Yakima River (upstream from Naches River)	Naches River basin	Total
Spring chinook salmon	78	1639	819	2535
Summer chinook salmon	1995	198	822	3015
Fall chinook salmon	1991	0	0	1991
Coho salmon	509	644	464	1617
Steelhead trout	110	246	179	535

Resident fish

Several species of resident fish are an important part of the sport-fishing industry, and can account for more than two-thirds of the fish caught in the basin (U.S. Army Corps of Engineers, 1978b). Cutthroat trout (Salmo clarki) and rainbow trout (nonanadromous trout or Salmo gairdneri) are two native species popular with fishermen. Other fish, such as bass, brown trout, and brook trout, have been introduced to the Yakima River. Many of the introduced species prefer warm-water habitat and have established themselves in the lower Yakima River without apparent threat to native species (Patten and others, 1970). The

Washington Department of Fisheries, however, contends that, owing to the piscivorous nature of brown trout, any activity which may expand their range, or enhance their populations may adversely affect populations of anadromous fish by predation related mortality.

Smallmouth bass (Micropterus dolomieu) were reportedly planted in the lower Snake and Yakima Rivers in the early 1930's (Henderson and Foster, 1956). Their distribution is primarily from the mouth to about RM 40. Largemouth bass (M. salmoides) share a part of this reach and also are numerous in the reach between Satus Creek and the City of Yakima (Patten and others, 1970). Species with a distribution similar to the largemouth bass are: carp (Cyprinus carpio), black crappie (Pomoxis nigromaculatus), bluegill (Lepomis macrochirus) and pumpkinseed (L. gibbosus). Northern squawfish (Ptychocheilus oregonensis), dace (Rhinichthys spp.), mountain whitefish (Prosopium williamsoni), chiselmouth (Acrocheilus alutaceus), redside shiner (Richarsdonius balteatus), and suckers (Catostomus spp.) are found in various densities along most of the length of the Yakima River (Patten and others, 1970). Sculpins (Cottus spp.), rainbow and cutthroat trout, and brown trout (Salmo trutta) are found mostly from Toppenish to near Thorp. Brook trout (Salvelinus fontinales) are rarely found in the Yakima River (Patten and others, 1970).

The observed decline of two native species of resident fish, the leopard dace (Rhinichthys falcatus) and sandroller (Columbia transmontana) in the Yakima River was attributed to low streamflows and warm-water conditions (U.S. Bureau of Reclamation, 1979, p. 64). Undesirable species, such as carp, have invaded all streams that were accessible and suitable for their existence. The occurrence of carp also suggests deteriorating habitat (Allen, 1976).

Kokanee in Bumping Lake are considered to be stunted due to overpopulation. Large catches of kokanee are encouraged, and in 1974 kokanee made up 71 percent of the sport catch (U.S. Bureau of Reclamation, 1979). Large numbers of kokanee also occurred in Rimrock Lake prior to 1979; Mongillo and Faulconer (1980) reported that more than 6 million kokanee were killed when Rimrock Lake was drained in 1979. By 1988 and 1989, the catch of kokanee in Rimrock Lake was increasing indicating that the population was undergoing significant restoration (Onni Perala, U.S. Bureau of Reclamation, written commun., November 1989).

Three hatchery facilities are used for resident trout planting programs and have produced more than 1 million trout annually for release in Yakima River basin (U.S. Bureau of Reclamation, 1979). Presently (1990), the facilities primarily produce steelhead trout (about 180,000 smolts). Fishery biologists have concerns about the long-term strength, health, and viability of fish populations that are affected by hatchery and planting programs, and by interspecies competition. By analyzing the genetic makeup of resident rainbow trout (Salmo gairdneri) populations in the upper Yakima River and tributaries, Campton and Johnston (1985) determined that the allele (genes that are responsible for hereditary variation) frequencies for wild rainbow trout in the upper Yakima were a mix between those for introduced hatchery populations and those for inland populations native to other areas of the Columbia River basin. They concluded that nonanadromous rainbow trout of hatchery origin may have survived and reproduced in relatively large numbers in the upper Yakima River because of major declines in the abundance of native steelhead and of two indigenous species of Pacific salmon (Oncorhynchus sp.).

Relation to Habitat and Water-sediment Chemistry

Major factors (modified from Confederated Tribes and Bands of the Yakima Indian Nation and others, 1990) presently suspected of affecting fishery in the Yakima River basin are :

(1) Fish passage problems associated with irrigation diversions in the tributaries;

(2) Passage and rearing habitat restrictions (resulting from low streamflows in both the main stem and the tributaries) that also limit fish access to shoreline cover, thus exposing fish to predators;

(3) Adverse effects to spawning and rearing habitat associated with rapid daily flow fluctuations downstream from large storage reservoirs;

(4) Deposition of fine sediment on fall chinook spawning beds in the lower river (see low-gradient reach between Sunnyside and Prosser Dams where fine sediment is deposited, figure 72);

(5) False attraction flows associated with agricultural-return flows during irrigation season;

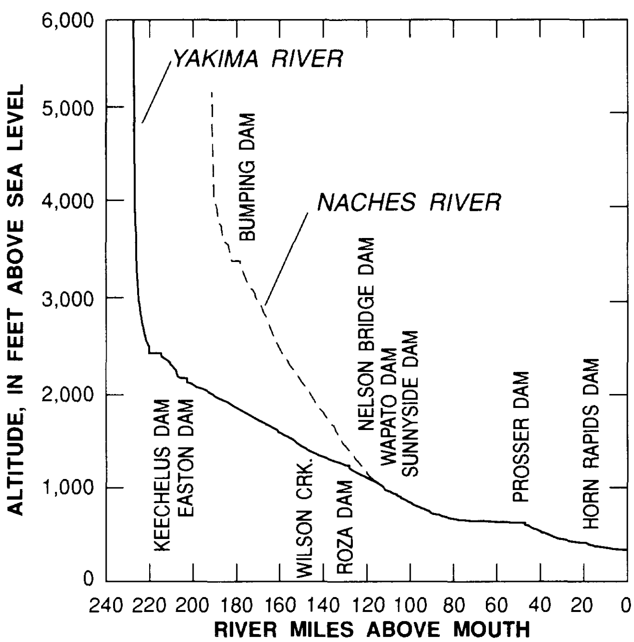

Figure 72.--Altitude of water surface for the Yakima and Naches Rivers in the Yakima River basin, Washington.

(6) Degraded rearing habitat (including lack of large organic debris) caused by prolonged, excessively high flows from reservoirs;

(7) High stream temperatures above 24 °C in the lower river reaches, which constitute a partial thermal block for fish passage and decrease available habitat for native, cold-water species;

(8) Elevated pesticide concentrations exceeding chronic toxicity criteria for aquatic life in the main stem and agricultural-return flows; and

(9) Degradation of riparian cover from grazing, tillage, mowing, and compaction that affects egg-to-smolt survival rates.

The importance of each of these factors has not been quantified.

Several water-resource developments have been planned to improve streamflow and fishery conditions in the Yakima River basin. Enlargement of Bumping Lake has been proposed to provide more water for fish transportation in the Naches River and lower Yakima River basins. Seventy-six percent of the tripled storage capacity would be allocated for use by fishery agencies. Enhancement of the resident fishery with new hatchery facilities and stocking of historically productive tributaries, such as Teanaway River and Rattlesnake Creek, were proposed. Ultimately, the U.S. Bureau of Reclamation expects anadromous-fish returns to increase by a factor of seven, subsequently increasing the commercial and sport catches.

Other Biological Data

In 1975-76, EPA collected benthic macroinvertebrate samples at four sites in the Yakima River: downstream from the cities of Cle Elum, Ellensburg, and Yakima, and at Kiona. The purpose of the sampling program was to develop a suitability index for swimming and fishing in the Yakima River (CH2M HILL, 1977); however, the index was not developed. Nevertheless, species identification and organism concentrations are available from EPA files (William Bogue, U.S. Environmental Protection Agency, written commun., 1987).

At the Cle Elum site, organisms belonging to the family, Simuliidae, were dominant in August; Hydropsyche sp. (Trichoptera) was the most numerous organism in winter (November and December) samples from Cle Elum, and in the summer and winter samples from Ellensburg and Yakima. At Kiona, Oligochaeta was dominant in the August and November samples, and Hydropsyche was dominant in December.

The average number of organisms for the 3 months of samples (December 1975; July 1976; and, November 1976) decreased from 2,300 individuals and 28 taxa at Ellensburg to 120 individuals and 12 taxa at the downstream Kiona site. This decreasing downstream trend agrees with the maximum estimated production of 8.21 grams of organisms per square foot in the Toppenish area, decreasing to 0.9 gram per square foot near Kiona (U.S. Department of Health, Education, and Welfare, 1962). The greatly reduced number of individuals and taxa indicates that Kiona may have a poorer habitat than the other three sites.

Three orders of insects, Ephemoroptera, Plecoptera, and Trichoptera (EPT), are considered to be relatively sensitive to degraded water-quality conditions (Steven V. Fend, U.S. Geological Survey, Menlo Park, California, written commun., August 1990). Members of these orders typically require large dissolved-oxygen concentrations, small turbidity levels, and low temperatures. The downstream Kiona site has the lowest numbers of EPT taxa and percent of individuals in the EPT taxa, suggesting a degradation of water-quality conditions. However, these differences between the Kiona site and the upstream sites could be due to natural temperature increases not associated with man's activities. Oligochaetes generally increase with fine sediment, temperature, and organic carbon concentrations. The presence of these Oligochaetes primarily at Kiona corresponds to downstream increases in fine sediment deposition, turbidity, temperature, and organic carbon input.

Phytoplankton (plant organisms that float or drift in water) data on identification and concentrations were available at several main-stem sites. Data were available for September 1961 at Yakima River downstream from Wilson Creek, and at Kiona (U.S. Department of Health, Education, and Welfare, 1962); and monthly data were available for Yakima River at Union Gap and Kiona for 1979-81 and 1975-81, respectively, (from the U.S. Geological Survey National Stream Quality Accounting Network program--NASQAN). For examining long-term changes, total cell concentrations for September months in 1961 and 1975-81 are shown in figure 73. This sparse amount of September data suggest that concentrations may have increased by a factor of 10 or more since 1961. Generally, the largest monthly phytoplankton concentrations at Kiona were observed between May and September from 1975-81. Even though the September data do not necessarily represent the largest concentrations, they indicate that blooms (arbitrarily defined as 500 cells per milliliter--Mackenthun and Ingram, 1967) annually occurred from 1975-81. These phytoplankton blooms contribute to the turbid water observed in the lower Yakima River. Cell concentrations at Kiona were notably larger than those at Union Gap, which is consistent with the larger instream concentrations of inorganic nitrogen and phosphorus that were available for biological uptake at Kiona.

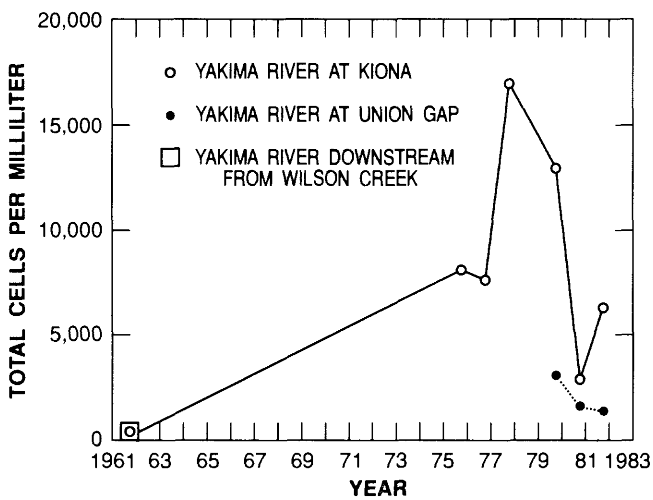

Figure 73.--Concentrations of phytoplankton for September at selected sites in the Yakima River, Washington, 1961-81.

Phytoplankton identification of the Kiona samples from 1961-81 reveals that oscillatoria (blue-green algae), cyclotella (diatom), and scenedesmus (green algae) are the codominant genera. Oscillatoria and cyclotella often are associated with the clogging of sand filters used for municipal water supplies; scenedesmus is found in sewage treatment ponds and generally has large phosphorus requirements. Other codominant genera observed in several of the Kiona samples include the diatoms: navicula, synedra, nitzschia, and melosira. A ranking of 60 of the most pollution-tolerant genera by 165 authorities (Doyle Stephens, U.S. Geological Survey, written commun., 1979) shows that the codominant genera at Kiona rank within the top 15 most tolerant genera. These genera are not necessarily indicators of pollution, but they often thrive under such conditions, oscillatoria being a notable example (Reid and Wood, 1976). If the algae were identified to species, the presence of polluted-water algae could be more accurately defined. For example, some species of the genus, cyclotella, are associated with polluted water and other species are associated with oligotrophic water (Cole, 1979).

NEEDS FOR FUTURE DATA COLLECTION AND ANALYSES

Future data-collection activities in the basin require close scrutiny of sampling, preservation, and analytical techniques to ensure that the data are representative of actual stream conditions. In addition, analytical procedures need to provide constituent reporting levels that are less than water-quality criteria and standards.

Water-quality issues that need to be addressed in future data-collection programs include eutrophication (nutrients), erosion and deposition (suspended sediment and turbidity), sanitary quality (fecal indicator bacteria), toxic compounds (trace organic compounds, trace elements, and radionuclides), effect of contaminants and habitat on biological communities, high water temperatures, and small dissolved-oxygen concentrations. Additional data are needed to describe spatial and temporal distributions as well as the seasonal sources of these contaminants in the aquatic environment.

Quantification of contaminant sources (point and nonpoint) will require computation of annual, seasonal, or daily loads using monthly or event-sampling data. Storm-event samplings should occur during the rising, peak and falling limbs of storm hydrographs. In addition to the routine monthly samplings, the sampling periods should include: winter storms, spring snowmelt, and low flows during irrigation and post-irrigation season. Future sampling of agricultural-return flows will provide data for determining yields of nutrients and pesticides from different crop types and agricultural practices.

Interpretation of instantaneous water-quality data including stream temperature, pH, dissolved oxygen, and nutrients is complicated by natural diel fluctuations and short-term changes in man's activities. Often times, the constituent concentrations in an instantaneous sample collected during the daylight hours are not representative of actual short-term variability that occurs at a site. Future samplings should include several samplings over a 24 to 48-hour period to determine short-term variability. These samplings should be made during different periods of the annual-hydrologic cycle that coincide with seasonal changes in major land- and water-use activities. An accurate description of water-quality conditions and trends cannot be made until short-term variability has been quantified.

An assessment of water quality in a basin requires knowledge of the spatial distribution of conditions at some predetermined level of detail (for example, sensitive to stream-quality conditions that are persistent over 25 river-mile reaches). In order to systematically gain this understanding, water-quality data could be collected synoptically, which involves sampling a large number of sites (50-200) during a short timeframe (1-2 week period). These samplings could be conducted during stable stream conditions for specific hydrologic periods when water-quality conditions in the basin are stressed. The data could be used to define major sources and sinks of contaminants in streams.

Sensitive indicators of degrading water-quality conditions are stream biota. Consequently, biological assessments of community structure and function, fish-tissue analyses, and primary productivity are recommended for future investigations in order to determine the effects of contaminants in water and bed sediment. Community structure includes a measure of the spatial and seasonal distribution of common aquatic organisms. Once it is defined, future changes in community structure can be evaluated relative to changes in water quality. Results from tissue analyses can be used to determine the spatial distribution of bioavailability and bioaccumulation of contaminants in the aquatic environment and to help explain changes in community structure.

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SUPPLEMENTAL DATA SECTION

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years

[This table includes only those sites with 48 or more observations that were collected from 1974-81 water years, except where noted otherwise]

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Streamflow, in cubic feet per second									
349	Yakima River at Cle Elum	1974-81	67	3.7	235	470	1,200	2,660	3,560	4,240
354	Yakima River at Ellensburg	1974-81	68	178	424	800	1,827	2,830	3,910	7,900
355	Yakima River at Umtanum	1974-81	70	350	709	1,100	2,260	3,270	4,430	8,180
320	Yakima River at Harrison Rd Bridge	1974-81	70	3.0	302	494	1,030	1,880	2,790	7,120
322	Yakima River-Terrace Heights Bridge	1974-81	71	700	1,050	1,900	2,850	4,000	5,790	16,600
40	Yakima River at Parker	1974-81	76	180	880	1,290	2,220	4,590	8,220	14,300
337	Yakima River at bridge near Granger	1974-81	62	200	415	680	1,550	3,200	6,710	12,800
338	Yakima River at bridge near Mabton	1974-81	63	200	840	1,600	2,200	3,300	6,140	13,900
100	Yakima River at Kiona	1974-81	96	525	1,040	1,760	2,400	4,580	8,470	15,400
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	53	75.0	816	1,195	1,350	1,400	1,450	1,500
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	52	60.0	711	1,160	1,340	1,400	1,440	1,500
311	Satus Drn 302 NW1/4 S 34 9N 22E	1974-81	65	.2	1.0	1.7	9.5	27.5	35.8	48
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	52	10.0	20.0	31.2	50.0	73.7	94.3	140
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	54	2.0	7.2	11.7	20.0	30	45.0	164
321	Naches River at Nelson Bridge	1974-81	70	100	341	515	1,260	2,280	3,090	5,700
323	Drain at Birchfield Road	1974-81	71	2.5	5.0	12.0	35.0	65.0	80.0	810
326	Wide Hollow Creek at Union Gap STP	1974-81	73	4.0	10.4	18.5	25.0	40.0	52.4	173
327	Ahtanum Creek at mouth	1974-81	70	5.0	12.0	20.0	46.0	105	243	700
328	Sulphur Cr at North above Sunnyside	1974-79	54	.5	1.0	1.5	2.0	3.1	5.0	16.0
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	3.0	9.6	25.0	60.0	125	150	320
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	20.0	38.0	50.0	100	160	210	380
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	45.0	57.0	87.5	150	220	282	450
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	1.4	57.7	81.2	182	260	360	460
335	Griffin Lake Inlet	1974-79	51	.2	2.2	3.0	4.0	6.0	8.0	25.0
339	East Toppenish Drain at Wilson Road	1974-81	66	2.0	4.7	9.7	20.0	40.0	53.0	70.0
340	Sub-Drain 35 at Parton Road	1974-81	64	8.0	16.0	23.0	33.0	63.0	75.5	85.0
341	Marion Drain at Highway 97	1974-81	67	70.0	97.0	140	175	270	376	600
342	Wanity Slough at Myers Road	1974-81	67	15.0	29.0	50.0	75.0	100	150	225
345	South Drain at Highway 22 nr Satus	1974-81	63	5.0	10.0	15.0	50.0	80.0	100	260
346	Granger Drain--Hwy 223 abv Granger	1974-81	70	10.0	17.3	25.0	34.5	45.0	70.0	120
347	Spring Creek at Hess Road	1974-81	63	1.1	4.0	5.0	18.0	48.0	63.0	1400
348	Snipes Cr at Old Inland Empire Road	1974-81	61	.1	2.0	3.5	35.0	57.5	95.6	135
352	Wipple Wasteway at Thrall Road	1974-79	53	8.0	20.0	30.5	50.0	80.0	120	212
353	Wilson Creek at Thrall Road	1974-81	57	25.0	40.0	65.0	85.0	120	197	519
	Stream temperature, in degrees Celsius									
349	Yakima River at Cle Elum	1974-81	71	.5	3.6	5.5	8.8	12.8	16.0	18.1
354	Yakima River at Ellensburg	1974-81	72	.5	2.5	4.2	8.7	13.2	15.5	18.2
355	Yakima River at Umtanum	1974-81	72	.0	1.7	4.0	8.2	13.0	15.5	19.9
320	Yakima River at Harrison Rd Bridge	1974-81	72	.4	2.9	5.0	9.3	14.1	16.3	20.3
322	Yakima River-Terrace Heights Bridge	1974-81	72	.0	2.1	5.0	9.0	13.2	16.0	20.3
40	Yakima River at Parker	1974-81	94	1.0	3.3	5.3	10.5	15.1	17.8	22.5
337	Yakima River at bridge near Granger	1974-81	71	1.0	3.0	6.7	11.0	16.2	18.9	21.0
338	Yakima River at bridge near Mabton	1974-81	72	.7	4.0	8.0	12.8	18.7	21.0	23.0
100	Yakima River at Kiona	1974-81	96	.0	3.4	5.9	11.6	18.0	22.0	27.3
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	2.5	4.9	7.0	13.7	19.2	21.9	25.5
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	57	2.6	4.0	7.2	14.0	19.0	22.3	25.5
311	Satus Drn 302 NW1/4 S 34 9N 22E	1974-81	65	3.0	5.1	8.0	12.1	16.0	18.7	23.0
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	54	3.5	4.5	6.4	9.6	13.2	15.5	18.3
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	54	.5	2.6	3.9	9.3	13.8	15.9	18.9
321	Naches River at Nelson Bridge	1974-81	73	.0	2.7	4.5	9.8	14.6	16.7	21.5
323	Drain at Birchfield Road	1974-81	72	2.0	5.4	7.3	12.5	16.6	20.7	28.9
326	Wide Hollow Creek at Union Gap STP	1974-81	73	4.2	7.0	10.0	12.5	15.1	17.7	20.0
327	Ahtanum Creek at mouth	1974-81	72	3.0	4.1	7.0	11.2	15.0	19.0	22.5
328	Sulphur Cr at North above Sunnyside	1974-79	54	3.2	5.0	8.7	12.0	15.9	18.0	19.2
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	4.6	6.9	9.6	12.0	15.1	18.3	19.5
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	4.0	6.2	9.5	12.1	15.5	18.2	19.2
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	4.0	6.4	9.2	12.0	15.3	18.5	19.7
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	4.0	7.0	9.5	12.7	16.4	19.0	20.3
335	Griffin Lake Inlet	1974-79	51	2.8	6.0	10.2	13.5	18.0	20.4	21.9
339	East Toppenish Drain at Wilson Road	1974-81	67	5.0	9.4	11.0	12.8	15.0	16.8	19.0
340	Sub-Drain 35 at Parton Road	1974-81	67	6.0	9.5	11.0	12.5	15.3	16.9	19.2
341	Marion Drain at Highway 97	1974-81	66	5.7	8.1	10.0	12.0	15.0	16.8	19.0
342	Wanity Slough at Myers Road	1974-81	67	4.3	6.9	9.0	12.2	16.0	17.9	20.5
345	South Drain at Highway 22 nr Satus	1974-81	66	2.5	6.8	9.0	12.0	16.8	19.0	22.0
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	3.0	7.6	10.0	12.0	15.0	18.0	19.0
347	Spring Creek at Hess Road	1974-81	65	1.0	6.0	8.6	13.0	17.7	20.5	23.2
348	Snipes Cr at Old Inland Empire Road	1974-81	62	1.0	5.1	8.6	13.8	18.0	21.6	23.5
352	Wipple Wasteway at Thrall Road	1974-79	55	2.8	5.2	7.0	10.0	13.1	15.9	19.0
353	Wilson Creek at Thrall Road	1974-81	59	1.0	3.0	6.5	9.8	14.0	15.5	18.6

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	pH values, in pH units									
349	Yakima River at Cle Elum	1974-81	72	6.6	7.2	7.4	7.5	7.6	7.7	7.9
354	Yakima River at Ellensburg	1974-81	74	7.2	7.3	7.4	7.5	7.6	7.7	7.9
355	Yakima River at Umtanum	1974-81	74	7.0	7.4	7.5	7.6	7.7	7.8	8.0
320	Yakima River at Harrison Rd Bridge	1974-81	72	6.8	7.2	7.4	7.5	7.7	7.9	8.6
322	Yakima River-Terrace Heights Bridge	1974-81	73	7.1	7.3	7.4	7.5	7.6	7.8	8.0
40	Yakima River at Parker	1974-81	94	6.5	7.5	7.6	7.8	8.1	8.3	9.1
337	Yakima River at bridge near Granger	1974-81	71	7.2	7.4	7.5	7.6	7.8	7.9	8.4
338	Yakima River at bridge near Mabton	1974-81	72	7.1	7.5	7.6	7.7	7.8	8.0	8.1
100	Yakima River at Kiona	1974-81	95	6.8	7.6	7.8	7.9	8.3	8.6	9.2
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	7.2	7.4	7.6	7.7	7.8	8.0	9.2
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	7.1	7.4	7.6	7.7	7.8	8.1	9.1
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	7.3	7.5	7.7	7.9	8.2	8.3	8.4
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	55	7.5	7.7	7.8	7.9	8.0	8.1	8.3
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	7.4	7.5	7.6	7.7	7.8	8.0	8.2
321	Naches River at Nelson Bridge	1974-81	74	7.2	7.2	7.3	7.5	7.6	7.7	8.4
323	Drain at Birchfield Road	1974-81	71	7.2	7.6	7.7	7.9	8.2	8.4	10.7
326	Wide Hollow Creek at Union Gap STP	1974-81	73	7.0	7.2	7.3	7.6	7.8	7.9	8.1
327	Ahtanum Creek at mouth	1974-81	72	7.3	7.5	7.7	7.8	8.0	8.1	8.6
328	Sulphur Cr at North above Sunnyside	1974-79	54	7.2	7.5	7.7	7.9	8.1	8.3	8.4
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	7.0	7.6	7.6	7.9	8.1	8.2	8.4
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	7.2	7.5	7.8	7.9	8.1	8.2	8.4
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	7.1	7.6	7.7	7.8	8.0	8.1	8.3
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	7.2	7.6	7.7	7.8	8.0	8.1	8.3
335	Griffin Lake Inlet	1974-79	51	7.3	7.6	7.7	7.9	8.0	8.1	8.5
339	East Toppenish Drain at Wilson Road	1974-81	67	7.1	7.2	7.3	7.4	7.5	7.6	8.0
340	Sub-Drain 35 at Parton Road	1974-81	67	7.3	7.4	7.5	7.6	7.7	7.8	8.1
341	Marion Drain at Highway 97	1974-81	67	7.2	7.5	7.6	7.7	7.8	7.9	8.0
342	Wanity Slough at Myers Road	1974-81	67	7.3	7.4	7.4	7.5	7.6	7.7	8.3
345	South Drain at Highway 22 nr Satus	1974-81	66	7.2	7.5	7.7	7.9	8.0	8.2	8.3
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	7.3	7.5	7.6	7.8	8.0	8.1	8.3
347	Spring Cr at Hess Road	1974-81	65	7.3	7.6	7.7	8.0	8.2	8.4	8.8
348	Snipes Cr at Old Inland Empire Road	1974-81	62	7.2	7.4	7.6	7.8	8.1	8.3	8.8
352	Wipple Wasteway at Thrall Road	1974-79	56	7.5	7.7	7.8	7.9	8.1	8.2	8.4
353	Wilson Creek at Thrall Road	1974-81	60	7.4	7.5	7.6	7.7	7.9	7.9	8.8
	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius									
349	Yakima River at Cle Elum	1974-81	71	27	42	53	62	73	87	94
354	Yakima River at Ellensburg	1974-81	73	63	65	75	89	106	114	125
355	Yakima River at Umtanum	1974-81	73	78	86	92	114	136	155	206
320	Yakima River at Harrison Rd Bridge	1974-81	73	71	85	100	120	146	176	321
322	Yakima River-Terrace Heights Bridge	1974-81	73	57	75	90	100	123	156	181
40	Yakima River at Parker	1974-81	94	73	91	104	130	158	190	228
337	Yakima River at bridge near Granger	1974-81	71	80	107	143	182	243	318	731
338	Yakima River at bridge near Mabton	1974-81	72	113	142	174	244	282	323	397
100	Yakims River at Kiona	1974-81	93	115	149	196	265	316	350	435
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	109	130	177	236	302	357	388
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	117	136	176	246	306	365	446
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	133	253	322	386	1,420	1,580	1,680
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	54	177	196	263	301	364	384	399
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	109	143	172	198	232	261	346
321	Naches River at Nelson Bridge	1974-81	74	46	60	64	76	85	98	140
323	Drain at Birchfield Road	1974-81	71	231	264	284	358	812	875	934
326	Wide Hollow Creek at Union Gap STP	1974-81	73	251	282	364	605	1,151	1,940	2,720
327	Ahtanum Creek at mouth	1974-81	72	100	142	180	294	345	375	417
328	Sulphur Cr at North above Sunnyside	1974-79	54	102	316	348	420	626	667	697
329	Sulphur Cr Wasteway at Factory Road	1974-79	54	135	161	187	272	730	776	812
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	189	251	290	392	660	706	748
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	223	261	306	389	670	726	777
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	211	262	306	377	659	712	851
335	Griffin Lake Inlet	1974-79	51	188	216	296	358	458	499	522
339	East Toppenish Drain at Wilson Road	1974-81	67	149	226	253	294	325	358	392
340	Sub-Drain 35 at Parton Road	1974-81	67	224	242	255	284	306	314	327
341	Marion Drain at Highway 97	1974-81	67	214	240	266	296	362	381	403
342	Wanity Slough at Myers Road	1974-81	67	116	147	167	187	233	246	265
345	South Drain at Highway 22 nr Satus	1974-81	66	94	243	339	386	771	820	843
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	322	364	390	475	659	706	798
347	Spring Creek at Hess Road	1974-81	64	181	208	257	320	717	747	799
348	Snipes Cr at Old Inland Empire Road	1974-81	62	122	148	168	205	712	804	909
352	Wipple Wasteway at Thrall Road	1974-79	55	172	215	262	330	479	494	523
353	Wilson Creek at Thrall Road	1974-81	59	131	155	193	210	236	248	261

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
Dissolved solids, in milligrams per liter [Data are shown for those sites having 10 or more observations]										
32	Yakima River at Union Gap	1979-81	30	52	57	68	81	97	105	117
100	Yakima River at Kiona	1975-81	83	72	96	122	164	196	217	290
33	North Fork Ahtanum Creek nr Tampico	1980-81	17	46	64	78	85	93	109	111
54	Toppenish Creek near Fort Simcoe	1974-81	21	60	77	80	98	108	119	147
Dissolved oxygen, in milligrams per liter										
349	Yakima River at Cle Elum	1974-81	59	6.8	9.1	9.9	10.9	12.2	12.6	13.8
354	Yakima River at Ellensburg	1974-81	63	8.1	9.1	9.7	10.7	11.9	12.4	13.4
355	Yakima River at Umtanum	1974-81	63	7.9	9.2	9.8	11.1	12.2	13.3	14.6
320	Yakima River at Harrison Rd Bridge	1974-81	62	8.4	9.4	10.1	11.1	12.5	13.5	14.8
322	Yakima River-Terrace Heights Bridge	1974-81	63	8.0	8.7	9.6	10.7	12.1	13.1	13.9
40	Yakima River at Parker	1974-81	94	8.6	9.8	10.5	11.8	13.1	13.7	14.4
337	Yakima River at bridge near Granger	1974-81	62	6.9	7.5	8.6	9.7	11.2	12.2	13.4
338	Yakima River at bridge near Mabton	1974-81	63	6.8	8.1	8.7	9.5	10.5	11.8	12.9
100	Yakima River at Kiona	1974-81	68	7.9	8.7	9.5	10.8	12.0	13.4	16.8
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	51	7.9	8.4	9.2	10.2	11.4	12.2	13.2
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	52	7.3	8.2	8.8	10.2	11.6	12.4	13.2
311	Satus Drain 302 NW1/4 Sec 34 9N 22E	1974-81	54	7.0	7.9	8.8	9.7	11.6	12.5	15.0
321	Naches River at Nelson Bridge	1974-81	64	7.8	9.2	10.2	11.1	12.4	13.1	14.7
323	Drain at Birchfield Road	1974-81	62	7.4	8.3	9.1	9.8	11.4	12.3	13.3
326	Wide Hollow Creek at Union Gap STP	1974-81	63	7.0	7.9	8.6	9.4	10.7	11.3	14.8
327	Ahtanum Creek at mouth	1974-81	62	8.1	9.0	10.0	10.8	11.8	12.5	13.9
329	Sulphur Cr Wasteway at Factory Road	1974-79	48	7.6	8.7	9.3	10.0	11.1	11.6	12.1
332	Sulphur Cr Wasteway at Duffy Road	1974-79	48	7.8	8.4	9.1	9.8	10.9	11.4	12.3
334	Sulphur Cr Wasteway at McGee Road	1974-81	63	6.4	7.7	8.6	9.3	10.4	11.0	11.6
339	East Toppenish Drain at Wilson Road	1974-81	56	1.4	3.8	5.0	7.2	8.4	10.2	13.6
340	Sub-Drain 35 at Parton Road	1974-81	56	6.4	7.1	7.6	8.6	9.1	9.6	10.2
341	Marion Drain at Highway 97	1974-81	57	4.0	7.3	8.1	8.9	9.9	10.6	11.8
342	Wanity Slough at Myers Road	1974-81	56	5.6	7.5	8.4	9.3	10.6	11.7	13.0
345	South Drain at Highway 22 nr Satus	1974-81	55	7.1	8.1	8.3	9.1	10.1	10.6	13.0
346	Granger Drain--Hwy 223 abv Granger	1974-81	62	6.2	7.4	8.0	8.5	9.3	9.8	11.8
347	Spring Creek at Hess Road	1974-81	54	7.7	8.4	8.8	10.0	11.4	12.2	13.4
348	Snipes Cr at Old Inland Empire Road	1974-81	51	7.8	8.2	8.7	9.6	11.1	12.2	13.0
353	Wilson Creek at Thrall Road	1974-81	51	8.0	9.3	10.1	11.4	12.4	13.4	14.3
Turbidity, in NTUs (nephlometric turbidity units)										
349	Yakima River at Cle Elum	1974-81	64	1.0	1.0	1.0	1.0	2.0	7.5	16
354	Yakima River at Ellensburg	1974-81	72	1.0	1.0	1.0	1.0	3.0	13	56
355	Yakima River at Umtanum	1974-81	72	1.0	1.0	1.0	2.0	4.0	14	72
320	Yakima River at Harrison Rd Bridge	1974-81	72	1.0	1.0	1.0	2.0	5.0	15	110
322	Yakima River-Terrace Heights Bridge	1974-81	73	1.0	1.0	1.0	3.0	5.0	16	130
40	Yakima River at Parker	1974-81	92	2.0	3.0	4.0	6.0	9.0	23	50
337	Yakima River at bridge near Granger	1974-81	71	1.0	2.0	3.0	6.0	11	16	31
338	Yakima River at bridge near Mabton	1974-81	72	1.0	2.0	4.0	6.0	10	17	50
100	Yakima River at Kiona	1974-81	96	.6	2.6	4.0	6.7	11	22	100
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	1.0	2.0	4.0	7.0	11	23	110
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	1.0	2.0	4.0	7.5	11	29	180
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	1.0	1.0	2.0	8.0	36	80	210
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	53	1.0	2.0	4.0	6.0	12	16	64
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	1.0	2.0	3.0	5.0	8.0	14	100
321	Naches River at Nelson Bridge	1974-81	74	1.0	1.0	1.0	2.0	4.0	11	40
323	Drain at Birchfield Road	1974-81	72	1.0	3.3	7.0	16	34	60	410
326	Wide Hollow Creek at Union Gap STP	1974-81	73	1.0	1.0	4.0	9.0	18	28	740
327	Ahtanum Creek at mouth	1974-81	72	1.0	1.0	2.0	3.0	7.0	10	100
328	Sulphur Cr at North above Sunnyside	1974-79	54	<.1	1.0	3.0	5.5	13	40	150
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	1.0	3.6	5.0	11	19	40	280
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	2.0	3.0	6.0	12	25	52	640
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	3.0	4.0	6.0	15	26	46	640
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	1.0	3.3	6.0	13	24	54	600
335	Griffin Lake Inlet	1974-79	51	2.0	3.0	5.0	8.0	21	35	180
339	East Toppenish Drain at Wilson Road	1974-81	66	1.0	1.0	2.0	3.0	5.2	10	18
340	Sub-Drain 35 at Parton Road	1974-81	66	1.0	1.0	2.0	3.0	6.2	9.3	85
341	Marion Drain at Highway 97	1974-81	67	1.0	1.8	3.0	4.0	7.0	13	27
342	Wanity Slough at Myers Road	1974-81	67	1.0	1.8	3.0	5.0	8.0	13	21
345	South Drain at Highway 22 nr Satus	1974-81	66	1.0	2.0	3.0	8.5	17	42	170
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	2.0	6.0	8.0	18	40	70	520
347	Spring Creek at Hess Road	1974-81	64	1.0	1.5	4.0	8.5	23	60	520
348	Snipes Cr at Old Inland Empire Road	1974-81	61	1.0	1.0	2.0	6.0	18	42	340
352	Wipple Wasteway at Thrall Road	1974-79	54	1.0	1.0	2.7	5.5	10	16	26
353	Wilson Creek at Thrall Road	1974-81	58	1.0	1.0	2.0	4.0	5.2	12	32

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Suspended sediment, in milligrams per liter									
349	Yakima River at Cle Elum	1974-81	68	<1	1	2	4	8	16	52
354	Yakima River at Ellensburg	1974-81	73	<1	1	3	6	10	20	133
355	Yakima River at Umtanum	1974-81	73	<1	2	4	8	14	32	171
320	Yakima River at Harrison Rd Bridge	1974-81	73	<1	3	5	10	20	52	261
322	Yakima River-Terrace Heights Bridge	1974-81	73	<1	3	6	10	20	32	535
40	Yakima River at Parker	1974-81	49	2	5	8	19	33	67	102
337	Yakima River at bridge near Granger	1974-81	71	4	8	13	22	36	60	155
338	Yakima River at bridge near Mabton	1974-81	72	<1	6	12	23	37	59	164
100	Yakima River at Kiona	1975-81	84	1	7	14	26	48	113	490
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	3	8	18	29	43	100	231
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	4	8	18	28	47	88	326
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	1	4	10	27	140	340	976
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	54	4	10	17	30	47	82	233
313	Coleman Cr NW 1/4 S20 17N 19E	1974-79	55	5	7	12	21	33	59	176
321	Naches River at Nelson Bridge	1974-81	74	<1	2	2	5	14	28	264
323	Drain at Birchfield Road	1974-81	72	4	9	22	60	182	286	1,360
326	Wide Hollow Creek at Union Gap STP	1974-81	73	3	7	14	19	31	60	2,190
327	Ahtanum Creek at mouth	1974-81	72	2	4	7	16	30	49	353
328	Sulphur Cr at North abv Sunnyside	1974-79	54	1	6	10	26	51	134	570
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	8	15	23	42	81	186	576
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	15	22	31	56	134	318	1,530
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	9	21	30	59	128	318	1,340
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	6	14	27	45	98	285	1,330
335	Griffin Lake Inlet	1974-79	51	5	9	13	33	74	122	180
339	East Toppenish Drain at Wilson Road	1974-81	67	2	4	7	12	26	46	65
340	Sub-Drain 35 at Parton Road	1974-81	67	3	6	8	17	27	49	153
341	Marion Drain at Highway 97	1974-81	67	5	7	10	19	32	48	99
342	Wanity Slough at Myers Road	1974-81	67	4	7	11	18	28	33	104
345	South Drain at Highway 22 nr Satus	1974-81	66	2	6	11	32	66	105	465
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	2	23	37	76	208	361	2,916
347	Spring Creek at Hess Road	1974-81	65	2	8	14	38	87	262	1,290
348	Snipes Cr at Old Inland Empire Road	1974-81	62	1	3	8	26	75	160	1,343
352	Wipple Wasteway at Thrall Road	1974-79	55	1	5	9	24	51	69	117
353	Wilson Creek at Thrall Road	1974-81	59	2	5	9	12	24	38	134
	Total organic plus ammonia nitrogen as nitrogen, in milligrams per liter [Data are shown for those sites having 10 or more observations]									
32	Yakima River at Union Gap	1979-81	30	.1	.2	.4	.5	.7	1.0	1.3
40	Yakima River at Parker	1975-81	75	.1	.2	.3	.4	.4	.7	1.7
48	Yakima River near Toppenish	1974-77	25	.1	.2	.2	.2	.3	.7	1.0
92	Yakima River at Mabton	1974-75	24	.2	.2	.3	.4	.5	.7	.9
94	Yakima River at Prosser	1974-74	12	.2	.2	.3	.4	.6	.9	1.0
100	Yakima River at Kiona	1974-81	91	.1	.3	.4	.5	.8	1.2	2.9
101	Yakima River at Van Geisan Bridge	1974-77	13	.3	.3	.4	.5	.7	1.3	1.4
7	Wilson Creek at Thrall	1975-75	12	.3	.3	.4	.5	.6	1.0	1.0
33	North Fork Ahtanum Creek nr Tampico	1980-81	17	.0	.1	.3	.4	.7	2.1	2.7
37	Ahtanum Creek at Goodman Road	1974-75	12	.2	.2	.3	.4	.5	.7	.8
52	Wanity Slough at Rocky Ford Road	1974-75	12	.2	.2	.4	.4	.5	.5	.5
53	Marion Drain near Granger	1974-75	24	.3	.3	.4	.4	.5	.7	1.0
54	Toppenish Creek near Fort Simcoe	1974-81	20	.1	.1	.2	.3	.6	1.0	2.5
62	Toppenish Creek near Satus	1974-75	24	.2	.3	.4	.4	.7	.8	1.4
70	Satus Creek at Satus	1974-75	24	.2	.2	.2	.3	.3	.4	.5
71	South Drain near Satus	1974-75	12	.4	.4	.4	.5	.7	1.7	2.0
86	DID 18 Drain at Sunnyside	1976-77	13	.4	.5	.7	1.0	2.1	3.8	4.7
87	Washout Drain at Sunnyside	1976-77	13	.4	.4	.5	.5	1.3	2.3	2.3
88	Black Canyon Creek at Waneta Road	1976-77	13	.4	.4	.5	.7	1.8	4.4	5.6
89	DID 9 Drain near Sunnyside	1976-77	13	.4	.4	.6	.7	.8	1.2	1.4
90	DID 3 Drain near Sunnyside	1976-77	13	1.4	1.6	1.9	3.0	3.6	3.7	3.7
91	Sulphur Creek Wasteway nr Sunnyside	1976-77	13	.4	.5	.7	.8	1.0	1.4	1.5

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Total ammonia, in milligrams per liter as nitrogen									
349	Yakima R at Cle Elum	1974-81	71	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.07
354	Yakima R at Ellensburg	1974-81	72	<.01	<.01	.01	.02	.03	.06	.11
355	Yakima R at Umtanum	1974-81	73	<.01	<.01	.01	.01	.03	.05	.12
320	Yakima R at Harrison Rd Bridge	1974-81	72	<.01	<.01	.01	.01	.03	.05	.14
322	Yakima River-Terrace Heights Bridge	1974-81	72	<.01	<.01	.01	.01	.03	.04	.12
40	Yakima River at Parker	1974-81	93	<.01	.04	.06	.09	.13	.20	.32
337	Yakima River at bridge near Granger	1974-81	70	<.01	.01	.02	.05	.11	.18	.38
338	Yakima River at bridge near Mabton	1974-81	71	<.01	.01	.02	.04	.07	.11	.19
100	Yakima River at Kiona	1974-81	96	<.01	<.01	.03	.07	.11	.17	.55
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	57	<.01	<.01	.01	.02	.04	.10	.26
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	57	<.01	<.01	.01	.02	.05	.08	.27
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	64	<.01	<.01	.01	.03	.10	.27	6.1
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	54	<.01	<.01	.01	.02	.03	.08	.13
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	54	<.01	<.01	.01	.02	.04	.06	.15
321	Naches River at Nelson Bridge	1974-81	73	<.01	<.01	<.01	.01	.02	.02	.05
323	Drain at Birchfield Road	1974-81	71	<.01	<.01	.03	.05	.10	.22	.59
326	Wide Hollow Creek at Union Gap STP	1974-81	72	<.01	<.02	.03	1.3	3.0	3.9	9.1
327	Ahtanum Creek at mouth	1974-81	71	<.01	<.01	.01	.02	.03	.05	1.6
328	Sulphur Cr at North above Sunnyside	1974-79	53	<.01	<.01	.01	.03	.05	.32	1.8
329	Sulphur Cr Wasteway at Factory Road	1974-79	54	<.01	<.01	.02	.03	.06	.11	2.7
332	Sulphur Cr Wasteway at Duffy Road	1974-79	54	.01	.02	.02	.05	.13	.30	1.9
333	Sulphur Cr Wasteway at Morse Road	1974-79	52	.01	.05	.09	.18	.29	.44	2.4
334	Sulphur Cr Wasteway at McGee Road	1974-81	71	<.01	.03	.08	.16	.27	.47	2.3
335	Griffin Lake Inlet	1974-79	50	<.01	.01	.03	.06	.13	.27	1.8
339	East Toppenish Drain at Wilson Road	1974-81	66	<.01	.06	.14	.33	1.0	1.9	5.9
340	Sub-Drain 35 at Parton Road	1974-81	66	<.01	<.01	.01	.02	.03	.06	.39
341	Marion Drain at Highway 97	1974-81	66	<.01	<.01	.01	.02	.03	.07	.18
342	Wanity Slough at Myers Road	1974-81	66	<.01	.01	.02	.07	.22	.34	.64
345	South Drain at Highway 22 nr Satus	1974-81	65	<.01	.02	.02	.04	.06	.10	.34
346	Granger Drain--Hwy 223 abv Granger	1974-81	70	<.01	.01	.09	.20	.41	.75	3.9
347	Spring Creek at Hess Road	1974-81	64	<.01	<.01	.01	.02	.04	.08	.21
348	Snipes Cr at Old Inland Empire Road	1974-81	61	<.01	<.01	<.01	.01	.02	.06	.12
352	Wipple Wasteway at Thrall Road	1974-79	55	<.01	<.01	.01	.02	.03	.04	.11
353	Wilson Creek at Thrall Road	1974-81	59	<.01	<.01	.01	.02	.03	.07	.11
	Dissolved nitrite plus nitrate as nitrogen, in milligrams per liter									
349	Yakima River at Cle Elum	1974-81	72	<.01	.01	.02	.03	.04	.07	.51
354	Yakima River at Ellensburg	1974-81	74	<.01	.02	.03	.06	.10	.18	.58
355	Yakima River at Umtanum	1974-81	74	<.01	.02	.06	.13	.20	.36	.62
320	Yakima River at Harrison Rd Bridge	1974-81	73	<.01	.02	.04	.10	.21	.36	2.5
322	Yakima River-Terrace Heights Bridge	1974-81	73	<.01	.02	.03	.06	.16	.26	.52
40	Yakima River at Parker	1974-81	93	.05	.09	.12	.17	.30	.44	.67
337	Yakima River at bridge near Granger	1974-81	71	.03	.14	.27	.54	.88	1.3	6.5
338	Yakima River at bridge near Mabton	1974-81	72	.18	.33	.55	1.0	1.2	1.4	1.9
100	Yakima River at Kiona	1974-81	96	.12	.37	.54	.89	1.2	1.5	1.9
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	.15	.27	.44	.74	1.2	1.4	1.7
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	.14	.30	.43	.81	1.2	1.6	2.7
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	64	.38	1.70	2.5	3.7	24.8	30.7	34.2
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	55	.04	.35	.58	.94	1.2	1.4	2.8
313	Coleman Cr NW 1/4 Sec 20 T17N R19E	1974-79	55	.02	.06	.14	.28	.47	.92	1.6
321	Naches River at Nelson Bridge	1974-81	74	<.01	.01	.02	.04	.06	.08	.22
323	Drain at Birchfield Road	1974-81	72	.07	.46	.65	.96	2.5	3.2	4.0
326	Wide Hollow Creek at Union Gap STP	1974-81	73	.05	.12	.85	1.1	1.6	2.1	3.5
327	Ahtanum Creek at mouth	1974-81	72	.03	.10	.33	.48	.67	.82	1.6
328	Sulphur Cr at North above Sunnyside	1974-79	54	.10	1.6	2.1	3.5	5.2	6.2	8.6
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	.32	.55	.82	1.5	6.8	7.8	8.3
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	.88	1.4	1.8	2.8	6.3	7.0	7.5
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	1.1	1.4	1.8	2.7	5.5	6.3	7.4
334	Sulphur Cr Wasteway at McGee Road	1974-81	72	.94	1.4	1.7	2.7	5.4	6.1	7.3
335	Griffin Lake Inlet	1974-79	51	.02	.16	.27	.51	1.0	1.4	3.5
339	East Toppenish Drain at Wilson Road	1974-81	67	.36	1.1	1.66	2.4	3.3	4.4	6.0
340	Sub-Drain 35 at Parton Road	1974-81	67	1.20	1.5	1.7	2.1	2.6	2.9	3.2
341	Marion Drain at Highway 97	1974-81	67	1.1	1.5	1.9	2.6	3.4	3.8	4.7
342	Wanity Slough at Myers Road	1974-81	67	.18	.61	.79	1.5	2.0	2.7	3.6
345	South Drain at Highway 22 nr Satus	1974-81	66	.20	.69	1.3	1.8	2.5	2.9	3.3
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	.83	1.5	1.8	2.3	3.5	4.0	8.4
347	Spring Creek at Hess Road	1974-81	65	.33	.60	.87	1.4	4.9	6.0	6.9
348	Snipes Cr at Old Inland Empire Road	1974-81	62	.02	.11	.21	.38	3.0	3.6	4.4
352	Wipple Wasteway at Thrall Road	1974-79	56	.11	.42	.63	.96	1.7	2.1	4.7
353	Wilson Creek at Thrall Road	1974-81	60	.03	.08	.16	.25	.37	.48	.64

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Total phosphorus as P, in milligrams per liter									
349	Yakima River at Cle Elum	1974-81	70	<0.01	0.01	0.01	0.02	0.04	0.06	0.14
354	Yakima River at Ellensburg	1974-81	72	.01	.01	.02	.03	.05	.12	.28
355	Yakima River at Umtanum	1974-81	72	.01	.02	.03	.04	.06	.13	.31
320	Yakima River at Harrison Rd Bridge	1974-81	73	.02	.03	.03	.04	.06	.14	.97
322	Yakima River-Terrace Heights Bridge	1974-81	73	.02	.02	.03	.04	.06	.12	.32
40	Yakima River at Parker	1974-81	93	<.01	.04	.06	.08	.11	.16	.50
337	Yakima River at bridge near Granger	1974-81	71	.06	.07	.09	.11	.17	.24	.34
338	Yakima River at bridge near Mabton	1974-81	72	.05	.08	.10	.12	.15	.22	.55
100	Yakima River at Kiona	1974-81	96	.02	.08	.10	.13	.16	.21	.57
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	.05	.08	.10	.13	.18	.25	1.1
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	.06	.08	.11	.14	.18	.29	1.2
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	.04	.09	.12	.21	.42	.77	2.8
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	53	.10	.11	.14	.21	.28	.39	.49
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	.06	.07	.09	.12	.18	.25	1.2
321	Naches River at Nelson Bridge	1974-81	74	.01	.01	.02	.02	.04	.08	.12
323	Drain at Birchfield Road	1974-81	72	.15	.19	.29	.38	.53	.69	3.3
326	Wide Hollow Creek at Union Gap STP	1974-81	73	.09	.11	.20	.81	1.7	2.1	4.5
327	Ahtanum Creek at mouth	1974-81	72	.05	.10	.11	.13	.17	.22	.47
328	Sulphur Cr at North above Sunnyside	1974-79	54	.06	.09	.10	.14	.23	.46	1.9
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	.06	.08	.11	.15	.24	.33	3.1
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	.06	.10	.14	.22	.30	.66	5.4
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	.13	.18	.24	.31	.47	.78	4.8
334	Sulphur Cr Wasteway at McGee Road	1974-81	71	.12	.17	.22	.29	.42	.68	5.2
335	Griffin Lake Inlet	1974-79	50	.11	.16	.23	.29	.32	.43	1.1
339	East Toppenish Drain at Wilson Road	1974-81	67	.15	.19	.25	.36	.63	.93	1.5
340	Sub-Drain 35 at Parton Road	1974-81	67	.01	.04	.06	.08	.13	.15	.50
341	Marion Drain at Highway 97	1974-81	67	.08	.11	.13	.14	.16	.20	.32
342	Wanity Slough at Myers Road	1974-81	67	.04	.08	.09	.11	.16	.21	.43
345	South Drain at Highway 22 nr Satus	1974-81	66	.14	.16	.19	.22	.28	.38	1.2
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	.16	.21	.28	.42	.69	.96	4.1
347	Spring Creek at Hess Road	1974-81	65	.02	.07	.10	.15	.28	.63	1.7
348	Snipes Cr at Old Inland Empire Road	1974-81	62	<.01	.06	.07	.10	.18	.31	1.2
352	Wipple Wasteway at Thrall Road	1974-79	54	.11	.14	.17	.21	.30	.36	.49
353	Wilson Creek at Thrall Road	1974-81	58	.05	.07	.09	.12	.14	.24	.51
	Dissolved orthophosphate as P, in milligrams per liter									
349	Yakima River at Cle Elum	1974-81	72	<.01	<.01	<.01	<.01	.01	.01	.04
354	Yakima River at Ellensburg	1974-81	73	<.01	<.01	<.01	.01	.02	.03	.08
355	Yakima River at Umtanum	1974-81	74	<.01	<.01	<.01	.01	.02	.05	.13
320	Yakima River at Harrison Rd Bridge	1974-81	73	<.01	<.01	<.01	.02	.03	.04	.70
322	Yakima River-Terrace Heights Bridge	1974-81	73	<.01	<.01	<.01	.01	.02	.03	.07
40	Yakima River at Parker	1974-81	92	<.01	.01	.02	.04	.05	.08	.14
337	Yakima River at bridge near Granger	1974-81	71	<.01	.02	.03	.05	.09	.13	.20
338	Yakima River at bridge near Mabton	1974-81	72	.01	.03	.04	.06	.08	.10	.14
100	Yakima River at Kiona	1974-81	96	.01	.04	.06	.08	.09	.11	.20
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	<.01	.03	.04	.05	.07	.09	.20
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	<.01	.02	.04	.06	.08	.10	.48
311	Satus Drain 302 NW1/4 S 34 9N 22E	1974-81	65	.02	.05	.06	.09	.11	.17	1.2
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	55	.04	.06	.08	.11	.16	.24	.35
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	.01	.02	.04	.06	.10	.15	.27
321	Naches River at Nelson Bridge	1974-81	74	<.01	<.01	.01	.01	.01	.02	.05
323	Drain at Birchfield Road	1974-81	72	.06	.09	.13	.19	.32	.37	.51
326	Wide Hollow Creek at Union Gap STP	1974-81	73	.01	.08	.14	.44	.98	1.6	3.6
327	Ahtanum Creek at mouth	1974-81	72	.03	.04	.05	.09	.10	.13	.21
328	Sulphur Cr at North above Sunnyside	1974-79	54	.03	.06	.06	.07	.09	.11	1.1
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	.01	.03	.04	.06	.08	.09	1.2
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	.02	.04	.06	.08	.10	.13	.93
333	Sulphur Cr Wasteway at Morse Road	1974-79	53	.06	.09	.11	.15	.19	.23	1.1
334	Sulphur Cr Wasteway at McGee Road	1974-81	71	.06	.09	.11	.16	.19	.25	1.1
335	Griffin Lake Inlet	1974-79	51	.03	.08	.12	.17	.22	.27	.56
339	East Toppenish Drain at Wilson Road	1974-81	67	.03	.12	.17	.26	.54	.82	1.5
340	Sub-Drain 35 at Parton Road	1974-81	67	.01	.02	.02	.04	.06	.08	.12
341	Marion Drain at Highway 97	1974-81	67	.03	.06	.08	.09	.10	.12	.18
342	Wanity Slough at Myers Road	1974-81	67	.01	.02	.03	.05	.08	.11	.30
345	South Drain at Highway 22 nr Satus	1974-81	66	.05	.08	.09	.12	.16	.18	.42
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	.08	.13	.15	.18	.21	.31	1.8
347	Spring Creek at Hess Road	1974-81	65	<.01	.02	.04	.06	.07	.09	.20
348	Snipes Cr at Old Inland Empire Road	1974-81	62	<.01	<.01	.02	.03	.05	.08	.45
352	Wipple Wasteway at Thrall Road	1974-79	56	.05	.07	.12	.165	.19	.22	.35
353	Wilson Creek at Thrall Road	1974-81	60	<.01	.03	.04	.06	.09	.10	.18
	Dissolved organic carbon as carbon, in milligrams per liter [Data from all sites are shown regardless of the number of observations]									
32	Yakima River at Union Gap	1979-81	9	2.4	2.4	2.8	3.5	6.4	15	15
100	Yakima River at Kiona	1978-81	15	1.8	1.9	2.4	4.8	6.9	45	93

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Weter-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Suspended organic carbon as carbon, in milligrams per liter [Data from all sites are shown regardless of the number of observations]									
32	Yakima River at Union Gap	1979-81	6	0.1	0.1	0.3	0.4	0.8	1.2	1.2
100	Yakima River at Kiona	1978-81	13	.1	.2	.4	.7	1.4	3.4	4.3
	Chemical oxygen demand, in milligrams per liter									
349	Yakima River at Cle Elum	1974-81	70	1	2	3	4	7	9	20
354	Yakima River at Ellensburg	1974-81	72	1	3	4	6	8	16	31
355	Yakima River at Umtanum	1974-81	72	1	3	5	7	10	14	25
320	Yakima River at Harrison Rd Bridge	1974-81	73	2	4	6	8	10	14	34
322	Yakima River-Terrace Heights Bridge	1974-81	73	1	4	5	7	10	14	29
337	Yakima River at bridge near Granger	1974-81	71	5	6	8	10	13	16	23
338	Yakima River at bridge near Mabton	1974-81	71	3	6	9	10	12	16	22
100	Yakima River at Kiona	1979-85	44	4	4	4	8	13	19	22
307	Chandler Canal--mile 0.6 nr Prosser	1974-81	58	5	7	9	11	15	22	29
308	Chandler Canal--mile 2.8 nr Prosser	1974-81	58	7	7	9	11	14	20	32
311	Satus Drain 302 NW1/4 Sec 34 9N 22E	1974-81	65	7	9	14	19	25	30	132
312	Cherry Cr SE 1/4 S 29 17N 19E	1974-79	53	0	8	12	15	20	24	55
313	Coleman Cr NW 1/4 S 20 17N 19E	1974-79	55	7	9	11	15	18	22	104
321	Naches River at Nelson Bridge	1974-81	73	1	3	4	6	8	12	75
323	Drain at Birchfield Road	1974-81	72	6	12	14	17	20	26	125
326	Wide Hollow Creek at Union Gap STP	1974-81	73	5	8	12	43	79	169	246
327	Ahtanum Creek at mouth	1974-81	72	4	7	8	10	14	18	53
328	Sulphur Cr at North above Sunnyside	1974-79	53	6	8	10	13	15	22	105
329	Sulphur Cr Wasteway at Factory Road	1974-79	55	5	9	10	13	16	19	164
332	Sulphur Cr Wasteway at Duffy Road	1974-79	55	6	10	12	14	18	21	187
333	Sulphur Cr Wasteway at Morse Road	1974-79	51	8	12	14	18	22	29	146
334	Sulphur Cr Wasteway at McGee Road	1974-81	71	6	11	14	16	21	32	172
335	Griffin Lake Inlet	1974-79	51	5	7	10	12	15	24	38
336	Griffin Lake Outlet	1974-79	46	8	15	19	22	25	30	35
339	East Toppenish Drain at Wilson Road	1974-81	67	4	7	9	11	14	17	19
340	Sub-Drain 35 at Parton Road	1974-81	67	2	5	6	8	11	13	17
341	Marion Drain at Highway 97	1974-81	67	2	6	7	9	11	13	17
342	Wanity Slough at Myers Road	1974-81	67	4	7	8	10	13	16	29
345	South Drain at Highway 22 nr Satus	1974-81	66	5	10	13	16	18	23	50
346	Granger Drain--Hwy 223 abv Granger	1974-81	71	2	11	15	19	26	37	222
347	Spring Creek at Hess Road	1974-81	65	9	11	12	16	18	22	37
348	Snipes Cr at Old Inland Empire Road	1974-81	62	5	8	9	12	18	23	35
352	Wipple Wasteway at Thrall Road	1974-79	54	7	10	11	14	18	23	26
353	Wilson Creek at Thrall Road	1974-81	58	5	8	11	13	16	21	38
	5-day Biochemical Oxygen Demand, in milligrams per liter [Data are shown for those sites having 10 or more observations]									
337	Yakima River at bridge near Granger	1975-79	27	.7	.9	1.1	1.4	2.3	2.9	3.8
338	Yakima River at bridge near Mabton	1975-79	28	.3	.8	1.1	1.3	2.1	2.6	4.7
297	Roza Main Canal at Beam Road	1975-79	22	.4	.5	.6	1.0	1.2	1.6	2.0
298	Sunnyside Canal at Beam Road	1975-79	19	.2	.5	.7	.9	1.1	1.6	1.6
328	Sulphur Cr at North above Sunnyside	1975-79	29	.4	.6	.7	1.0	1.4	2.7	6.0
329	Sulphur Cr Wasteway at Factory Road	1975-79	31	.4	.7	.9	1.2	1.7	2.2	3.5
330	Drain DID #3 at South Hill Road	1975-77	18	.6	2.2	3.8	4.8	6.1	9.1	10
331	Drain DID #3 at Duffy Road	1975-77	18	1.0	2.4	4.0	7.7	11.8	15.5	20.0
332	Sulphur Cr Wasteway at Duffy Road	1975-79	31	.3	.5	1.2	1.8	2.5	4.9	6.0
333	Sulphur Cr Wasteway at Morse Road	1975-79	30	.2	1.4	2.0	2.7	4.0	5.4	7.4
334	Sulphur Cr Wasteway at McGee Road	1975-79	31	.4	1.1	1.7	2.5	3.5	5.1	8.5
335	Griffin Lake Inlet	1975-79	31	.6	.9	1.1	1.5	2.3	3.3	5.3
336	Griffin Lake Outlet	1975-79	25	1.5	2.0	3.0	3.8	4.4	6.0	8.0
346	Granger Drain--Hwy 223 abv Granger	1975-79	28	.5	.8	1.2	2.0	3.0	5.9	12.0
356	Drain DID #3 abv Rendering Plant	1975-77	17	2.0	2.3	3.2	5.5	9.8	16.0	22.0

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile: 10	25	50 (median)	75	90	Maximum
	Dissolved calcium, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	5.7	6.4	6.9	8.2	9.5	12	12
6	Yakima River near Thorp	1975-75	24	1.9	4.6	5.0	7.6	10	12	14
27	Yakima River near Terrace Heights	1975-75	24	8.7	8.8	10	11	14	18	22
40	Yakima River at Parker	1975-75	24	7.3	8.2	10	12	15	17	19
48	Yakima River near Toppenish	1975-75	24	7.5	9.2	11	12	16	20	28
92	Yakima River at Mabton	1975-75	24	11	12	16	22	26	29	36
94	Yakima River at Prosser	1975-75	24	11	12	14	20	27	30	33
100	Yakima River at Kiona	1975-75	36	11	12	16	21	30	32	36
3	Cle Elum River near Cle Elum	1975-75	24	4.0	4.2	5.0	6.2	7.2	9.2	12
53	Marion Drain near Granger	1975-75	24	23	24	25	28	34	38	42
62	Toppenish Creek near Satus	1975-75	24	21	24	25	30	37	47	50
70	Satus Creek at Satus	1975-75	24	9.5	12	17	22	28	29	30
	Dissolved magnesium, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	.3	.6	.9	1.4	1.6	2.0	2.2
6	Yakima River near Thorp	1975-75	24	1.3	1.6	2.1	2.5	3.2	3.9	4.1
27	Yakima River near Terrace Heights	1975-75	24	2.5	2.6	2.9	3.4	4.4	5.8	6.1
40	Yakima River at Parker	1975-75	24	1.4	2.0	3.0	4.0	4.9	6.8	7.9
48	Yakima River near Toppenish	1975-75	24	2.1	2.6	3.2	4.4	5.6	6.8	7.4
92	Yakima River at Mabton	1975-75	24	3.0	3.4	5.2	7.7	9.7	11	11
94	Yakima River at Prosser	1975-75	24	2.9	4.0	5.9	7.7	9.9	11	11
100	Yakima River at Kiona	1975-75	36	3.8	4.1	5.2	7.7	10	11	12
3	Cle Elum River near Cle Elum	1975-75	24	.4	1.5	2.0	2.2	2.7	3.7	5.0
53	Marion Drain near Granger	1975-75	24	8.5	8.6	9.7	10	13	14	14
62	Toppenish Creek near Satus	1975-75	24	8.7	9.1	10	12	16	20	21
70	Satus Creek at Satus	1975-75	24	4.1	5.4	7.7	10	12	12	13
	Dissolved sodium, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	2.0	2.2	2.4	2.6	3.1	4.2	4.9
6	Yakima River near Thorp	1975-75	24	1.1	1.4	1.6	2.2	3.1	3.4	3.7
27	Yakima River near Terrace Heights	1975-75	24	2.7	3.1	3.6	4.8	5.5	8.0	8.6
40	Yakima River at Parker	1975-75	24	3.4	3.8	4.8	6.3	8.0	11	12
48	Yakima River near Toppenish	1975-75	24	2.1	3.5	4.4	6.6	8.4	10	12
92	Yakima River at Mabton	1975-75	24	5.7	6.8	8.9	12	17	18	19
94	Yakima River at Prosser	1975-75	24	4.8	6.4	7.8	12	18	20	21
100	Yakima River at Kiona	1975-75	36	5.6	6.7	8.6	12	19	20	21
3	Cle Elum River near Cle Elum	1975-75	24	.8	1.0	1.3	1.7	3.2	3.9	5.6
53	Marion Drain near Granger	1975-75	24	11	12	13	14	18	19	20
62	Toppenish Creek near Satus	1975-75	24	13	14	15	20	28	40	41
70	Satus Creek at Satus	1975-75	24	5.2	6.4	12	17	21	22	25
	Dissolved potassium, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	.3	.4	.5	.7	1.0	1.6	1.8
6	Yakima River near Thorp	1975-75	24	.1	.2	.2	.4	.4	.6	1.1
27	Yakima River near Terrace Heights	1975-75	24	.5	.6	1.0	1.2	2.0	5.0	6.4
40	Yakima River at Parker	1975-75	24	.6	.8	.9	1.3	1.6	2.2	2.7
48	Yakima River near Toppenish	1975-75	24	.6	.8	1.1	1.4	2.0	2.6	3.6
92	Yakima River at Mabton	1975-75	24	1.2	1.4	1.7	2.8	3.2	3.4	3.5
94	Yakima River at Prosser	1975-75	24	1.1	1.3	1.6	2.7	3.2	3.8	4.1
100	Yakima River at Kiona	1975-75	36	1.2	1.5	1.7	2.4	3.1	3.7	3.9
3	Cle Elum River near Cle Elum	1975-75	24	.2	.2	.2	.4	.6	.7	1.0
53	Marion Drain near Granger	1975-75	24	2.6	2.7	3.1	3.6	4.2	4.5	4.6
62	Toppenish Creek near Satus	1975-75	24	2.9	3.0	3.2	3.9	5.0	5.6	6.4
70	Satus Creek at Satus	1975-75	24	1.5	1.8	2.2	2.8	3.4	3.8	4.1
	Dissolved alkalinity, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	7	16	20	24	27	30	33
6	Yakima River near Thorp	1975-75	24	13	20	24	31	40	43	44
27	Yakima River near Terrace Heights	1975-75	24	29	32	37	43	54	67	71
40	Yakima River at Parker	1975-75	24	32	35	39	52	60	78	89
48	Yakima River near Toppenish	1975-75	24	33	36	39	53	60	78	88
92	Yakima River at Mabton	1975-75	24	45	51	59	88	113	117	126
94	Yakima River at Prosser	1975-75	24	46	50	59	90	118	124	131
100	Yakima River at Kiona	1975-75	36	47	53	62	88	123	137	142
3	Cle Elum River near Cle Elum	1975-75	24	9	17	21	26	31	39	48
53	Marion Drain near Granger	1975-75	24	100	103	111	117	148	151	154
62	Toppenish Creek near Satus	1975-75	24	98	110	119	138	172	236	242
70	Satus Creek at Satus	1975-75	24	42	55	94	119	138	147	162
422	Keechelus Lake	1975-75	15	12	12	14	15	16	19	19

Table 49.--Summary of selected instantaneous streamflow and water-quality constituent values at selected sites in the Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number	Site name	Water-year period	Number of observations	Minimum	Value at indicated percentile 10	25	50 (median)	75	90	Maximum
	Dissolved sulfate, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	0.5	1.2	1.8	2.2	2.8	3.4	9.7
6	Yakima River near Thorp	1975-75	23	.8	1.0	1.3	1.4	1.6	2.2	2.5
27	Yakima River near Terrace Heights	1975-75	24	1.8	1.8	2.2	3.1	4.7	5.6	5.8
40	Yakima River at Parker	1975-75	24	1.9	2.2	3.2	4.2	5.1	7.0	7.4
48	Yakima River near Toppenish	1975-75	24	1.8	2.3	3.6	4.4	5.8	6.9	7.9
92	Yakima River at Mabton	1975-75	24	3.1	4.3	7.6	12	16	17	19
94	Yakima River at Prosser	1975-75	24	3.7	4.3	7.1	11	15	18	21
100	Yakima River at Kiona	1975-75	36	4.3	5.6	7.8	10	18	20	21
3	Cle Elum River near Cle Elum	1975-75	24	.5	.5	.9	1.3	1.7	2.0	2.0
53	Marion Drain near Granger	1975-75	24	7.1	9.0	9.4	12	15	15	19
62	Toppenish Creek near Satus	1975-75	24	5.8	9.1	10	14	26	34	41
70	Satus Creek at Satus	1975-75	24	1.8	3.7	5.7	7.6	12	14	15
	Dissolved chloride, in milligrams per liter [1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	1.3	1.3	2.2	2.8	4.1	4.6	5.8
6	Yakima River near Thorp	1975-75	23	.3	.8	1.0	1.6	2.0	2.7	3.9
27	Yakima River near Terrace Heights	1975-75	24	.6	.8	1.5	2.2	2.8	3.3	4.1
40	Yakima River at Parker	1975-75	24	.8	1.3	2.0	2.8	3.8	5.0	5.5
48	Yakima River near Toppenish	1975-75	24	1.1	1.4	2.1	3.0	3.6	4.4	5.2
92	Yakima River at Mabton	1975-75	24	1.8	2.1	3.8	4.6	5.6	6.7	7.5
94	Yakima River at Prosser	1975-75	24	2.0	2.2	3.2	4.6	6.2	7.9	8.3
100	Yakima River at Kiona	1975-75	36	1.5	2.2	3.6	5.1	6.6	7.8	8.4
3	Cle Elum River near Cle Elum	1975-75	24	.1	.4	.8	1.0	1.1	1.7	2.6
53	Marion Drain near Granger	1975-75	24	3.5	3.8	4.4	4.8	5.7	6.5	7.0
62	Toppenish Creek near Satus	1975-75	24	3.4	4.0	4.7	6.6	11	15	16
70	Satus Creek at Satus	1975-75	24	1.1	1.8	3.2	4.0	5.1	6.4	6.6
	Fecal coliform bacteria, in colonies per 100 milliliters [Summary for sites with 5 or more observations in 1975 water year]									
1	Yakima River above Cle Elum	1975-75	24	1	1	1	2	4	11	160
349	Yakima River at Cle Elum	1975-75	5	2	2	2	2	5	5	5
6	Yakima River near Thorp	1975-75	23	1	1	2	2	5	17	30
354	Yakima River at Ellensburg	1975-75	5	8	8	27	70	180	230	230
355	Yakima River at Umtanum	1975-75	5	2	2	12	79	230	350	350
27	Yakima River near Terrace Heights	1975-75	24	<1	<1	2	17	45	132	230
40	Yakima River at Parker	1975-75	24	<1	1	4	60	128	180	370
48	Yakima River near Toppenish	1975-75	24	1	1	5	22	125	330	1,700
92	Yakima River at Mabton	1975-75	23	56	80	140	230	420	804	6,100
94	Yakima River at Prosser	1975-75	23	8	58	110	240	460	1220	2,300
100	Yakima River at Kiona	1975-75	34	25	62	80	135	245	400	1,500
101	Yakima River at Van Geisan Bridge	1975-75	23	<1	9	40	62	200	332	340
3	Cle Elum River near Cle Elum	1975-75	24	1	1	1	2	4	11	28
7	Wilson Creek at Thrall	1975-75	24	<1	22	128	370	555	2550	11,000
24	Naches River at Naches	1975-75	24	1	1	1	2	4	20	130
26	Naches River near North Yakima	1975-75	24	<1	<1	1	5	10	78	420
53	Marion Drain near Granger	1975-75	23	20	40	260	360	670	936	1,800
60	Toppenish Creek at Alfalfa	1975-75	11	5	5	55	140	280	494	530
62	Toppenish Creek near Satus	1975-75	23	5	6	100	280	350	620	1,600
70	Satus Creek at Satus	1975-75	23	1	8	50	120	230	388	2,100
312	Cherry Cr SE 1/4 S 29 17N 19E	1975-75	5	240	240	320	1,100	2,300	3,300	3,300
313	Coleman Cr NW 1/4 S 20 17N 19E	1975-75	5	130	130	230	920	9,150	17,000	17,000
329	Sulphur Cr Wasteway at Factory Road	1975-75	5	250	250	325	650	2,500	4,000	4,000
330	Drain DID #3 at South Hill Road	1975-75	5	<1	<1	<1	<1	3	5	5
331	Drain DID #3 at Duffy Road	1975-75	5	80	80	590	3,500	5,900	8,000	8,000
332	Sulphur Cr Wasteway at Duffy Road	1975-75	5	600	600	850	1,600	2,325	3,000	3,000
333	Sulphur Cr Wasteway at Morse Road	1975-75	5	750	750	1,005	1,800	7,425	10,800	10,800
334	Sulphur Cr Wasteway at McGee Road	1975-75	5	400	400	1,080	2,200	2,750	3,200	3,200
335	Griffin Lake Inlet	1975-75	5	150	150	525	1,200	1,950	2,100	2,100
350	Wilson Creek at Sanders Road	1975-75	5	490	490	895	3,300	5,950	7,000	7,000
351	Wilson Creek at Dammon Road	1975-75	5	230	230	765	1,700	6,400	7,900	7,900
352	Wipple Wastway at Thrall Road	1975-75	5	350	350	635	1,300	2,850	3,300	3,300
353	Wilson Creek at Thrall Road	1975-75	5	79	79	105	700	1,550	1,700	1,700
356	Drain DID #3 abv Rendering Plant	1975-75	5	4	4	5	14	23	25	25
	Dissolved silica, in milligrams per liter									
100	Yakima River at Kiona	1975-81	83	14	18	20	22	25	28	32

Table 50.--Regression models used to estimate constituent transport for selected sites in the Yakima River basin, Washington, 1974, 1977, and 1980 water years. (All available data collected from 1970-85 water years were used to calibrate the transport models shown in this table.)

[ln (C * Q * 0.0027) = I + a (TIME) + b (sine (2 * pi *TIME)) + c (cosina (2 * pi * TIME)) + d (ln (Q)): where ln is the natural logarithm; C is the constituent concentration in milligrams per liter; Q is streamflow in cubic feet per second; I is the regression intercept; a, b, c, and d are the regression coefficients; TIME is the date in decimal years minus 1960; pi is 3.141592; and RMSE is the root mean squsre error in percent; C * Q * 0.0027 = constituent load in tons per year; USGS = U.S. Geological Survey site; USBR = U.S. Bureau of Reclamation site; P80154 = parameter code for suspended sediment; P00530 = parameter code for total nonfilterable residue]

	Regression coefficients					RMSE		
Site name	I	a	b	c	d	1974	1977	1980
Dissolved solids (calculated sum of constituents) based on specific conductance								
Yakima River at Cle Elum	-1.772	0.000	0.111	0.117	0.925	7.6	7.2	7.5
Yakima River at Ellensburg	-1.107	.014	.125	.074	.857	9.9	9.5	10.2
Yakima river at Umtanum	.365	.000	.043	.057	.738	7.4	6.7	7.1
Naches River near Yakima	-.153	-.034	.055	.037	.848	6.7	4.1	5.5
Yakima River abv Ahtanum Creek	.291	.000	.056	.112	.774	5.8	4.3	5.0
Yakima River at Mabton (USGS)	2.118	-.023	-.102	.131	.659	5.7	4.1	5.4
Yakima River at Mabton (USBR)	.371	.314	-.136	.056	.754	11.7	9.7	11.2
Yakima River at Kiona	2.537	-.010	-.111	.080	.596	3.0	1.9	2.5
Dissolved solids (residue on evaporation at 180 degrees Celsius)								
Yakima River abv Ahtanum Creek	-.178	.000	-.013	.142	.831	11.6	10.1	10.9
Suspended sediment								
Yakima River at Cle Elum	-6.360	.000	.000	.000	1.264	14.2	12.4	13.0
Yakima River at Ellensburg	-9.345	.000	.702	.235	1.698	16.9	13.2	18.2
Yakima River at Umtanum	-9.235	.000	.644	.115	1.716	14.2	8.0	11.3
Naches River near Yakima	-9.416	.078	.000	.000	1.545	18.6	4.8	11.9
Yakima River abv Ahtanum Creek	-10.529	.000	.000	.000	1.968	9.6	2.4	5.5
Yakima River at Mabton (USGS)	-7.427	.000	.122	-.642	1.613	11.7	2.7	7.6
Yakima River at Mabton (USBR)	-4.937	.000	.453	-.488	1.256	22.9	9.7	17.7
Yakima River at Kiona P80154	-10.740	.024	-.002	-.367	1.988	9.4	1.1	5.8
Yakima River at Kiona P00530	-8.127	-.065	-.022	-.689	1.836	45.7	9.5	20.1
Totsl Phosphorus ss P								
Yakima River at Cle Elum	-9.385	-.062	.000	.000	1.068	19.9	14.3	13.3
Yakima River at Ellensburg	-11.225	.000	.377	.463	1.26	14.5	12.8	16.0
Yakima River at Umtanum	-9.128	.000	.228	.090	1.013	10.5	8.3	9.2
Naches River near Yakima	-10.927	-.028	.000	.000	1.269	10.1	3.4	6.5
Yakima River abv Ahtanum Creek	-8.784	-.061	-.110	.226	1.220	28.4	15.6	13.8
Yakima River at Mabton (USGS)	-7.721	.000	.000	.000	.964	12.9	9.6	11.2
Yakima River at Mabton (USBR)	-7.583	.000	.113	.155	.947	14.6	10.2	12.5
Yakima River at Kiona	-7.335	-.032	.000	.000	.980	5.7	2.5	3.9
Dissolved orthophosphate as P								
Yakima River at Cle Elum	-8.133	-.187	.000	.000	1.015	18.2	12.8	10.9
Yakima River at Ellensburg	-6.054	-.167	.049	.531	.783	26.0	19.2	21.6
Yakima River at Umtanum	-5.796	.000	.000	.000	.414	12.0	11.2	11.4
Naches River near Yakima	-8.294	-.125	.333	.170	.958	13.8	6.3	8.4
Yakima River at Mabton (USGS)	-5.464	-.070	-.054	.178	.729	12.7	12.9	18.4
Yakima River at Mabton (USBR)	-6.206	.057	.038	.244	.534	14.2	11.7	13.3
Yakima River at Kiona	-7.216	-.022	-.154	.156	.861	4.2	2.2	3.1
Dissolved phosphorus as P								
Yakima River abv Ahtanum Creek	-7.759	.000	.000	.000	.867	18.8	14.4	15.3
Total organic plus ammonia nitrogen as N								
Yakima River at Cle Elum	-3.940	.000	.059	-.596	.510	28.8	27.8	27.9
Yakima River at Umtanum	-9.354	.000	.000	.000	1.310	23.5	20.6	21.8
Naches River near Yakima	-8.292	.047	-.029	-.394	.987	23.1	15.2	19.0
Yakima River abv Ahtanum Creek	-7.374	.000	.000	.000	1.099	18.5	12.7	14.5
Yakima River at Mabton (USGS)	-9.470	.184	-.021	.309	.979	17.1	21.2	35.3
Yakima River at Kiona	-6.272	.058	.000	.000	.832	6.3	3.9	6.1
Dissolved ammonia as N								
Yakima River abv Ahtanum Creek	-9.097	.000	.302	.377	1.072	51.9	37.7	42.3
Total ammonia as N								
Yakima River at Cle Elum	-11.215	.113	.126	-.237	.798	12.3	10.4	10.8
Yakima River at Ellensburg	-8.264	.085	.000	.000	.560	20.3	16.6	20.2
Yakima River at Umtanum	-10.748	.115	.000	.000	.821	13.1	9.5	10.9
Naches River near Yakima	-10.328	.000	.000	.000	1.067	14.1	6.0	10.0
Yakima River at Mabton (USGS)	-10.886	.081	-.186	.411	1.187	21.1	20.6	39.5
Yakima River at Mabton (USBR)	-8.227	.085	.115	.546	.676	25.6	19.5	23.3
Yakima River at Kiona	-5.643	-.130	.220	.341	.891	11.4	5.2	6.6
Dissolved nitrite plus nitrate as N								
Yakima River at Cle Elum	-11.122	.065	.000	.000	1.062	13.3	10.4	10.7
Yakima River at Ellensburg	-8.192	.000	.347	.595	.910	16.3	15.6	18.3
Yakima River at Umtanum	-6.074	.098	.066	.274	.494	12.5	10.4	10.9
Naches River near Yakima	-7.521	-.032	.155	.223	.866	11.6	6.2	8.3
Yakima River abv Ahtanum Creek	-6.405	.000	-.114	.467	.854	18.8	15.2	15.7
Yakima River at Mabton (USGS)	-1.717	.000	.000	.000	.440	14.2	15.4	13.6
Yakima River at Mabton (USBR)	-4.148	.080	-.238	.123	.558	12.7	10.9	12.4
Yakima River at Kiona	-3.359	.013	-.212	.166	.624	4.5	3.2	4.0

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years

["*" = no flow adjustment made, Irr = based on data from irrigation season only, R^2 = coefficient of determination; the equation type corresponds to the equation numbers used by Crawford and others, 1983, p. 11-12]

Map reference number and site name	Period of record	Number of obser-vations	Non-flow adjusted: Prob-ability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Prob-ability level	Flow adjusted: Trend, percent change per year	Flow adjusted: R^2	Flow adjusted: Equa-tion type
Streamflow (unit = cubic feet per second)										
40 Yakima River at Parker	731018-810907	130	0.00	-182	-8.2	2,220	*	*	*	*
40 Yakima River at Parker	590831-850916	403	.10	27.4	1.5	1,780	*	*	*	*
100 Yakima River at Kiona	731018-810902	244	.00	-222	-9.2	2,400	*	*	*	*
100 Yakima River at Kiona	521211-850911	966	.31	-11.4	-.4	2,670	*	*	*	*
297 Roza Main Canal at Beam Road	740416-790813	33	.20	-25.0	-3.6	700	*	*	*	*
298 Sunnyside Canal at Beam Road	740416-790926	31	.11	-50.0	-5.9	850	*	*	*	*
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.01	-2.0	-14.8	13.5	*	*	*	*
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	54	.00	-36.4	-2.7	1,350	*	*	*	*
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	54	.00	-40.6	-3.0	1,340	*	*	*	*
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	66	.30	.2	2.1	9.5	*	*	*	*
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.20	-3.7	-7.4	50.0	*	*	*	*
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	54	.01	-3.3	-16.5	20.0	*	*	*	*
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.61	-.8	-11.4	7.0	*	*	*	*
320 Yakima River at Harrison Rd Bridge	740321-810916	71	1.00	.0	.0	1,030	*	*	*	*
321 Naches River at Nelson Bridge	740321-810915	71	.02	-84.7	-6.7	1,260	*	*	*	*
322 Yakima River-Terrace Heights Bridge	740321-810914	72	.03	-190	-6.7	2,850	*	*	*	*
323 Drain at Birchfield Road	740321-810915	73	.79	.0	.0	35.0	*	*	*	*
324 Wide Hollow Creek near Gromore	740321-770926	35	.48	-.3	-15.0	2.0	*	*	*	*
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.23	-2.5	-14.7	17.0	*	*	*	*
326 Wide Hollow Creek at Union Gap STP	740321-810915	74	.05	-1.2	-4.8	25.0	*	*	*	*
327 Ahtanum Creek at mouth	740415-810915	71	.39	-2.3	-5.0	46.0	*	*	*	*
328 Sulphur Cr at North above Sunnyside	740416-790926	54	.81	.0	.0	2.0	*	*	*	*
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.15	-3.8	-6.3	60.0	*	*	*	*
330 Drain DID #3 at South Hill Road	740319-770927	37	.48	.0	.0	22.5	*	*	*	*
331 Drain DID #3 at Duffy Road	740319-770927	35	1.00	.0	.0	35.0	*	*	*	*
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.04	-7.5	-7.5	100	*	*	*	*
333 Sulphur Cr Wasteway at Morse Road	740319-790926	54	.08	-10.0	-6.7	150	*	*	*	*
334 Sulphur Cr Wasteway at McGee Road	740319-810914	73	.54	-2.7	-1.5	182	*	*	*	*
335 Griffin Lake Inlet	740416-790926	52	.47	.0	.0	4.0	*	*	*	*
336 Griffin Lake Outlet	740416-790926	43	.00	-.6	-15.0	4.0	*	*	*	*
337 Yakima River at bridge near Granger	740521-810914	62	.05	-128	-8.2	1,550	*	*	*	*
338 Yakima River at bridge near Mabton	740522-810914	63	.49	-100	-4.5	2,200	*	*	*	*
339 East Toppenish Drain at Wilson Road	740320-810219	67	.04	-2.0	-10.0	20.0	*	*	*	*
340 Sub-Drain 35 at Parton Road	740320-810219	65	.62	.2	.6	33.0	*	*	*	*
341 Marion Drain at Highway 97	740320-810219	68	.00	-14.0	-8.0	175	*	*	*	*
342 Wanity Slough at Myers Road	740320-810219	68	.00	-10.0	-13.3	75.0	*	*	*	*
345 South Drain at Highway 22 nr Satus	740320-810219	64	.48	-.8	-1.6	50.0	*	*	*	*
346 Granger Drain--Hwy 223 abv Granger	740521-810914	71	.00	3.8	11.0	34.5	*	*	*	*
347 Spring Creek at Hess Road	740521-810219	65	.90	.0	.0	18.0	*	*	*	*
348 Snipes Cr at Old Inland Empire Road	740521-810219	63	.01	1.7	4.8	35.0	*	*	*	*
349 Yakima River at Cle Elum	740321-810916	68	.10	-101	-8.4	1,200	*	*	*	*
350 Wilson Creek at Sanders Road	740321-770926	36	.89	.0	.0	4.0	*	*	*	*
351 Wilson Creek at Dammon Road	740321-770926	36	.48	-1.7	-6.8	25.0	*	*	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.35	4.0	8.0	50.0	*	*	*	*
353 Wilson Creek at Thrall Road	740321-810916	57	.57	-1.7	-2.0	85.0	*	*	*	*
Stream temperature (unit = degrees Celsius)										
40 Yakima River at Parker	731018-810907	92	.94	-.025	-.2	10.5	0.29	-1.6	0.04	7
100 Yakima River at Kiona	731018-810902	96	.05	.200	1.7	11.6	.07	-1.7	.12	8
297 Roza Main Canal at Beam Road	740416-790813	33	1.00	.000	.0	13.0	.45	1.5	.38	7 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.91	.000	.0	14.5	.17	2.2	.59	7 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.46	.183	1.2	14.8	.11	4.3	.11	6
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	53	.01	.300	2.2	13.7	.01	2.2	*	* (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	51	.01	.290	2.1	14.0	.01	2.1	*	* (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.11	.245	2.0	12.1	.35	2.3	.50	7
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.27	.100	1.0	9.6	.19	3.0	.18	3
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	53	.60	.100	1.1	9.3	.60	1.1	*	*
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.47	.400	3.1	12.8	.46	1.6	.20	8
320 Yakima River at Harrison Rd Bridge	740321-810916	70	.02	.313	3.3	9.3	.02	3.3	*	*
321 Naches River at Nelson Bridge	740321-810915	69	.39	.159	1.6	9.8	.39	1.8	*	*
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.03	.171	1.9	9.0	.01	4.5	.12	5
323 Drain at Birchfield Road	740321-810915	71	.92	.000	.0	12.5	.89	0.5	.21	4.5
324 Wide Hollow Creek near Gromore	740321-770926	35	.69	.300	2.0	14.8	.14	6.8	.15	8
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	1.00	.000	.0	12.8	.30	2.5	.16	8
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.43	-.050	-.4	12.5	.33	.7	.07	8
327 Ahtanum Creek at mouth	740321-810915	70	.79	.000	.0	11.2	.80	-.2	.08	8

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of observations	Non-flow adjusted: Probability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Probability level	Flow adjusted: Trend, percent change per year	R^2	Equation type
Stream temperature (unit = degrees Celsius)										
328 Sulphur Cr at North above Sunnyside	740416-790926	52	0.48	-0.087	-0.7	12.0	1.0	-0.3	0.25	7
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.34	-.075	-.6	12.0	.47	2.5	.22	4.4
330 Drain DID #3 at South Hill Road	740319-770927	37	.30	-.200	-1.5	13.2	.90	-.8	.19	5
331 Drain DID #3 at Duffy Road	740319-770927	35	1.00	.000	.0	13.1	.57	5.2	.18	6
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.66	-.066	-.5	12.1	.77	1.3	.28	7
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.65	-.050	-.4	12.0	.55	1.9	.26	7
334 Sulphur Cr Wasteway at McGee Road	740319-810914	72	.02	.250	2.0	12.7	.03	2.8	.21	4.1
335 Griffin Lake Inlet	740416-790926	51	.94	.050	.4	13.5	.94	1.9	*	*
336 Griffin Lake Outlet	740416-790926	38	.51	.199	1.2	16.6	.67	3.3	.08	8
337 Yakima River at bridge near Granger	740320-810914	62	.05	.299	2.7	11.0	.90	.0	.31	4.8
338 Yakima River at bridge near Mabton	740320-810914	63	.04	.355	2.8	12.8	.24	1.8	.09	4.6
339 East Toppenish Drain at Wilson Road	740320-810219	66	.24	.100	.8	12.8	.02	2.2	.17	8
340 Sub-Drain 35 at Parton Road	740320-810219	64	.04	.183	1.5	12.5	.10	1.6	.31	4.3
341 Marion Drain at Highway 97	740320-810219	66	.35	.133	1.1	12.0	.05	2.4	.08	8
342 Wanity Slough at Myers Road	740320-810219	67	.16	.229	1.9	12.2	.16	1.9	*	*
345 South Drain at Highway 22 nr Satus	740320-810219	63	.53	.050	.4	12.0	.46	1.7	.45	6
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.00	.360	3.0	12.0	.35	1.0	.07	7
347 Spring Creek at Hess Road	740521-810219	63	.09	.167	1.3	13.0	.46	2.0	.10	7
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.43	.100	.7	13.8	.40	-1.1	.22	7
349 Yakima River at Cle Elum	740321-810916	67	.17	.175	2.0	8.8	.13	2.4	.25	4.5
350 Wilson Creek at Sanders Road	740321-770926	36	1.00	.250	2.6	9.5	.02	-1.4	.14	8
351 Wilson Creek at Dammon Road	740321-770926	36	1.00	.000	.0	9.8	1.00	.0	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.94	.000	.0	10.0	.76	-0.7	.28	3
353 Wilson Creek at Thrall Road	740321-810916	57	.07	.200	2.0	9.8	.78	1.1	.16	4.5
Specific conductance (unit = microsiemens per centimeter at 25 degrees Celsius)										
40 Yakima River at Parker	731018-810907	92	.73	.33	.3	130	.01	-2.1	.35	3
100 Yakima River at Kiona	731018-810902	93	.74	1.4	.5	265	.00	-1.7	.75	8
297 Roza Main Canal at Beam Road	740416-790813	33	.28	2.6	2.5	103	.60	1.4	.60	4.5(Irr)
298 Sunnyside Canal at Beam Road	740416-790926	31	.45	1.5	1.4	106	.66	.36	.45	6 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.07	18.4	3.5	518	.07	-2.4	.58	4.5
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	53	.02	8.0	3.4	236	.50	1.1	.20	6 (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	52	.06	6.5	2.6	246	.88	.4	.26	6 (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.05	12.0	3.1	386	.03	5.9	.65	7
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.03	7.7	2.5	301	.59	.6	.24	4.4
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-770815	54	.34	3.6	1.8	198	.88	.0	.22	4.7
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	1.00	-.5	-.2	282	.05	-4.1	.20	4.6
320 Yakima River at Harrison Rd Bridge	740321-810916	70	.03	2.5	2.1	120	.32	1.3	.25	4.6
321 Naches River at Nelson Bridge	740321-810915	70	.16	1.0	1.3	76	.64	.4	.45	7
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.00	3.3	3.3	100	.01	1.7	.53	4.7
323 Drain at Birchfield Road	740321-810915	70	.10	-5.6	-1.6	358	.96	-.2	.42	4.5
324 Wide Hollow Creek near Gromore	740321-770926	35	.51	13.0	3.8	341	.51	-1.5	.47	7
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.44	-11.0	-3.8	286	.07	-7.0	.26	7
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.00	-73.1	-12.1	605	.00	-13.8	.04	7
327 Ahtanum Creek at mouth	740321-810915	70	.32	2.9	1.0	294	.64	.6	.53	7
328 Sulphur Cr at North above Sunnyside	740416-790926	54	.88	1.3	.3	420	.24	2.2	.31	4.5
329 Sulphur Cr Wasteway at Factory Road	740319-790926	54	.23	7.0	2.6	272	.66	1.8	.60	3
330 Drain DID #3 at South Hill Road	740319-770927	37	1.00	2.3	.4	525	.61	-1.0	.31	8
331 Drain DID #3 at Duffy Road	740319-770927	35	.48	-8.0	-1.6	499	1.00	.1	.34	4.6
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.25	10.3	2.6	392	.47	-1.3	.63	6
333 Sulphur Cr Wasteway at Morse Road	740319-790926	54	.06	13.3	3.4	389	.15	-2.2	.58	4.5
334 Sulphur Cr Wasteway at McGee Road	740319-810914	72	.73	2.2	.6	377	.46	.9	.44	2
335 Griffin Lake Inlet	740416-790926	51	.01	17.5	4.9	358	.01	4.4	.03	7
336 Griffin Lake Outlet	740416-790926	42	.20	7.0	2.0	356	.69	-.5	.23	8
337 Yakima River at bridge near Granger	740320-810914	62	.00	13.3	7.3	182	.00	4.8	.24	7
338 Yakima River at bridge near Mabton	740320-810914	63	.00	6.5	2.7	244	.01	2.2	.70	8
339 East Toppenish Drain at Wilson Road	740320-810219	66	.68	2.0	.7	294	.22	-1.1	.30	3
340 Sub-Drain 35 at Parton Road	740320-810219	64	.10	-1.9	-.7	284	.13	-.7	.28	2
341 Marion Drain at Highway 97	740320-810219	67	.08	2.4	.8	296	.28	-.6	.30	2
342 Wanity Slough at Myers Road	740320-810219	67	.37	2.0	1.1	187	.10	-1.3	.25	7
345 South Drain at Highway 22 nr Satus	740320-810219	63	.71	-1.8	-.5	386	.39	-.8	.76	4.5
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.12	5.8	1.2	475	.00	4.0	.12	7
347 Spring Creek at Hess Road	740521-810219	62	.66	-2.6	-.8	320	.75	.6	.59	4.5
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.33	-4.1	-2.0	205	.06	7.0	.67	3
349 Yakima River at Cle Elum	740321-810916	67	.01	2.7	4.3	62	.47	.8	.35	4.5
350 Wilson Creek at Sanders Road	740321-770926	36	.69	-5.0	-3.5	143	1.00	.9	.39	8
351 Wilson Creek at Dammon Road	740321-770926	36	.43	-3.0	-1.4	207	.60	-.3	.15	7
352 Wipple Wasteway at Thrall Road	740321-790815	53	.36	-3.0	-.9	330	.76	2.0	.44	4.4
353 Wilson Creek at Thrall Road	740321-810916	57	.02	4.8	2.3	210	.09	2.1	.12	4.8

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of observations	Non-flow adjusted: Probability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Non-flow adjusted: Median units	Flow adjusted: Probability level	Flow adjusted: Trend, percent change per year	Flow adjusted: R^2	Flow adjusted: Equation type
Turbidity (unit = Nephelometric Turbidity Unit)										
40 Yakima River at Parker	731018-810907	92	0.32	0.000	0.0	6	0.71	0.6	0.46	8
100 Yakima River at Kiona	731018-810902	96	.04	-.554	-7.9	7	.21	-4.7	.32	8
297 Roza Main Canal at Beam Road	740416-790813	33	.11	-.292	-9.7	3	.04	-14.2	.10	7 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.01	-.750	-15.0	5	.01	-15.0	*	* (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	42	.42	.000	.0	3	.02	20.5	.22	7
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	52	.58	-.200	-2.9	7	.58	-2.9	*	* (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	51	.87	.000	.0	8	.87	.0	*	* (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.81	.000	.0	8	.41	-3.7	.37	8
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.16	-.583	-9.7	6	.32	-9.5	.10	7
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-770815	53	.05	-.633	-12.7	5	.23	-6.5	.05	8
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.32	-.333	-11.1	3	.63	-14.1	.13	7
320 Yakima River at Harrison Rd Bridge	740321-810916	67	.14	.000	.0	2	.33	-4.9	.19	8
321 Naches River at Nelson Bridge	740321-810915	70	.12	.000	.0	2	.50	2.2	.39	8
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.31	.000	.0	3	.51	2.2	.30	8
323 Drain at Birchfield Road	740321-810915	70	.80	.333	2.0	16	.57	-2.9	.18	8
324 Wide Hollow Creek near Gromore	740321-770926	35	.38	.000	.0	2	.18	-9.4	.18	6
325 Wide Hollow Cr at W. Washington Ave	740321-770926	36	.68	.000	.0	3	.90	3.1	.13	7
326 Wide Hollow Creek at Union Gap STP	740321-810915	72	.00	-2.000	-22.2	9	.00	-23.5	*	*
327 Ahtanum Creek at mouth	740321-810915	70	.02	-.333	-11.1	3	.35	-2.4	.43	8
328 Sulphur Cr at North above Sunnyside	740416-790926	52	.01	-1.000	-16.7	6	.04	-19.0	.10	8
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.00	-1.667	-15.2	11	.00	-18.4	.02	7
330 Drain DID #3 at South Hill Road	740319-770927	37	.12	-3.000	-10.7	28	.15	-10.0	.05	7
331 Drain DID #3 at Duffy Road	740319-770927	35	.04	-4.000	-16.7	24	.57	-5.7	.12	6
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.03	-1.500	-12.5	12	.03	-10.3	.08	7
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.01	-1.450	-9.7	15	.09	-8.1	.07	7
334 Sulphur Cr Wasteway at McGee Road	740319-810914	71	.08	-1.000	-7.7	13	.07	-8.0	.08	8
335 Griffin Lake Inlet	740416-790926	51	1.00	.000	.0	8	1.00	-.0	*	*
336 Griffin Lake Outlet	740416-790926	38	.00	-3.000	-27.3	11	.00	-28.6	*	*
337 Yakima River at bridge near Granger	740320-810914	62	.58	.000	.0	6	.33	7.0	.00	8
338 Yakima River at bridge near Mabton	740320-810914	62	.40	-.267	-4.4	6	1.00	.0	.30	8
339 East Toppenish Drain at Wilson Road	740320-810219	65	.18	.000	.0	3	.23	-2.5	.03	7
340 Sub-Drain 35 at Parton Road	740320-810219	63	.00	-.400	-13.3	3	.03	-12.1	.07	7
341 Marion Drain at Highway 97	740320-810219	67	.15	-.291	-7.3	4	.78	2.1	.22	6
342 Wanity Slough at Myers Road	740320-810219	67	.45	.000	.0	5	.80	.4	.09	7
345 South Drain at Highway 22 nr Satus	740320-810219	63	.08	-.333	-3.7	9	.42	-3.8	.40	8
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.20	-.667	-3.7	18	.00	-12.0	.06	7
347 Spring Creek at Hess Road	740521-810219	61	.03	-1.083	-12.0	9	.06	-13.4	.38	7
348 Snipes Cr at Old Inland Empire Road	740521-810219	60	.00	-1.000	-16.7	6	.02	-18.9	.24	7
349 Yakima River at Cle Elum	740321-810916	60	.01	-.100	-10.0	1	.10	-10.3	.12	7
350 Wilson Creek at Sanders Road	740321-770926	36	.11	-1.000	-33.3	3	.19	-17.8	.12	8
351 Wilson Creek at Dammon Road	740321-770926	36	.79	.000	.0	3	.79	.0	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.10	-.500	-8.3	6	.00	-16.2	.23	7
353 Wilson Creek at Thrall Road	740321-810916	57	.47	.000	.0	4	.47	.0	*	*
Suspended sediment (unit = milligrams per liter)										
40 Yakima River at Parker	740508-810907	34	.77	1.500	7.9	19	.02	21.4	.43	8
100 Yakima River at Kiona	741022-810902	82	.72	-.792	-3.0	26	.12	5.1	.44	8
297 Roza Main Canal at Beam Road	740416-790813	32	.11	-1.000	-9.1	11	.91	1.0	.35	8 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.73	-.400	-2.0	20	.82	7.5	.05	2 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.67	.417	4.2	10	.02	22.9	.19	8
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	53	.08	1.708	5.9	29	.08	6.1	*	* (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	52	.31	1.200	4.3	28	.31	4.3	*	* (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.64	-.533	-2.0	27	.45	-5.7	.36	8
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.88	-.567	-1.9	30	.82	-1.0	.04	7
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	53	.41	-1.167	-5.6	21	.37	-4.8	.08	8
319 Cottonwood Canal Drain SE1/4 Sec 28	731018-770926	39	.54	-1.500	-18.8	8	.33	-12.6	.19	8
320 Yakima River at Harrison Rd Bridge	740321-810916	70	.27	.417	4.2	10	.02	11.7	.32	8
321 Naches River at Nelson Bridge	740321-810915	70	.00	1.000	20.0	5	.00	29.4	.22	8
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.60	.250	2.5	10	.05	10.1	.29	7
323 Drain at Birchfield Road	740321-810915	69	.67	-.786	-1.3	60	.95	-.5	.28	6
324 Wide Hollow Creek near Gromore	740321-770926	35	.14	-2.000	-33.3	6	.14	-23.0	.16	8
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.51	-1.000	-12.5	8	.80	6.7	.12	7
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.10	-1.200	-6.3	19	.09	-6.9	.18	8
327 Ahtanum Creek at mouth	740321-810915	70	.67	-.083	-.5	16	.19	5.0	.48	8
328 Sulphur Cr at North above Sunnyside	740416-790926	52	.03	-5.000	-19.2	26	.06	-23.6	.02	8

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of obser-vations	Non-flow adjusted: Prob-ability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Prob-ability level	Flow adjusted: Trend, percent change per year	R^2	Equa-tion type
Suspended sediment (unit = milligrams per liter)										
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	0.01	-6.000	-14.3	42	0.01	-16.6	0.04	7
330 Drain DID #3 at South Hill Road	740319-770927	37	.61	7.000	6.9	102	.61	6.9	*	*
331 Drain DID #3 at Duffy Roed	740319-770927	35	.78	26.000	20.6	126	.09	25.0	.01	6
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.06	-4.500	-8.0	56	.11	-8.4	.04	7
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.29	-3.625	-6.1	59	.41	-3.8	.06	7
334 Sulphur Cr Wasteway et McGee Road	740319-810914	67	.02	-4.083	-9.1	45	.02	-11.8	.24	8
335 Griffin Lake Inlet	740416-790926	51	.42	-1.292	-3.9	33	.42	-3.9	*	*
336 Griffin Lake Outlet	740416-790926	38	.23	-1.800	-7.5	24	.23	-7.5	*	*
337 Yakima River at bridge near Granger	740320-810914	62	.05	2.500	11.4	22	.05	9.6	*	*
338 Yakima River at bridge near Mabton	740320-810914	63	1.00	.000	.0	23	.13	7.6	.14	8
339 East Toppenish Drain et Wilson Road	740320-810219	66	.32	.550	4.6	12	.27	5.4	.09	4.5
340 Sub-Drain 35 at Parton Road	740320-810219	64	.76	.000	.0	17	.76	.0	*	*
341 Marion Drain at Highway 97	740320-810219	67	.32	-.417	-2.2	19	.32	2.2	*	*
342 Wanity Slough at Myers Road	740320-810219	67	.42	.500	2.8	18	.10	8.4	.03	4.2
345 South Drain at Highway 22 nr Satus	740320-810219	63	.75	.000	.0	32	.67	1.0	.50	7
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.19	-3.333	-4.4	76	.19	-4.0	*	*
347 Spring Creek at Hess Road	740521-810219	63	.05	-1.500	-3.9	38	.11	-6.7	.41	7
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.02	-4.100	-15.8	26	.01	-16.8	.26	8
349 Yakima River at Cle Elum	740321-810916	64	.71	.000	.0	4	.41	3.8	.03	6
350 Wilson Creek at Sanders Road	740321-770926	36	.43	-1.500	-21.4	7	.30	-21.0	.11	7
351 Wilson Creek at Dammon Road	740321-770926	36	1.00	.000	.0	7	1.00	.0	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.01	-2.333	-9.7	24	.00	-20.9	.30	7
353 Wilson Creek at Thrall Road	740321-810916	57	.89	.000	.0	12	.89	1.3	.02	7
Total phosphorus as phosphorus (unit = milligrams per liter)										
40 Yakima River at Parker	731018-810907	91	.00	-.005	-6.2	.08	.00	-5.5	.00	7
100 Yakima at Kiona	731018-810902	96	.66	.000	.0	.13	.20	-1.3	.11	8
297 Roza Main Canal at Beam Road	740416-790813	33	.66	.000	.0	.04	.66	.0	*	* (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.65	.003	4.3	.07	.17	6.0	.09	7 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.28	.005	7.1	.07	.00	18.0	.10	8
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	53	.01	.010	7.7	.13	.26	2.8	.15	6 (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	52	.19	.005	3.6	.14	.08	-7.5	.17	2 (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.44	-.005	-2.4	.21	.56	-1.4	.14	7
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.94	.000	.0	.21	.94	-.1	.03	7
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	53	.16	.003	2.5	.12	.16	.1	*	*
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.03	-.010	-7.7	.13	.03	.1	*	*
320 Yakima River at Harrison Rd Bridge	740321-810916	70	.21	.001	2.5	.04	.44	3.0	.03	2
321 Naches River at Nelson Bridge	740321-810915	70	.43	-.0004	-2.0	.02	.57	-1.7	.12	8
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.25	-.003	-7.5	.04	.47	2.0	.04	3
323 Drain at Birchfield Road	740321-810915	71	.24	-.007	-1.8	.38	.24	-1.4	*	*
324 Wide Hollow Creek near Gromore	740321-770926	35	.20	-.005	-2.8	0.18	.69	1.4	.16	7
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.23	-.005	-4.2	.12	.13	-3.9	.22	4.8
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.00	-.158	-19.5	.81	.00	-22.4	.00	3
327 Ahtanum Creek at mouth	740321-810915	70	.20	-.003	-2.3	.13	.28	-1.7	.06	8
328 Sulphur Cr at North abv Sunnyside	740416-790926	52	.09	-.010	-7.1	.14	.09	-7.1	*	*
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.09	-.010	-6.7	.15	.09	-6.7	*	*
330 Drain DID #3 at South Hill Road	740319-770927	37	.52	-.010	-.7	1.4	.61	-.9	.17	7
331 Drain DID #3 at Duffy Road	740319-770927	35	1.00	-.003	-.3	1.1	1.00	-.3	*	*
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.03	-.020	-9.1	.22	.03	.2	*	*
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.60	-.008	-2.6	.31	.60	-2.7	*	*
334 Sulphur Cr Wasteway at McGee Road	740319-810914	71	.05	-.015	-5.2	.29	.06	-4.0	.00	2
335 Griffin Lake Inlet	740416-790926	50	.23	.005	1.7	.29	.31	2.4	.10	5
336 Griffin Lake Outlet	740416-790926	38	.06	-.008	-4.0	.20	.06	-3.8	*	*
337 Yakima River at bridge near Granger	740320-810914	62	.01	.006	5.5	.11	.05	4.6	.05	8
338 Yakima River at bridge near Mabton	740320-810914	63	.35	.002	1.7	.12	.30	2.3	.00	8
339 East Toppenish Drain at Wilson Road	740320-810219	66	.91	.000	.0	.36	.09	-5.6	.38	8
340 Sub-Drain 35 at Parton Road	740320-810219	64	.27	-.003	3.8	.08	.40	-2.9	.09	7
341 Marion Drain at Highway 97	740320-810219	67	1.00	.000	.0	.14	.61	.4	.02	2
342 Wanity Slough at Myers Road	740320-810219	67	.39	-.001	-.9	.11	.40	-1.3	.00	7
345 South Drain at Highway 22 nr Satus	740320-810219	63	.76	.003	1.4	.22	.76	.5	.03	8
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.19	-.015	-3.6	.42	.04	-4.8	.00	5
347 Spring Creek at Hess Road	740521-810219	63	.32	-.007	-4.7	.15	.32	-3.5	.20	7
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.10	-.007	-7.0	.10	.08	-11.9	.01	4.5
349 Yakima River at Cle Elum	740321-810916	67	.87	.000	.0	.02	1.00	-.1	.00	2
350 Wilson Creek at Sanders Road	740321-770926	35	.67	.000	.0	.09	.67	.0	*	*
351 Wilson Creek at Dammon Road	740321-770926	36	.44	-.010	-10.0	.10	.44	-10.0	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.94	-.003	-1.4	.21	.45	-2.3	.03	7
353 Wilson Creek at Thrall Road	740321-810916	57	.84	.000	.0	.12	.94	.0	.00	4.3

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of observations	Non-flow adjusted: Probability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Probability level	Flow adjusted: Trend, percent change per year	R^2	Equation type
Dissolved orthophosphate as phosphorus (unit = milligrams per liter)										
40 Yakima River at Parker	731018-810907	90	0.17	0.000	0.0	0.04	0.00	-7.1	0.41	4.7
100 Yakima River at Kiona	731018-810902	52	.85	.000	.0	.08	.35	-1.1	.00	3
297 Roza Main Canal at Beam Road	740416-790813	33	.74	.000	.0	.02	.83	-2.2	.12	6 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.07	.0005	1.7	.03	.07	1.7	*	* (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	42	.01	.005	25.0	.02	.02	20.4	*	*
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	53	.00	.004	8.0	.05	.11	4.0	.08	2 (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	51	.05	.003	5.0	.06	.88	.4	.04	2 (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.86	.000	.0	.09	.86	.0	*	*
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.58	.000	.0	.11	.58	.0	*	*
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	53	.01	.005	8.3	.06	.10	6.1	.03	7
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.07	-.010	-11.1	.09	.07	-11.1	*	*
320 Yakima River at Harrison Rd Bridge	740321-810916	70	.08	.001	5.0	.02	.08	2.9	*	*
321 Naches River at Nelson Bridge	740321-810915	70	.19	-.001	-10.0	.01	.19	-12.4	*	*
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.75	.000	.0	.01	.18	-5.0	.08	8
323 Drain at Birchfield Road	740321-810915	71	1.00	.000	.0	.19	.76	-.5	.20	7
324 Wide Hollow Creek near Gromore	740321-770926	35	.50	-.008	-5.7	.14	.89	-0.6	.10	7
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.58	.000	.0	.08	.05	-9.9	.23	8
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.00	-.096	- 21.8	.44	.00	-30.7	.05	4.5
327 Ahtanum Creek at mouth	740321-810915	70	.63	.000	.0	.09	.25	-1.8	.42	7
328 Sulphur Cr at North above Sunnyside	740416-790926	52	1.00	.000	.0	.07	1.00	.0	*	*
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.34	.002	3.3	.06	.77	-.8	.19	8
330 Drain DID #3 at South Hill Road	740319-770927	37	1.00	-.010	-1.3	.78	.61	-.9	.41	7
331 Drain DID #3 at Duffy Road	740319-770927	35	.47	.013	2.8	.47	.48	3.3	.41	8
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.71	.000	.0	.08	.15	-5.7	.04	6
333 Sulphur Cr Wasteway at Morse Road	730319-790926	53	.07	.010	6.7	.15	.60	1.3	.08	6
334 Sulphur Cr Wasteway at McGee Road	740319-810914	71	.00	.006	3.8	.16	.01	3.0	.07	6
335 Griffin Lake Inlet	740416-790926	51	.04	.014	8.2	.17	.04	8.1	*	*
336 Griffin Lake Outlet	740416-790926	38	.44	.003	7.5	.04	.39	10.9	.00	4
337 Yakima River at bridge near Granger	740320-810914	62	.00	.004	8.0	.05	.02	8.3	.13	7
338 Yakima River at bridge near Mabton	740320-810914	63	.03	.003	5.0	.06	.06	4.0	.40	8
339 East Toppenish Drain at Wilson Road	740320-810219	66	.20	.010	3.8	.26	.27	-4.5	.26	8
340 Sub-Drain 35 at Parton Road	740320-810219	64	.50	-.0003	-.7	.04	.90	-.4	.15	8
341 Marion Drain at Highway 97	740320-810219	67	.42	.000	.1	.09	.57	1.0	.05	7
342 Wanity Slough at Myers Road	740320-810219	67	.73	-.0002	-.4	.05	.73	.4	*	*
345 South Drain at Highway 22 nr Satus	740320-810219	63	.48	.000	.0	.12	.42	-.7	.39	8
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.03	.005	2.8	.18	0.03	2.8	*	*
347 Spring Creek at Hess Road	740521-810219	63	.80	.000	.0	.06	.80	.0	*	*
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.55	.001	3.3	.03	.16	5.0	.72	7
349 Yakima River at Cle Elum	740321-810916	67	.12	.000	<10.0	<.1	.12	5.6	*	*
350 Wilson Creek at Sanders Road	740321-770926	36	1.00	.000	.0	.04	1.00	.0	.00	3
351 Wilson Creek at Dammon Road	740321-770926	36	1.00	.000	.0	.05	.60	3.7	.04	8
352 Wipple Wasteway at Thrall Road	740321-790815	53	1.00	.000	.0	.17	.70	.6	.01	7
353 Wilson Creek at Thrall Road	740321-810916	57	.03	.004	6.7	.06	.03	7.2	*	*
Suspended phosphorus as phosphorus (calculated as follows: total phosphorus minus orthophosphate, unit = milligrams per liter)										
40 Yakima River at Parker	731018-810907	75	.38	.000	.0	.04	.50	2.1	.13	8
100 Yakima River at Kiona	731018-810902	95	.14	-.003	-6.0	.05	.19	-3.0	.27	8
297 Roza Main Canal at Beam Road	740416-790813	33	.51	-.002	-6.7	.03	.82	-.3	.11	8 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	1.0	.000	.0	.04	.49	2.9	.06	5 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	42	.83	.002	5.0	.04	.22	15.6	.16	7
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	52	.21	.006	7.5	.08	.87	.7	.10	7 (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	51	.53	.003	4.3	.07	.88	.4	.01	8 (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	65	.37	-.003	-2.5	.12	.36	-5.9	.23	7
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.06	-.005	-7.1	.07	.40	-4.3	.06	8
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-770815	53	.49	-.004	-6.7	.06	1.00	.0	.04	7
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.45	-.005	-10.0	.05	.45	-10.0	*	*
320 Yakima River at Harrison Rd Bridge	740321-810916	68	.96	.000	.0	.03	.75	1.8	.07	7
321 Naches River at Nelson Bridge	740321-810915	70	.75	-.0001	-.3	.02	.44	6.0	.14	4.5
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.04	-.001	-5.0	.02	.76	1.4	.11	7
323 Drain at Birchfield Road	740321-810915	70	.05	-.006	-4.3	.14	.03	-8.6	.14	7
324 Wide Hollow Creek near Gromore	740321-770926	35	.48	-.002	-5.0	.04	.48	-4.2	*	*
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.50	.000	.0	.04	.50	.0	*	*
326 Wide Hollow Creek at Union Gap STP	740321-810915	72	.00	-.061	-25.4	.24	.00	-24.3	.00	6
327 Ahtanum Creek at mouth	740321-810915	70	.09	-.003	-7.5	.04	.44	-2.4	.19	7
328 Sulphur Cr at North above Sunnyside	740416-790926	52	.04	-.010	-16.7	.06	.04	-17.1	*	*

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of observations	Non-flow adjusted: Probability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Probability level	Flow adjusted: Trend, percent change per year	R^2	Equation type
Suspended phosphorus as phosphorus (calculated as follows: total phosphorus minus orthophosphate, unit = milligrams per liter)										
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	0.01	-0.010	-12.5	0.08	0.01	-12.5	*	*
330 Drain DID #3 at South Hill Road	740319-770927	37	.90	.005	1.2	.43	.90	1.2	*	*
331 Drain DID #3 at Duffy Road	740319-770927	35	.78	-.010	-2.3	.43	.78	-2.3	*	*
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.01	-.018	-13.8	.13	.00	-16.7	0.01	7
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.01	-.015	-10.7	.14	.01	-10.7	*	*
334 Sulphur Cr Wasteway at McGee Road	740319-810914	70	.00	-.014	-11.7	.12	.00	-11.2	*	*
335 Griffin Lake Inlet	740416-790926	50	.86	.000	.0	.08	.86	.0	*	*
336 Griffin Lake Outlet	740416-790926	38	.03	-.010	-6.7	.15	.03	-6.7	*	*
337 Yakima River at bridge near Granger	740320-810914	62	.63	.002	3.3	.06	.81	1.4	.03	8
338 Yakima River at bridge near Mabton	740320-810914	62	.48	-.001	-2.0	.05	.95	-.7	.05	3
339 East Toppenish Drain at Wilson Road	740320-810219	66	.29	-.007	-7.8	.09	.05	-10.0	.07	4.6
340 Sub-Drain 35 at Parton Road	740320-810219	64	.22	-.002	-5.0	.04	.29	-5.4	.04	7
341 Marion Drain at Highway 97	740320-810219	67	.21	-.002	-4.0	.05	.46	3.4	.11	3
342 Wanity Slough at Myers Road	740320-810219	67	.39	-.001	-1.7	.06	.77	-1.9	.01	8
345 South Drain at Highway 22 nr Satus	740320-810219	63	1.00	.000	.0	.09	1.00	.1	.29	7
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.02	-.018	-9.5	.19	.00	-11.6	.00	2
347 Spring Creek at Hess Road	740521-810219	62	.16	-.008	-8.9	.09	.75	-3.3	.18	3
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.02	-.005	-7.1	.07	.01	-12.6	.12	7
349 Yakima River at Cle Elum	740321-810916	66	.82	.000	.0	.01	1.00	.9	.01	3
350 Wilson Creek at Sanders Road	740321-770926	35	.41	-.009	-18.0	.05	.41	-17.0	*	*
351 Wilson Creek at Dammon Road	740321-770926	36	.79	.004	10.0	.04	.51	7.7	.38	6
352 Wipple Wasteway at Thrall Road	740321-790815	53	.36	-.003	-5.0	.06	.03	-12.9	.18	7
353 Wilson Creek at Thrall Road	740321-810916	57	.49	-.002	-3.3	.06	.49	-2.5	*	*
Total ammonia as nitrogen (unit = milligrams per liter)										
40 Yakima River at Parker	731018-810907	91	.01	-.006	-6.7	.09	.01	-6.2	.00	7
100 Yakima River at Kiona	731018-810902	96	.00	-.010	-14.3	.07	.00	-15.9	.00	3
297 Roza Main Canal at Beam Road	740416-790813	32	.06	.001	10.0	.01	.44	11.9	.15	2 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	29	.16	.000	.0	.02	.14	2.2	.00	8 (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	41	.00	.005	50.0	.01	.01	37.6	.00	3
307 Chandler Canal--mile 0.6 nr Prosser	731018-810219	52	.00	.003	15.0	.02	.05	12.1	.08	6 (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	51	.00	.005	25.0	.02	.08	17.5	.00	7 (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	64	.00	.005	16.7	.03	.03	17.3	.00	7
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	51	.09	.003	15.0	.02	.11	12.7	.07	4.4
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	52	.15	.002	10.0	.02	.94	-.5	.08	6
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	38	.78	.000	.0	.01	1.00	.4	.05	8
320 Yakima River at Harrison Rd Bridge	740321-810916	69	.00	.003	30.0	.01	.00	35.1	.00	6
321 Naches River at Nelson Bridge	740321-810915	69	.00	.002	20.0	.01	.00	18.1	.00	2
322 Yakima River-Terrace Heights Bridge	740321-810914	70	.00	.003	30.0	.01	.00	24.9	.04	4.5
323 Drain at Birchfield Road	740321-810915	70	.16	-.003	-6.0	.05	.18	-6.6	.00	5
324 Wide Hollow Creek near Gromore	740321-770926	34	.88	.000	.0	.01	.58	-14.6	.01	2
325 Wide Hollow Cr at W. Washington Ave	740321-770926	36	1.00	.000	.0	.01	1.00	-2.7	.00	3
326 Wide Hollow Creek at Union Gap STP	740321-810915	72	.00	-.330	-25.4	1.3	.00	-49.8	.00	7
327 Ahtanum Creek at mouth	740321-810915	69	.04	.000	.0	.02	.31	3.7	.00	7
328 Sulphur Cr at North above Sunnyside	740416-790926	51	.22	.003	10.0	.03	.26	9.2	.00	7
329 Sulphur Cr Wasteway at Factory Road	740319-790926	54	.00	.005	16.7	.03	.46	16.6	.01	4.5
330 Drain DID #3 at South Hill Road	740319-770927	36	.08	.243	27.7	.88	.05	27.4	.02	7
331 Drain DID #3 at Duffy Road	740319-770927	34	1.00	-.005	-.6	.80	.46	1.1	.01	5
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	54	.01	.010	20.0	.05	.00	22.1	.08	8
333 Sulphur Cr Wasteway at Morse Road	740319-790926	52	.04	.018	10.0	.18	.59	2.2	.05	5
334 Sulphur Cr Wasteway at McGee Road	740319-810914	71	.65	-.002	-1.2	.16	.34	-3.6	.04	2
335 Griffin Lake Inlet	740416-790926	50	.00	.020	33.3	.06	.00	42.3	.02	4.5
336 Griffin Lake Outlet	740416-790926	37	.25	.004	20.0	.02	.54	13.6	.00	7
337 Yakima River at bridge near Granger	740320-810914	61	.00	.010	20.0	.05	.02	19.4	.01	7
338 Yakima River at bridge near Mabton	740320-810914	62	.06	.003	7.5	.04	.07	7.9	.07	8
339 East Toppenish Drain at Wilson Road	740320-810219	65	1.00	.000	.0	.33	.02	-15.7	.37	8
340 Sub-Drain 35 at Parton Road	740320-810219	63	.01	.003	15.0	.02	.02	13.0	.02	3
341 Marion Drain at Highway 97	740320-810219	66	.00	.003	15.0	.02	.00	16.7	*	*
342 Wanity Slough at Myers Road	740320-810219	66	.00	.007	10.0	.07	.18	8.5	.02	7
345 South Drain at Highway 22 nr Satus	740320-810219	62	.04	.004	10.0	.04	.02	10.1	.02	7
346 Granger Drain--Hwy 223 abv Granger	740521-810914	69	.48	.007	3.5	.20	.67	3.6	.00	6
347 Spring Creek at Hess Road	740521-810219	62	.00	.005	25.0	.02	.04	16.9	.01	7
348 Snipes Cr at Old Inland Empire Road	740521-810219	60	.00	.003	30.0	.01	.00	34.5	.00	4.1
349 Yakima River at Cle Elum	740321-810916	66	.01	.000	.0	.01	.08	9.8	.03	4.6
350 Wilson Creek at Sanders Road	740321-770926	35	.56	.000	.0	.01	.38	20.6	.08	7
351 Wilson Creek at Dammon Road	740321-770926	35	.66	.000	.0	.02	.89	16.4	.13	6
352 Wipple Wasteway at Thrall Road	740321-790815	52	.19	.000	.0	.02	.58	2.5	.00	8
353 Wilson Creek at Thrall Road	740321-810916	56	.46	.000	.0	.02	.53	-3.2	.14	8

Table 51.--Summary of trends in streamflow and selected water-quality constituents, Yakima River basin, Washington, 1974-81 water years--Continued

Map reference number and site name	Period of record	Number of obser-vations	Non-flow adjusted: Prob-ability level	Non-flow adjusted: Trend, in units per year	Non-flow adjusted: Trend, percent of median per year	Median units	Flow adjusted: Prob-ability level	Flow adjusted: Trend, percent change per year	R^2	Equa-tion type
Dissolved nitrite plus nitrate as nitrogen (unit = milligrams per liter)										
40 Yakima River at Parker	731018-810907	91	0.70	0.002	1.2	0.17	0.73	-0.5	0.08	8
100 Yakima River at Kiona	731018-810902	96	.00	.054	6.1	.89	.19	2.3	.31	8
297 Roza Main Canal at Beam Road	740416-790813	33	.59	-.002	-2.8	.07	.74	4.0	.10	8 (Irr)
298 Sunnyside Canal at Beam Road	740416-790926	30	.91	-.002	-2.2	.09	1.0	-2.2	*	* (Irr)
300 KID Coyote Canyon Drain near Bottom	750319-790927	43	.17	.091	4.3	2.1	.07	-3.9	.48	8 (Irr)
307 Chandler Canal--mile 0.6 nr Proaser	731018-810219	53	.02	.064	8.6	.74	.02	8.8	*	* (Irr)
308 Chandler Canal--mile 2.8 nr Prosser	731018-810219	52	.04	.070	8.6	.81	.04	8.6	*	* (Irr)
311 Satus Drain 302 NW1/4 S34 9N 22E	731018-810219	64	.02	.360	9.7	3.7	.01	12.6	.56	8
312 Cherry Cr SE 1/4 S 29 17N 19E	731018-790815	52	.12	.057	6.1	.94	.25	3.7	.33	6
313 Coleman Cr NW 1/4 S 20 17N 19E	731018-790815	53	.05	.028	10.0	.28	.60	8.1	.17	8
319 Cottonwood Canal Drain SE1/4 S28	731018-770926	39	.63	-.020	-8.0	.25	.47	-7.3	.24	8
320 Yakima River at Harrison Rd Bridge	740321-810916	96	.00	.011	11.0	.10	.00	11.6	*	*
321 Naches River at Nelson Bridge	740321-810915	70	1.00	.000	.0	.04	.91	-.6	.16	8
322 Yakima River-Terrace Heights Bridge	740321-810914	71	.00	.010	16.7	.06	.02	14.5	.17	8
323 Drain at Birchfield Road	740321-810915	71	.00	.045	4.7	.96	.03	5.1	.36	4.6
324 Wide Hollow Creek near Gromore	740321-770926	35	.89	.003	1.5	.20	.89	1.2	*	*
325 Wide Hollow Cr at W. Washington Ave	740321-770926	37	.20	-.050	-7.9	.63	.02	-16.6	.20	7
326 Wide Hollow Creek at Union Gap STP	740321-810915	73	.00	.070	6.4	1.1	.39	4.3	.07	4.7
327 Ahtanum Creek at mouth	740321-810915	70	.01	.031	6.5	.48	.02	5.8	.02	3
328 Sulphur Cr at North above Sunnyside	740416-790926	52	.11	.180	5.1	3.5	.01	10.0	.39	7
329 Sulphur Cr Wasteway at Factory Road	740319-790926	55	.01	.190	12.7	1.5	.01	12.7	*	*
330 Drain DID #3 at South Hill Road	740319-770927	37	.90	-.020	-.7	2.8	.45	-3.9	0.25	7
331 Drain DID #3 at Duffy Road	740319-790926	34	.25	.80	34.8	2.3	.78	-1.8	.13	7
332 Sulphur Cr Wasteway at Duffy Road	740319-790926	55	.00	.177	6.3	2.8	.89	.4	.60	8
333 Sulphur Cr Wasteway at Morse Road	740319-790926	53	.00	.202	7.5	2.7	.94	.2	.62	8
334 Sulphur Cr Wasteway at McGee Road	740319-810914	72	.07	.092	3.4	2.7	.28	3.3	.43	4.4
335 Griffin Lake Inlet	740416-790926	51	.00	.085	16.7	.51	.00	16.7	*	*
336 Griffin Lake Outlet	740416-790926	38	.44	-.002	-3.3	.06	.44	-2.7	*	*
337 Yakima River at bridge near Granger	740320-810914	61	.00	.095	17.6	.54	.00	13.7	.47	8
338 Yakima River at bridge near Mabton	740320-810914	63	.00	.088	8.8	1.00	.01	5.0	.60	6
339 East Toppenish Drain at Wilson Road	740320-810219	66	.01	.182	7.6	2.4	.01	7.6	*	*
340 Sub-Drain 35 at Parton Road	740320-810219	64	.10	.053	2.5	2.1	.51	1.8	.24	4.3
341 Marion Drain at Highway 97	740320-810219	67	.00	.130	5.0	2.6	.43	.7	.29	7
342 Wanity Slough at Myers Road	740320-810219	67	.53	.038	2.5	1.5	.13	-4.7	.16	7
345 South Drain at Highway 22 nr Satus	740320-810219	63	.42	.033	1.8	1.8	.39	1.0	.30	6
346 Granger Drain--Hwy 223 abv Granger	740521-810914	70	.00	.060	2.6	2.3	.00	6.1	.08	7
347 Spring Creek at Hess Road	740521-810219	63	.00	.099	7.1	1.4	.13	10.5	.53	4.5
348 Snipes Cr at Old Inland Empire Road	740521-810219	61	.65	.009	2.4	.38	.00	12.0	.69	8
349 Yakima River at Cle Elum	740321-810916	67	.49	.000	.0	.03	.49	.0	*	*
350 Wilson Creek at Sanders Road	740321-770926	36	.49	.005	12.5	.04	.49	12.5	*	*
351 Wilson Creek at Dammon Road	740321-770926	36	.79	.010	4.0	.25	.79	6.8	*	*
352 Wipple Wasteway at Thrall Road	740321-790815	53	.23	.050	5.2	.96	.23	9.9	.37	8
353 Wilson Creek at Thrall Road	740321-810916	57	.01	.028	11.2	.25	.04	11.4	.17	2
Fecal-coliform bacteria (unit = colonies per 100 millititers)										
40 Yakima River at Parker	761005-850916	93	.008	4	7.1	56	.008	6.5	*	*
100 Yakima River at Kiona	761216-850911	79	.014	10	14	72	.17	9.0	.24	7

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years

[Listing contains 502 sites; map reference number is the identifier used in plate 1 and on the U.S. Geological Survey computer in Portland, Oregon; map reference numbers have not been consecutively assigned in the listing; some sites are repeated in the listing if they were sampled by more than one agency; USGS = U.S. Geological Survey; FS = U.S. Forest Service; USBR = U.S. Bureau of Reclamation; EPA = U.S. Environmental Protection Agency; DOE = Washington Department of Ecology; BPI = Bureau of Plant Industry; CH2M = CH2M Hill; FWS = U.S. Fish and Wildlife Service]

Map reference number	Site name	Agency	Agency identification number
1	Yakima River above Cle Elum River near Cle Elum, Wash.	USGS	12477600
2	Domerie Creek near Roslyn, Wash.	USGS	12479100
3	Cle Elum River near Cle Elum, Wash.	USGS	12479300
4	Yakima River at Cle Elum, Wash.	USGS	12479500
5	Teanaway River near Cle Elum, Wash.	USGS	12480600
6	Yakima River near Thorp, Wash.	USGS	12482600
7	Wilson Creek at Thrall, Wash.	USGS	12484490
8	Yakima River at Roza Dam, Wash.	USGS	12484900
9	Roza Canal at Beam Road near Zillah, Wash.	USGS	12485005
10	Roza Canal at Scoon Road near Sunnyside, Wash.	USGS	12485010
11	Roza Canal below Sulphur Creek Wasteway near Sunnyside, Wash.	USGS	12485012
12	Roza Canal at Black Canyon Creek near Sunnyside, Wash.	USGS	12485014
13	Roza Canal at Factory Road near Sunnyside, Wash.	USGS	12485016
14	Roza Canal at Wilgus Road near Grandview, Wash.	USGS	12485018
15	Wenas Creek at Wenas Road Crossing near Selah, Wash.	USGS	12485960
16	Middle Fork Naches River near Cliffdell, Wash.	USGS	12487200
17	Bumping River at American River, Wash.	USGS	12488100
18	American River near Nile, Wash.	USGS	12488500
19	Rattlesnake Creek near Nile, Wash.	USGS	12489300
20	Naches River at Oak Flat near Nile, Wash.	USGS	12489500
21	Naches River near Naches, Wash.	USGS	12490010
22	Tieton River at Canal Headworks near Naches, Wash.	USGS	12492500
23	Tieton River at Oak Creek Game Range, Wash.	USGS	12493000
24	Naches River at Naches, Wash.	USGS	12494400
25	Naches River near Yakima, Wash.	USGS	12498700
26	Naches River near North Yakima, Wash.	USGS	12499000
27	Yakima River near Terrace Heights, Wash.	USGS	12500010
28	Moxee Drain at Birchfield Road near Union Gap, Wash.	USGS	12500420
29	Wide Hollow Creek at Goodman Road at Union Gap, Wash.	USGS	12500439
30	Wide Hollow Creek at Union Gap, Wash.	USGS	12500440
31	Wide Hollow Creek near mouth at Union Gap, Wash.	USGS	12500445
32	Yakima River above Ahtanum Creek at Union Gap, Wash.	USGS	12500450
33	North Fork Ahtanum Creek near Tampico, Wash.	USGS	12500500
34	North Fork Ahtanum Creek at Tampico, Wash.	USGS	12500600
35	South Fork Ahtanum Creek at Conrad Ranch near Tampico, Wash.	USGS	12501000
36	South Fork Ahtanum Creek at Tampico, Wash.	USGS	12501600
37	Ahtanum Creek at Goodman Road at Union Gap, Wash.	USGS	12502490
38	Ahtanum Creek at Union Gap, Wash.	USGS	12502500
39	Main Canal near Parker, Wash. (Wapato Canal)	USGS	12503500
40	Yakima River at Parker, Wash.	USGS	12503950
41	Sunnyside Canal at Beam Road near Granger, Wash.	USGS	12504505
42	Sunnyside Canal at Maple Grove Road near Sunnyside, Wash.	USGS	12504510
43	Sunnyside Canal below Sulphur Creek Wasteway near Sunnyside, Wash	USGS	12504512
44	Sunnyside Canal at Edison Road near Sunnyside, Wash.	USGS	12504514
45	Sunnyside Canal at Bethnay Road near Grandview, Wash.	USGS	12504516
46	Sunnyside Canal at Grandview, Wash.	USGS	12504518
47	Yakima River near Parker, Wash.	USGS	12505000
48	Yakima River near Toppenish, Wash.	USGS	12505300
49	East Toppenish Drain at Wilson Road near Toppenish, Wash.	USGS	12505350
50	Sub 35 Drain at Parton Road near Granger, Wash.	USGS	12505410
51	Granger Drain at Granger, Wash.	USGS	12505450
52	Wanity Slough at Rocky Ford Road near Toppenish, Wash.	USGS	12505480
53	Marion Drain near Granger, Wash.	USGS	12505500
54	Toppenish Creek near Fort Simcoe, Wash.	USGS	12506000
55	North Fork Simcoe Creek near Fort Simcoe, Wash.	USGS	12506300
56	South Fork Simcoe Creek near Fort Simcoe, Wash.	USGS	12506330
57	Agency Creek near Fort Simcoe, Wash.	USGS	12506600
58	Mud Lake Drain near Harrah, Wash.	USGS	12507090
59	Mill Creek at Canyon Road near White Swan, Wash.	USGS	12507100
60	Toppenish Creek at Alfalfa, Wash.	USGS	12507500
61	Toppenish Creek at Indian Church Road near Granger, Wash.	USGS	12507508
62	Toppenish Creek near Satus, Wash.	USGS	12507510
63	Coulee Drain at North Satus Road near Satus, Wash.	USGS	12507560
64	Satus Creek above Logy Creek near Toppenish, Wash.	USGS	12507940
65	Logy Creek near Toppenish, Wash.	USGS	12507950
66	Dry Creek near Toppensih, Wash.	USGS	12508460
67	Satus Creek at Plank Road near Satus, Wash.	USGS	12508590
68	Satus Creek near Satus, Wash.	USGS	12508600
69	Satus Creek at North Satus Road at Satus, Wash.	USGS	12508610
70	Satus Creek at Satus, Wash.	USGS	12508621
71	South Drain near Satus, Wash.	USGS	12508630
72	Satus Drain 302 at Highway 22 near Mabton, Wash.	USGS	12508660
73	Satus Drain 303 at Looney Road near Mabton, Wash.	USGS	12508690
74	Drain 61.0 at SLI Road near Sunnyside, Wash.	USGS	12508753
75	Drain 61.0 near Sunnyside, Wash. (Daily Sediment X 100)	USGS	12508755
76	Drain 60.7 at SLI Road near Sunnyside, Wash.	USGS	12508765
77	Drain 60.5 at SLI Road near Sunnyside, Wash.	USGS	12508766
78	Drain 60.7 near Sunnyside, Wash.	USGS	12508769
79	Drain 59.6 at SLI Road near Sunnyside, Wash.	USGS	12508770
80	Drain 60.0 at SLI Road near Sunnyside, Wash.	USGS	12508771

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years--Continued

Map reference number	Site name	Agency	Agency identification number
81	Drain 60.2 at SLI Road near Sunnyside, Wash.	USGS	12508773
82	Drain 59.6 below Drain 60.2 near Sunnyside, Wash.	USGS	12508775
83	Drain 59.4 at SLI Road near Sunnyside, Wash.	USGS	12508776
84	Drain 59.4 tributary at SLI Road near Sunnyside, Wash.	USGS	12508778
85	Drain 59.4 near Sunnyside, Wash. (Daily Sediment X 100)	USGS	12508779
86	DID 18 Drain at Sunnyside, Wash.	USGS	12508790
87	Washout Drain at Sunnyside, Wash.	USGS	12508810
88	Black Canyon Creek at Waneta Road near Sunnyside, Wash.	USGS	12508820
89	DID 9 Drain near Sunnyside, Wash.	USGS	12508830
90	DID 3 Drain near Sunnyside, Wash.	USGS	12508840
91	Sulphur Creek Wasteway near Sunnyside, Wash.	USGS	12508850
92	Yakima River at Mabton, Wash.	USGS	12508990
93	Grandview Drain at Chase Road near Grandview, Wash.	USGS	12508997
94	Yakima River at Prosser, Wash.	USGS	12509489
95	Wamba Drain at Prosser, Wash.	USGS	12509492
96	Shelby Drain at Shelby Road at Prosser, Wash.	USGS	12509496
97	Spring Creek at Hess Road near Prosser, Wash.	USGS	12509700
98	Snipes Creek near Prosser, Wash.	USGS	12509820
99	Corral Canyon Creek near Benton City, Wash.	USGS	12510200
100	Yakima River at Kiona, Wash.	USGS	12510500
101	Yakima River at Van Geisan Bridge near Richland, Wash.	USGS	12511800
102	08N/22E-02M01, Wash.	USGS	461226120020201
103	Drain 302 at SR 22 Bridge near Mabton, Wash.	USGS	461331120031401
104	Turbine Lateral above Griffin Road near Grandview, Wash.	USGS	461615119511101
105	Grandview Canal at County Line Road near Grandview, Wash.	USGS	461615119522201
106	Snipes Mountain Wasteway above Did-3 Drain near Sunnyside, Wash.	USGS	461630120004101
107	North Drain at Farm Road near North Satus Road near Satus, Wash.	USGS	461644120084601
108	Snipes Mt. Lateral at Drop 8 near Sunnyside, Wash.	USGS	461701120020501
109	Coulee Drain at North Satus Road near Satus, Wash.	USGS	461749120084501
110	Snipes Mt. Lateral at Mile 9.0 near Sunnyside, Wash.	USGS	461755120022101
111	Lower Pump 14 Lateral downstream from Wilgus Road near Grandview, Wash.	USGS	461757119491901
112	Snipes Mt. Lateral at Mile 9.09 near Sunnyside, Wash.	USGS	461809120022801
113	Turbine Lateral near Grandview, Wash.	USGS	461818119535301
114	Upper Pump 14 Lateral above Missimer Road near Grandview, Wash.	USGS	461822119483501
115	Snipes Mt. Lateral at Drop 4 near Sunnyside, Wash.	USGS	461929120041701
116	Drain 60.7 below Sediment Pond near Sunnyside, Wash.	USGS	462114119563501
117	Side Outflow on Sediment Pond Drain 60.7 near Sunnyside, Wash.	USGS	462114119563502
118	Drain 60.7 above Sediment Pond near Sunnyside, Wash.	USGS	462115119563301
119	Drain 60.7 tributary above Sediment Pond near Sunnyside, Wash.	USGS	462115119563302
120	Diversion from Roza Canal at Mile 61.4, Wash.	USGS	462143119551700
121	Diversion from Roza Canal at Mile 60.8, Wash.	USGS	462158119553900
122	Drain 61.0 above Roza Canal near Sunnyside, Wash.	USGS	462202119552401
123	Diversion from Roza Canal at Mile 60.3, Wash.	USGS	462204119560400
124	Drain 60.7 above Roza Canal near Sunnyside, Wash.	USGS	462205119554201
125	Diversion from Roza Canal at Mile 59.9, Wash.	USGS	462214119562700
126	Diversion from Roza Canal at 59.9, Wash. (Once Daily Value)	USGS	462214119562702
127	Outlook Canal below Independence Road near Sunnyside, Wash.	USGS	462216120022101
128	Diversion from Roza Canal at Mile 59.5 near Sunnyside, Wash.	USGS	462221119565300
129	Diversion from Roza Canal at Mile 59.3 near Sunnyside, Wash.	USGS	462222119570400
130	Pump 9A Lateral below Scoon Road near Sunnyside, Wash.	USGS	462424120010401
147	Domerie Creek above Rosyln Intake, Wash.	FS	113FORS6 17010001
148	French Cabin Creek, Wash.	FS	113FORS6 17010002
149	Cooper River, Wash.	FS	113FORS6 17010005
150	Stave Creek 22, Wash.	FS	113FORS6 17010006
151	Stave Creek 1-1, Wash.	FS	113FORS6 17010007
152	Cle Elum River above reservoir, Wash.	FS	113FORS6 17010010
153	Silver Creek above Faston Intake, Wash.	FS	113FORS6 17010013
154	Salmon La Sac Creek near Pesort, Wash.	FS	113FORS6 17010014
155	Jim Creek, Wash.	FS	113FORS6 17011001
156	Hyak Creek Head of Lake Keechelus, Wash.	FS	113FORS6 17011002
157	Big Creek, Wash.	FS	113FORS6 17011003
158	Little Creek, Wash.	FS	113FORS6 17011004
159	Box Canyon Creek, Wash.	FS	113FORS6 17011006
160	Thetis Creek, Wash.	FS	113FORS6 17011007
161	Stampede Creek, Wash.	FS	113FORS6 17011008
162	Yakima River, Wash.	FS	113FORS6 17011009
163	Rocky Run, Wash.	FS	113FORS6 17011010
164	Mill Creek, Wash.	FS	113FORS6 17011011
165	Roaring Creek, Wash.	FS	113FORS6 17011012
166	Silver Creek, Wash.	FS	113FORS6 17011013
167	Cold Creek, Wash.	FS	113FORS6 17011014
168	Kachess River, Wash.	FS	113FORS6 17011015
169	Meadow Creek at Bridge, Wash.	FS	113FORS6 17011016
170	Gale Creek at Bridge, Wash.	FS	113FORS6 17011019
171	Resort Creek 6-3, Wash.	FS	113FORS6 17011022
172	Resort Creek 17, Wash.	FS	113FORS6 17011024
173	Wolfe Creek 24, Wash.	FS	113FORS6 17011025
174	West Log Creek, Wash.	FS	113FORS6 17011028
175	Hyak Creek at Tunnel Creek, Wash.	FS	113FORS6 17011029
176	Cabin Creek 4-2, Wash.	FS	113FORS6 17011033
177	Cabin Creek 4-4, Wash.	FS	113FORS6 17011035
178	Cabin Creek 4-5, Wash.	FS	113FORS6 17011036
179	Cabin Creek 3-3, Wash.	FS	113FORS6 17011037
180	Cabin Creek 50 ft. above Log Creek, Wash.	FS	113FORS6 17011039
181	Log Creek 50 ft. above Cabin Creek, Wash.	FS	113FORS6 17011040

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years--Continued

Map reference number	Site name	Agency	Agency identification number
182	Log Creek 14-2, Wash.	FS	113FORS6 17011042
183	Log Creek 14-3, Wash.	FS	113FORS6 17011043
184	Log Creek 14-4, Wash.	FS	113FORS6 17011044
185	Hyak Creek above Sewage Plant, Wash.	FS	113FORS6 17011045
186	Silver Creek at Powerline Road, Wash.	FS	113FORS6 17011046
187	North Fork Teanaway River, Wash.	FS	113FORS6 17012001
188	Teanaway River Bridge-Swauk Highway, Wash.	FS	113FORS6 17012002
189	Stafford Creek below Standup Creek, Wash.	FS	113FORS6 17012003
190	Middle Fork Teanaway River at Forest Service Boundary, Wash.	FS	113FORS6 17012004
192	Cougar Creek, Wash.	FS	113FORS6 17016002
193	Swauk Creek below Mineral Spring, Wash.	FS	113FORS6 17016003
194	Swauk Creek below Durst Spring, Wash.	FS	113FORS6 17016004
195	Swauk Creek at Hurley Creek, Wash.	FS	113FORS6 17016005
196	Swauk Creek at Swauk Forest Camp, Wash.	FS	113FORS6 17016006
197	Swauk Creek at Pipe Creek, Wash.	FS	113FORS6 17016007
198	Boulder Creek at Robinson Junction, Wash.	FS	113FORS6 17016008
199	Lion Gulch above Liberty Road, Wash.	FS	113FORS6 17016009
200	Swauk Creek above Williams Creek, Wash.	FS	113FORS6 17016010
201	Ill Creek above Dam -1/2 Mile above Swauk Creek, Wash.	FS	113FORS6 17016011
202	Baker Creek above Swauk, Wash.	FS	113FORS6 17016012
203	Medicine Creek above Campground, Wash.	FS	113FORS6 17016013
204	Swauk Creek above Mineral Spring Resort, Wash.	FS	113FORS6 17016014
205	Blue Creek above Highway 97, Wash.	FS	113FORS6 17016015
206	Hovey Creek above Highway 97, Wash.	FS	113FORS6 17016016
207	Iron Creek above Highway 97, Wash.	FS	113FORS6 17016017
208	Swauk Creek above Campground Section 12, Wash.	FS	113FORS6 17016018
209	Pipe Creek above Mine, Wash.	FS	113FORS6 17016019
210	Swauk Creek above Hurley Creek, Wash.	FS	113FORS6 17016020
211	Naneum Creek below Howard Creek, Wash.	FS	113FORS6 17016021
212	Staff Gage at Virden, Wash.	FS	113FORS6 17016022
213	Section Line 29 1 30, Wash.	FS	113FORS6 17016023
214	First Creek, Wash.	FS	113FORS6 17016024
215	Boulder Creek, Wash.	FS	113FORS6 17016025
216	North of Jeep Trail, Wash.	FS	113FORS6 17016026
217	Swauk Creek, Wash.	FS	113FORS6 17016027
218	Naneum Creek, Wash.	FS	113FORS6 17016028
219	Side Drainage above Swauk Creek, Wash.	FS	113FORS6 17016029
220	Hovey Creek North of Road 217, Wash.	FS	113FORS6 17016030
221	Hovey Creek South of Road 217, Wash.	FS	113FORS6 17016031
222	Head of South Fork Baker, Wash.	FS	113FORS6 17016032
223	North Fork Taneum Creek, Wash.	FS	113FORS6 17017001
224	South Fork Taneum Creek, Wash.	FS	113FORS6 17017002
225	Manastash Creek, Wash.	FS	113FORS6 17017003
226	Shoestring Lake Creek, Wash.	FS	113FORS6 17017004
227	South Fork Manastash Creek at Section 17/16, Wash.	FS	113FORS6 17017005
228	North Fork Manastash Creek at Forest Service Boundary, Wash.	FS	113FORS6 17017006
229	South Fork Manastash Creek at Staff Gage, Wash.	FS	113FORS6 17017007
230	Turbidity Map on North Fork, Wash.	FS	113FORS6 17017008
231	South Fork Taneum Creek at Forest Service Boundary, Wash.	FS	113FORS6 17017009
232	Turbidity Map on North Fork, Wash.	FS	113FORS6 17017010
233	Staff Gage on Taneum Creek, Wash.	FS	113FORS6 17017011
234	North Fork Taneum Creek at Section 20/19, Wash.	FS	113FORS6 17017012
235	Taneum Creek, Wash.	FS	113FORS6 17017026
236	Crow Creek, Wash.	FS	113FORS6 17018001
237	Quartz Creek, Wash.	FS	113FORS6 17018002
238	Pile-Up Creek, Wash.	FS	113FORS6 17018004
239	South Fork Little Naches River, Wash.	FS	113FORS6 17018006
240	Bear Creek, Wash.	FS	113FORS6 17018007
241	Upper Little Naches River, Wash.	FS	113FORS6 17018008
242	Middle Fork Little Naches River, Wash.	FS	113FORS6 17018009
243	Little Naches Lower, Wash.	FS	113FORS6 17018010
244	American River Upper, Wash.	FS	113FORS6 17019001
245	Bumping River, Wash.	FS	113FORS6 17020002
246	Naches River, Wash.	FS	113FORS6 17021001
247	Milk Creek, Wash.	FS	113FORS6 17021002
248	South Fork Tieton River, Wash.	FS	113FORS6 17024001
249	Conrad Meadows, Wash.	FS	113FORS6 17024002
250	Indian Creek, Wash.	FS	113FORS6 17024004
251	Clear Creek, Wash.	FS	113FORS6 17024005
252	Oak Creek at mouth, Wash.	FS	113FORS6 17025001
253	Oak Creek, Wash.	FS	113FORS6 17025002
254	North Fork Oak Creek, Wash.	FS	113FORS6 17025003
255	South Fork Oak Creek, Wash.	FS	113FORS6 17025004
256	Oak Creek at Counterfeit, Wash.	FS	113FORS6 17025005
257	Middle Fork Oak Creek, Wash.	FS	113FORS6 17025006
258	Upper Oak Creek, Wash.	FS	113FORS6 17025007
286	American River Lower, Wash.	FS	113FORS6 17190002
289	Hause Creek Sene Sec 28 T14N R14E, Wash.	FS	113FORS6 17250010
290	Soup Creek NWSE SEC 28 T14N R14E, Wash.	FS	113FORS6 17250011
292	DID No. 25 at State Highway No. 12, Wash.	USBR	1119USBR YAV001
293	Mile 28 Drain at State Highway Sid, Wash.	USBR	1119USBR YAV002
294	DID 2 East Branch at Confluence with Mile 28 Drain, Wash.	USBR	1119USBR YAV003
295	Drain 27.2 at Knowles Road RID, Wash.	USBR	1119USBR YAV004
296	26.6 Drain at Kirk Road crossing, Wash.	USBR	1119USBR YAV005
297	Roza Main Canal at Beam Road crossing, Wash.	USBR	1119USBR YAV006

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years--Continued

Map reference number	Site name	Agency	Agency identification number
298	Sunnyside Canal at Beam Road crossing, Wash.	USBR	1119USBR YAV007
299	KID Hover Wasteway near Bottom above East culvert, Wash.	USBR	1119USBR YAV008
300	KID Coyote Canyon Drain near Bottom, Wash.	USBR	1119USBR YAV010
301	KID Main Canal near head at Gaging station, Wash.	USBR	1119USBR YAV011
302	Main Drain at Highway No. 22, Wash.	USBR	1119USBR YAV012
303	WID Main Drain at Robbins Road, Wash.	USBR	1119USBR YAV013
304	WID Main Drain at Lateral C Road, Wash.	USBR	1119USBR YAV014
305	Below Drop No. 3 WID Main Canal, Wash.	USBR	1119USBR YAV015
306	WID Main Canal near Canal Intake, Wash.	USBR	1119USBR YAV016
307	Chandler Canal Mile 0.6 near Prosser, Wash.	USBR	1119USBR YAV017
308	Chandler Canal Mile 2.8 near Prosser, Wash.	USBR	1119USBR YAV018
309	Satus 2 Canal NW1/4 S17 9N 21E, Wash.	USBR	1119USBR YAV019
310	Nequist Drain NW1/4 S25 9N 21E, Wash.	USBR	1119USBR YAV020
311	Satus Drain 302 NW1/4 S34 9N 22E, Wash.	USBR	1119USBR YAV021
312	Cherry Creek SE 1/4 S29 17N 19E, Wash.	USBR	1119USBR YAV022
313	Coleman Creek NW 1/4 S20 17N 19E, Wash.	USBR	1119USBR YAV023
314	Ellensburg Town Canal NE1/4 S6, Wash.	USBR	1119USBR YAV024
315	Cascade Canal NE1/4 S31 18N 19E, Wash.	USBR	1119USBR YAV025
316	Kittitas Canal SE1/4 S6 18N 19E, Wash.	USBR	1119USBR YAV026
317	Tieton Canal SW1/4 S11 14N 16E, Wash.	USBR	1119USBR YAV027
318	Cowiche Creek SE1/4 S9 13N 18E, Wash.	USBR	1119USBR YAV028
319	Cottonwood Canal Drain SE1/4 S28, Wash.	USBR	1119USBR YAV029
320	Yakima River at Harrison Road Bridge, Wash.	USBR	1119USBR YAV101
321	Naches River at Nelson Bridge, Wash.	USBR	1119USBR YAV102
322	Yakima River at Terrace Heights Bridge, Wash.	USBR	1119USBR YAV103
323	Drain at Birchfield Road, Wash.	USBR	1119USBR YAV104
324	Wide Hollow Creek near Gromore, Wash.	USBR	1119USBR YAV105
325	Wide Hollow Creek at West Washington Avenue, Wash.	USBR	1119USBR YAV107
326	Wide Hollow Creek at Union Gap Sewage Treatment Plant, Wash.	USBR	1119USBR YAV108
327	Ahtanum Creek at mouth, Wash.	USBR	1119USBR YAV109
328	Sulphur Creek at North above Sunnyside, Wash.	USBR	1119USBR YAV115
329	Sulphur Creek Wasteway at Factory Road Sunnyside, Wash.	USBR	1119USBR YAV116
330	Drain DID #3 at South Hill Road, Wash.	USBR	1119USBR YAV117
331	Drain DID #3 at Duffy Road, Wash.	USBR	1119USBR YAV118
332	Sulphur Creek Wasteway at Duffy Road, Wash.	USBR	1119USBR YAV119
333	Sulphur Creek Wasteway at Morse Road, Wash.	USBR	1119USBR YAV120
334	Sulphur Creek Wasteway at McGee Road, Wash	USBR	1119USBR YAV121
335	Griffin Lake Inlet, Wash.	USBR	1119USBR YAV122
336	Griffin Lake Outlet, Wash.	USBR	1119USBR YAV123
337	Yakima River at Bridge near Granger, Wash.	USBR	1119USBR YAV124
338	Yakima River at Bridge near Mabton, Wash.	USBR	1119USBR YAV125
339	East Toppenish Drain at Wilson Road, Wash.	USBR	1119USBR YAV128
340	Sub-Drain 35 at Parton Road, Wash.	USBR	1119USBR YAV129
341	Marion Drain at Highway 97, Wash.	USBR	1119USBR YAV130
342	Wanity Slough at Myers Road, Wash.	USBR	1119USBR YAV131
343	Toppenish Creek at Cook Road, Wash.	USBR	1119USBR YAV133
344	Satus Creek East of North Satus Road, Wash.	USBR	1119USBR YAV134
345	South Drain at Highway 22 near Satus, Wash.	USBR	1119USBR YAV135
346	Granger Drain at Highway 223 above Granger, Wash.	USBR	1119USBR YAV137
347	Spring Creek at Hess Road, Wash.	USBR	1119USBR YAV138
348	Snipes Creek at Old Inland Empire Road, Wash.	USBR	1119USBR YAV139
349	Yakima River at Cle Elum, Wash.	USBR	1119USBR YAV140
350	Wilson Creek at Sanders Road, Wash.	USBR	1119USBR YAV141
351	Wilson Creek at Dammon Road, Wash.	USBR	1119USBR YAV142
352	Wipple Wasteway at Thrall Road, Wash.	USBR	1119USBR YAV145
353	Wilson Creek at Thrall Road, Wash.	USBR	1119USBR YAV146
354	Yakima River at Ellensburg, Wash.	USBR	1119USBR YAV147
355	Yakima River at Umtanum, Wash.	USBR	1119USBR YAV148
356	Drain DID#3 15 Ft. above Rendring Plant Outlet, Wash.	USBR	1119USBR YAV150
357	Drain at Elks Golf Course, Wash.	USBR	1119USBR YAV151
358	Teanaway River at Highway 10 Bridge, Wash.	USBR	1119USBR YAV152
359	Swauk Creek near Highway 10 Bridge, Wash.	USBR	1119USBR YAV153
360	Yakima River at Thorp Highway Bridge, Wash.	USBR	1119USBR YAV154
361	Taneum Creek at Anderson's Loafing Shed, Wash.	USBR	1119USBR YAV155
362	Manastash Creek at Brown Road Bridge, Wash.	USBR	1119USBR YAV156
363	Reecer Creek near mouth, Wash.	USBR	1119USBR YAV157
364	Yakima River at Thrall Public Access, Wash.	USBR	1119USBR YAV158
365	Sorenson Creek, Wash.	USBR	1119USBR YAV159
366	Yakima River 100 Ft. below Roza Dam, Wash.	USBR	1119USBR YAV164
367	Yakima River 1.5 Mile above Roza Dam,below Burbank Creek, Wash.	USBR	1119USBR YAV165
368	Cle Elum Reservoir at Pump Barge, Wash.	USBR	1119USBR YCE003
369	Bumping River at-road crossing above lake, Wash.	USBR	1119USBR YES001
370	Ahtanum Creek 4 Mile East of Tampico by footbridge, Wash.	USBR	1119USBR YES100
371	North Fork of Teanaway River above Dickey Creek, Wash.	USBR	1119USBR YES101
372	Little Naches River at USGS Gauge, Wash.	USBR	1119USBR YES102
373	Rattlesnake Creek 1 Mile above State Forest Map, Wash.	USBR	1119USBR YES103
374	Toppenish Creek at Bia Gauge, Wash.	USBR	1119USBR YES104
375	Satus Creek at Bia Gauging Map, Wash.	USBR	1119USBR YES105
376	Yakima River near Horlick, Wash.	USBR	1119USBR YES313
377	Simcoe Creek 1 Mile West of Power Map, Wash.	USBR	1119USBR YES600
378	Squaw Creek .3 Mile above U.S. Highway 97 Bridge, Wash.	USBR	1119USBR YES750
379	Richland Canal .5 Mile below headgate, Wash.	USBR	1119USBR YFS101
380	Chandler Canal 1.2 Miles below headgates, Wash.	USBR	1119USBR YFS102
381	Status Feeder Canal 0.1 Mile below headgates, Wash.	USBR	1119USBR YFS103
382	Sunnyside Canal 0.3 Mile below headgates, Wash.	USBR	1119USBR YFS104

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years--Continued

Map reference number	Site name	Agency	Agency identification number
383	New Reservation Canal 0.5 Mile below headgates, Wash.	USBR	1119USBR YFS105
384	Chandler Canal .7 Mile above fish screens, Wash.	USBR	1119USBR YFS106
385	Rim Rock Reservoir 100 meters above dam, Wash.	USBR	1119USBR YRO004
386	Yakima River at Ellensburg Water Intake (RM161), Wash.	EPA	10EPATOX 04A001
387	Yakima River at Highway 224 near Richland (RM 9.30), Wash.	EPA	10EPATOX 04A002
388	Naches River at Yakima Municipal Water Intake (RM 9.7), Wash.	EPA	10EPATOX 04F001
389	Naches River at mouth at Twin Bridges near Yakima, Wash.	EPA	10EPATOX 04F002
391	WPSS Pasco, Wash.	EPA	1110NET 540009
392	WPSS Richland, Wash.	EPA	1110NET 540089
398	Yakima River at Ellensburg, Wash.	EPA	1119C050 540052
399	Yakima River at Kiona, Wash.	EPA	1119C050 543005
401	Big Creek, Wash.	EPA	1119C050 543493
402	Big Creek, Wash.	EPA	1119C050 543494
403	Jim Creek, Wash.	EPA	1119C050 543495
404	Big Creek, Wash.	EPA	1119C050 543496
405	Cabin Creek, Wash.	EPA	1119C050 543497
406	Cole Creek, Wash.	EPA	1119C050 543498
407	Cabin Creek, Wash.	EPA	1119C050 543499
408	Cabin Creek, Wash.	EPA	1119C050 543500
409	Log Creek, Wash.	EPA	1119C050 543501
410	Cabin Creek, Wash.	EPA	1119C050 543502
411	Tributary below Cabin Creek, Wash.	EPA	1119C050 543503
412	Cabin Creek, Wash.	EPA	1119C050 543504
413	Cabin Creek, Wash.	EPA	1119C050 543505
414	Silver Creek at Yakima River, Wash.	EPA	1119C050 543506
415	Silver Creek, Wash.	EPA	1119C050 543507
416	Yakima River at Easton, Wash.	EPA	1119C050 543508
417	Meadows Creek, Wash.	EPA	1119C050 543509
418	Upper Meadow Creek Main Stem, Wash.	EPA	1119C050 543510
419	North Fork Meadows Creek, Wash.	EPA	1119C050 543511
420	South Fork Meadows Creek, Wash.	EPA	1119C050 543512
421	Keechelus Lake, Wash.	EPA	11EPALES 530601
422	Keechelus Lake, Wash.	EPA	11EPALES 530602
423	Keechelus Lake, Wash.	EPA	11EPALES 530603
424	Yakima River at Granger, Wash.	FWS	11FWS 044
427	Yakima River at Van Giesen Bridge, Wash.	DOE	21540000 37A060
428	Yakima River near Richland, Wash.	DOE	21540000 37A070
429	Yakima River at Kiona, Wash.	DOE	21540000 37A090
430	Yakima River at Prosser, Wash.	DOE	21540000 37A110
431	Yakima River at Mabton, Wash.	DOE	21540000 37A130
432	Yakima River at Granger North Side, Wash.	DOE	21540000 37A149
433	Yakima River at Granger South Side, Wash.	DOE	21540000 37A150
434	Yakima River near Toppenish, Wash.	DOE	21540000 37A170
435	Yakima River at Parker, Wash.	DOE	21540000 37A190
436	Yakima River above Ahtanum Creek, Wash.	DOE	21540000 37A200
437	Yakima River near Terrace Heights, Wash.	DOE	21540000 37A210
438	Satus Creek at Satus, Wash.	DOE	21540000 37B060
439	Toppenish Creek near Satus, Wash.	DOE	21540000 37C060
440	Marion Drain near Granger, Wash.	DOE	21540000 37D080
441	Wide Hollow Creek at Union Gap, Wash.	DOE	21540000 37E070
442	Wide Hollow Creek at Goodman Road, Wash.	DOE	21540000 37E090
443	Naches River at Yakima on U.S. Highway 97, Wash.	DOE	21540000 38A050
444	Naches River at Yakima, Wash.	DOE	21540000 38A070
445	Naches River at Naches, Wash.	DOE	21540000 38A110
446	Naches River near Naches, Wash.	DOE	21540000 38A130
447	Tieton River at Oak Creek, Wash.	DOE	21540000 38B070
448	Rattlesnake Creek near Nile, Wash.	DOE	21540000 38C070
449	Bumping River at American River, Wash.	DOE	21540000 38D070
450	American River at American River, Wash.	DOE	21540000 38E070
451	Little Naches River near Cliffdell, Wash.	DOE	21540000 38F070
452	Yakima River near Thorp, Wash.	DOE	21540000 39A070
453	Yakima River at Cle Elum, Wash.	DOE	21540000 39A080
454	Yakima River near Cle Elum, Wash.	DOE	21540000 39A090
455	Cle Elum River near Cle Elum, Wash.	DOE	21540000 39B070
456	Wilson Creek at Thrall, Wash.	DOE	21540000 39C070
457	Teanaway River near Cle Elum, Wash.	DOE	21540000 39D070
458	Ahtanum Creek near Tampico Damsite, Wash.	EPA	1119C050 543021
459	Yakima River, Wash.	EPA	11EPALES 5306A1
460	Meadow Creek, Wash.	EPA	11EPALES 5306B1
461	Roaring Creek, Wash.	EPA	11EPALES 5306C1
462	Cold Creek, Wash.	EPA	11EPALES 5306D1
463	Gold Creek, Wash.	EPA	11EPALES 5306E1
464	Yakima River near Birchfield Drain, Wash.	DOE	21540000 37A195
500	Sulphur Creek at Green Valley Road, Wash.	CH2M	
501	Sulphur Creek at Duffy Road, Wash.	CH2M	
502	Sulphur Creek at Alexander Road, Wash.	CH2M	
503	Sulphur Creek 1200100 downstream of Sheller Road, Wash.	CH2M	
504	Sulphur Creek at Sunnyside Canal, Wash.	CH2M	
505	DID 3 Drain on Needham Feedlot property, Wash.	CH2M	
506	DID 9 Drain at Sunnyside Mabton Highway, Wash.	CH2M	
507	DID 5 Drain along Tear Road, Wash.	CH2M	
508	Washout Drain at Allen Road, Wash.	CH2M	
509	DID 18 Drain at Vernita Highway, Wash.	CH2M	
510	DID 3 Drain at East First St. in Sunnyside, Wash.	CH2M	
511	Wasteway from Snipes Mt Lateral and turbine, tributary to DID 3	CH2M	

Table 52.--Listing of sites with historical water-quality data in the Yakima River basin, Washington, 1940-85 water years--Continued

Map reference number	Site name	Agency	Agency identification number
512	DID 3 Drain at Duffy Road, Wash.	CH2M	
513	DID 3 Drain, adjacent to Yakima Rendering Company Plant, Wash.	CH2M	
514	Tributary to main DID 3 Drain at Midvale Road, Wash.	CH2M	
515	DID 3 Drain at South Hill Road, Wash.	CH2M	
516	Outfall of Sunnyside Sewage Treatment Plant into DID 3, Wash.	CH2M	
517	DID 3 Drain at Highway 12, Wash.	CH2M	
518	DID 3 Drain at Outlook Road, Wash.	CH2M	
519	Tributary to DID 3 Drain at Reeves Road, Wash.	CH2M	
520	Tributary to DID 9 at Euclid Road, Wash.	CH2M	
521	Tributary to DID 9 Drain at Euclid and 500 yds North of Stover Road, Wash.	CH2M	
522	Tributary to DID 5 Drain at Allen Road, Wash.	CH2M	
523	Tributary to DID 5 Drain at Alexander Road, Wash.	CH2M	
524	Tributary to DID 5 Drain at Factory Road, Wash.	CH2M	
525	Washout Drain at Van Belle and Washout Road, Wash.	CH2M	
526	DID 17 Drain at Vernita Highway, Wash.	CH2M	
527	Tributary to DID 18 at Van Belle Road, Wash.	CH2M	
529	Roza Main Canal at District Line Road, Wash.	CH2M	
530	Sunnyside Main Canal at Maple Grove Road, Wash.	CH2M	
531	Sunnyside Main Canal at Highway 12, near Grandview, Wash.	CH2M	
532	Sunnyside Main Canal at District Line Road, Wash.	CH2M	
533	Roza Main Canal at Scoon Road, Wash.	CH2M	
534	Roza Main Canal at Wilgus Road, Wash.	CH2M	
535	Roza Main Canal just off Konnowock Pass Road, Wash.	CH2M	
536	Sunnyside Main Canal at Highway 12, 0.9 mile from dam, Wash.	CH2M	
537	Yakima River near Martin, Wash.	USGS	12474500
538	Mosquito Creek near Easton, Wash.	USGS	12474700
539	Kachess River near Easton, Wash.	USGS	12476000
540	Cle Elum River near Roslyn, Wash.	USGS	12479000
541	South Fork Manastash Creek tributary near Ellensburg, Wash.	USGS	12483300
542	Deep Creek near Goose Prairie, Wash.	USGS	12487400
543	Bumping River near Nile, Wash.	USGS	12488000
544	Hause Creek near Rimrock, Wash.	USGS	12491700
545	Naches River below Tieton River near Naches, Wash.	USGS	12494000
546	Satus Creek at U.S. Highway 97 crossing, Wash.	USGS	461408120250401
547	Dry Creek at U.S. Highway 97 crossing, Wash.	USGS	461515120243801
548	South Drain, Wash.	USGS	461535120075701
549	Satus Irrigation Return, Wash.	USGS	461625120084301
550	Toppenish Creek, Wash.	USGS	461857120125601
551	Wapato Project, Main Drain, Map 8, Wash.	BPI	461913120132501
552	Wapato Project, Main Drain, Map 7, Wash.	BPI	461928120204301
553	Wapato Project, Main Drain, Map 6, Wash.	BPI	461930120261701
554	Wapato Project, Main Drain, Map 9, Wash.	BPI	462025120115801
555	Wapato Project, Main Drain, Map 5, Wash.	BPI	462047120323401
556	Agency Creek, Wash.	USGS	462210120462501
557	Wapato Project, Drain of 6400 AC SW of Wapato between Laterial 2 and 3	BPI	462352120284301
558	Wapato Project, Map 3, Wash.	BPI	462602120284301
559	Wapato Project, Map 2, Wash.	BPI	462630120311801
560	Wapato Canal at Union Gap, Wash.	USGS	463050120283401
561	Wapato Project, Main Canal, Map 1, Wash.	BPI	463122120284001
562	Ahtanum Creek near mouth, Wash.	USGS	463300120312501
564	South Fork Tieton River, Wash.	USGS	463647121101801
565	North Fork Tieton River, Wash.	USGS	463720121175601
566	Naches River near Selah, Wash.	USGS	463750120351001
567	Clear Creek at Rimrock, Wash.	USGS	463836121170301
568	Wildcat Creek, Wash.	USGS	463955121072501
569	Milk Creek near Rimrock, Wash.	USGS	464007121050801
570	Tieton River at Windy Point, Wash.	USGS	464145120550001
571	Oak Creek, Wash.	USGS	464335120482501
572	Naches River, Wash.	USGS	464445120471501
574	Rattlesnake Creek, Wash.	USGS	464915120560501
575	Wenas Creek, Wash.	USGS	464959120424101
576	Deep Creek, Wash.	USGS	464959121183601
577	Nile Creek, Wash.	USGS	465015120570001
578	American River below Timber Creek, Wash.	USGS	465454121230701
579	Wilson Creek near Thrall, Wash.	USGS	465535120300201
580	Cherry Creek above Wilson Creek near Thrall, Wash.	USGS	465536120295901
581	Naches River at Cliffdell, Wash.	USGS	465655121041501
582	American River at Hells Crossing, Wash.	USGS	465754121155801
583	Milk Creek, Wash.	USGS	465850121051501
584	Bumping River, Wash.	USGS	465910121055001
585	Little Naches River, Wash.	USGS	465935121060501
586	Big Creek near Nelson Siding, Wash.	USGS	471153121051701
587	Swauk Creek, Wash.	USGS	471201120422801
588	First Creek, Wash.	USGS	471230120415301
589	North Fork Teanaway River, Wash.	USGS	471518120524001
590	West Fork Teanaway River, Wash.	USGS	471531120541301
591	Middle Fork Teanaway River, Wash.	USGS	471532120534901
592	Swauk Creek, Wash.	USGS	471934120401801
593	Cle Elum River, Wash.	USGS	472120121062001
594	Little Creek, Wash.	USGS	471154121051701
905	Teanaway River below forks near Cle Elum, Wash.	USGS	12480000
906	Naneum Creek near Ellensburg, Wash.	USGS	12483800
915	Yakima River at Umtanum, Wash.	USGS	12484500

Table 53.--Sites with dissolved-oxygen concentrations less than Washington State standards in the Yakima River basin, Washington, 1959-85 water years

Stream class	Map reference number	Site name	Number of determi- minations	Number of determinations less than State standards
		Class A -- Main stem		
A	349	Yakima River at Cle Elum	106	6
A	376	Yakima River near Horlick	14	4
A	355	Yakima River at Umtanum	111	5
A	322	Yakima River-Terrace Heights Bridge	64	1
A	47	Yakima River near Parker	30	1
A	337	Yakima River at bridge near Granger	63	7
A	432	Yakima River at Granger--North Side	18	1
A	92	Yakima River at Mabton	65	3
A	338	Yakima River at bridge near Mabton	64	5
A	94	Yakima River at Prosser	65	4
A	100	Yakima River at Kiona	269	10
		Class A -- Tributaries, canals, and drains		
A	7	Wilson Creek at Thrall	103	4
A	53	Marion Drain near Granger	48	8
A	62	Toppenish Creek near Satus	46	5
A	70	Satus Creek at Satus	47	3
A	292	DID No. 25 at State Highway No. 12	44	24
A	293	Mile 28 Drain at State Highway	43	18
A	294	DID 2 East Branch at Mile 28 Drain	43	19
A	295	Drain 27.2 at Knowles Road	26	9
A	296	26.6 Drain at Kirk Rd crossing	30	15
A	297	Roza Main Canal at Beam Road	57	7
A	298	Sunnyside Canal at Beam Road	57	5
A	299	Kid Hover Wasteway near bottom	11	4
A	300	Kid Coyote Canyon Drain near bottom	60	6
A	301	Kid Main Canal near head at gage	27	10
A	302	Main Drain at Highway 22	46	8
A	303	WID Main Drain at Robbins Road	21	3
A	304	WID Main Drain at Lateral C Road	21	5
A	305	Below Drop No 3--WID Main Canal	12	4
A	306	WID Main Canal nr Canal Intake	20	5
A	307	Chandler Canal--mile 0.6 nr Prosser	76	9
A	308	Chandler Canal--mile 2.8 nr Prosser	78	8
A	309	Satus 2 Canal NW 1/4 S17 9N 21E	16	7
A	310	Nequist Drain NW1/4 Sec 25 T9N R21E	22	21
A	311	Satus Drain 302 NW1/4 Sec 34 9N 22E	73	14
A	312	Cherry Creek SE 1/4 Sec 29 T17N R19E	75	5
A	313	Coleman Cr NW 1/4 Sec 20 T17N R19E	67	2
A	314	Ellensburg Town Canal NE1/4 Sec 6	13	2
A	315	Cascade Canal NE1/4 Sec 31 18N 19E	15	3
A	317	Tieton Canal SW1/4 Sec 11 T14N R16E	13	2
A	318	Cowiche Creek SE1/4 Sec 9 T13N R18E	20	2
A	319	Cottonwood Canal Drain SE1/4 Sec 28	52	2
A	321	Naches River at Nelson Bridge	104	5
A	323	Drain at Birchfield Road	64	5
A	324	Wide Hollow Creek near Gromore	30	9
A	326	Wide Hollow Creek at Union Gap STP	64	8
A	330	Drain DID #3 at South Hill Road	33	8
A	331	Drain DID #3 at Duffy Road	33	3
A	335	Griffin Lake Inlet	47	12
A	336	Griffin Lake Outlet	43	19
A	339	East Toppenish Drain at Wilson Road	57	38
A	340	Sub Drain 35 at Parton Road	57	20
A	341	Marion Drain at Highway 97	58	12
A	342	Wanity Slough at Myers Road	57	9
A	345	South Dr at Highway 22 nr Satus	56	5
A	346	Granger Drain--Hwy 223 abv Granger	63	16
A	347	Spring Creek at Hess Rd	56	1

Table 53.--Sites with dissolved-oxygen concentrations less than Washington State standards in the Yakima River basin, Washington, 1959-85 water years--Continued.

Stream class	Map reference number	Site name	Number of determi-minations	Number of determinations less than State standards
		Class A -- Tributaries, canals, and drains--Continued		
A	348	Snipes Cr at Old Inland Empire Road	53	3
A	352	Wipple Wasteway at Thrall Road	55	4
A	353	Wilson Creek at Thrall Road	59	1
A	356	Drain DID #3 abv Rendering Plant	25	7
A	357	Drain at Elks Golf Course	30	23
A	358	Teanaway River at Highway 10 bridge	43	6
A	361	Taneum Creek Anderson's Loafing Shed	10	2
A	362	Manastash at Brown Road Bridge	10	2
A	370	Ahtanum Creek- 4 mi east of Tampico	34	4
A	373	Rattlesnake Cr--above Forest Station	26	2
A	374	Toppenish Creek at BIA gage	34	6
A	375	Satus Creek at BIA gage	34	8
A	377	Simcoe Cr--1 mi west of Power Map	34	6
A	378	Squaw Creek--0.3 mi abv Hwy 97 Bridge	18	6
A	505	DID 3 Drain on Needham Feedlot	15	8
A	506	DID 9 Drain at Sunnyside-Mabton Hwy	15	1
A	507	DID 5 Drain along Tear Road	15	1
A	516	Sunnyside STP effluent to DID 3	1	1
		Class B -- Sulphur Creek		
B	328	Sulphur Cr at North above Sunnyside	47	2
B	334	Sulphur Cr Wasteway at McGee Road	64	1
		Class AA -- Main stem headwater		
AA	1	Yakima River above Cle Elum	47	3
		Class AA -- Headwater tributaries		
AA	3	Cle Elum River near Cle Elum	47	3
AA	16	Middle Fork Naches River near Cliffdell	23	2
AA	17	Bumping River at American River	32	6
AA	18	American River near Nile	33	2
AA	23	Tieton River at Oak Cr Game Range	57	5
AA	236	Crow Creek	8	7
AA	237	Quartz Creek	3	2
AA	238	Pile-up Creek	8	4
AA	240	Bear Creek	1	1
AA	242	Middle Fk Little Naches River	1	1
AA	243	Lower Little Naches	3	2
AA	244	Upper American River	3	1
AA	246	Naches River	10	4
AA	247	Milk Creek	1	1
AA	251	Clear Creek	18	8
AA	252	Oak Creek at mouth	7	3
AA	257	Middle Fork Oak Creek	6	1
AA	258	Upper Oak Creek	6	1
AA	368	Cle Elum Reservoir at pump barge	74	31
AA	372	Little Naches River at USGS gage	33	7
AA	385	Rimrock Reservoir--100 m abv dam	67	50
AA	421	Keechelus Lake	15	5
AA	422	Keechelus Lake	22	6
AA	423	Keechelus Lake	9	5
AA	451	Little Naches River near Cliffdell	35	4

Table 54.--Summary of dissolved major-metal end trace-element data in the Yakima River basin, Washington, 1953-85 water years

[The classification "dissolved" is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample passing through a 0.45 micrometer (µm) filter; µg/L = micrograms per liter, mg/L = milligrams per liter; data are not necessarily representative of monthly variations and should not be used for inter- and intra-site comparisons; "--" = no data; hardness in milligrams per liter as calcium carbonate]

Map reference number	Site name	Water-year period	Number of samples	Minimum value (µg/L)	Value (µg/L) at indicated percentile: 10	25	50 (median)	75	90	Maximum value (µg/L)	Minimum hardness (mg/L)
					Arsenic						
4	Yakima River at Cle Elum	1962-68	16	<5	<5	<5	<5	<5	<5	<5	18
5	Teanaway River near Cle Elum	1962-66	10	<5	<5	<5	<5	<5	<5	<5	42
7	Wilson Creek at Thrall	1966-68	6	<10	<10	<10	<10	<10	<10	<10	78
16	Middle Fork Naches River--Cliffdell	1963-65	6	<5	<5	<5	<5	<5	<5	<5	15
21	Naches River near Naches	1963-66	8	<5	<5	<5	<5	<5	10	10	16
25	Naches River near Yakima	1960-68	14	<5	<5	<5	<5	<5	<5	<5	19
32	Yakima River at Union Gap	1979-85	38	<1	<1	<1	1	1	2	2	31
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	1	2	2	2	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	1	1	2	2	2	24
47	Yakima River near Parker	1962-68	9	<10	<10	<10	<10	<10	10	10	27
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	1	1	2	2	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	1	2	2	2	42
100	Yakima River at Kiona	1962-65	8	<5	<5	<5	<5	<5	10	10	43
100	Yakima River at Kiona	1975-85	53	<1	<1	1	2	2	3	18	44
					Barium						
32	Yakims River at Union Gap	1979-85	38	5	10	10	16	20	21	100	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	5	8	10	10	20	20	20	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	4	4	10	10	20	20	20	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	6	8	10	10	20	20	20	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	8	8	17	20	20	20	20	31
100	Yakima River at Kiona	1978-85	36	14	18	20	28	38	43	200	38
					Boron						
4	Yakima River at Cle Elum	1953-69	97	<10	<10	<10	<10	15	50	220	17
5	Teanaway River near Cle Elum	1962-66	19	<10	<10	<10	<10	10	20	20	42
7	Wilson Creek at Thrall	1966-68	5	<10	<10	<10	<10	<10	<10	<10	36
16	Middle Fork Naches River--Cliffdell	1963-65	6	<10	<10	<10	<10	12	20	20	15
17	Bumping River at American River	1963-64	7	<10	<10	<10	<10	20	20	20	12
18	American River near Nile	1963-64	8	<10	<10	<10	<10	<10	20	20	14
21	Naches River near Naches	1963-66	16	<10	<10	<10	<10	<10	26	40	16
23	Tieton River at Oak Cr Game Range	1963-66	8	<10	<10	<10	<10	<10	<10	<10	21
25	Naches River near Yakima	1962-69	15	<10	<10	<10	10	20	48	60	19
26	Naches River near North Yakima	1960-66	11	<10	<10	<10	<10	<10	<10	<10	19
32	Yakima River at Union Gap	1980-81	24	<10	<10	<10	10	20	35	70	31
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<10	<10	<10	<10	20	20	60	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<10	<10	<10	10	20	30	30	24
47	Yakima River near Parker	1962-69	9	<10	<10	<10	<10	15	30	30	27
54	Toppenish Creek near Fort Simcoe	1980-81	22	<10	<10	<10	<10	20	30	50	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	4	4	8	10	20	20	20	31
100	Yakima River at Kiona	1953-82	162	<10	<10	<10	<10	30	50	100	38
292	DID No. 25 at State Highway No. 12	1968-74	44	<10	<10	12	30	60	75	150	120
293	Mile 28 Drain at State Highway	1968-74	43	<10	<10	<10	30	50	76	150	110
294	DID 2 east branch at Mile 28 Drain	1968-74	44	<10	<10	<10	30	58	85	130	135
295	Drain 27.2 at Knowles Road	1968-73	26	<10	<10	<10	20	50	103	130	46
296	26.6 Drain at Kirk Rd crossing	1968-74	31	<10	10	20	40	70	228	300	46
297	Roza Main Canal at Beam Road	1968-73	26	<10	<10	<10	20	32	70	90	31
298	Sunnyside Canal at Beam Road	1968-73	27	<10	<10	<10	20	40	72	110	27
299	KID Hover Wasteway near bottom	1968-71	12	<10	<10	20	35	85	110	110	65
300	KID Coyote Canyon Drain near Bottom	1968-71	21	<10	<10	<10	<10	40	92	120	90
301	KID Main Canal near head at gage	1968-73	27	<10	<10	10	20	70	90	100	40
302	Main Drain at Highway No. 22	1968-74	42	<10	<10	<10	20	42	80	90	69
303	WID Main Drain at Robbins Road	1968-77	20	<10	<10	<10	<10	58	89	90	90
304	WID Main Drain at Lateral C Road	1968-71	20	<10	<10	<10	<10	38	77	110	88
305	Below Drop No 3--WID Main Canal	1968-70	10	<10	<10	18	40	58	89	90	36
306	WID Main Canal nr Canal Intake	1968-74	19	<10	<10	<10	20	60	70	90	28
307	Chandler Canal--mile 0.6 nr Prosser	1970-74	28	<10	<10	10	30	48	80	90	40
308	Chandler Canal--mile 2.8 nr Prosser	1970-74	27	<10	<10	10	20	40	62	90	39
309	Satus 2 Canal. NW 1/4 S17 9N 21E	1971-73	16	<10	<10	<10	35	60	86	100	31
310	Nequist Drain NW1/4 S25 9N 21E	1971-74	23	20	34	50	80	110	120	130	260
311	Satus Drain 302 NW1/4 S34 9N 22E	1971-74	20	<10	<10	10	20	58	79	110	48
312	Cherry Cr SE 1/4 S 29 17N 19E	1971-74	23	<10	<10	10	20	50	60	80	83
313	Coleman Cr NW 1/4 S 20 17N 19E	1971-74	23	<10	<10	<10	20	40	50	70	52
314	Ellensburg Town Canal NE1/4 S6	1971-74	13	<10	<10	<10	20	35	154	230	30
315	Cascade Canal NE1/4 S31 18N 19E	1971-74	15	<10	<10	<10	10	30	90	150	37
316	Kittitas Canal SE1/4 S6 18N 19E	1971-73	12	<10	<10	<10	<10	28	40	40	10
317	Tieton Canal SW1/4 S11 14N 16E	1971-73	13	<10	<10	<10	20	30	74	90	17
318	Cowiche Creek SE1/4 S9 13N 18E	1971-74	21	<10	<10	<10	20	35	48	70	33
319	Cottonwood Canal Drain SE1/4 S28	1971-74	19	10	10	20	30	50	60	60	67
451	Little Naches River near Cliffdell	1963-65	8	<1	<1	<1	<1	2	6	9	15

Table 54.--Summary of dissolved major-metal and trace-element data in the Yakima River basin, Washington, 1953-85 water years--Continued

Map reference number	Site name	Water-year period	Number of samples	Minimum value (µg/L)	Value (µg/L) at indicated percentile 10	25	50 (median)	75	90	Maximum value (µg/L)	Minimum hardness (mg/L)
					Cadmium						
32	Yakima River at Union Gap	1980-85	36	<1	<1	<1	<1	<1	<1	1	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	1	1	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	<1	<1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	1	2	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	<1	<1	42
100	Yakima River at Kiona	1975-79	19	<2	<2	<2	<2	2	2	7	44
100	Yakima River at Kiona	1980-85	32	<1	<1	<1	<1	<1	1	3	50
					Chromium						
4	Yakima River at Cle Elum	1962-70	19	<10	<10	<10	<10	<10	10	10	18
5	Teanaway River near Cle Elum	1962-66	10	<10	<10	<10	<10	10	10	10	42
6	Yakima River near Thorp	1975-75	24	<20	<20	<20	<20	<20	<20	<20	18
7	Wilson Creek at Thrall	1966-70	8	<10	<10	<10	<10	10	10	10	36
16	Middle Fork Naches River--Cliffdell	1963-65	6	<10	<10	<10	<10	<10	<10	<10	15
21	Naches River near Naches	1963-66	8	<10	<10	<10	<10	10	30	30	16
25	Naches River near Yakima	1960-70	17	<10	<10	<10	<10	<10	10	10	19
26	Naches River near North Yakima	1972-73	23	<20	<20	<20	<20	<20	<20	<20	19
32	Yakima River at Union Gap	1980-85	36	<1	<1	<1	<1	<1	1	10	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<10	<10	<10	<10	<10	<10	<10	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<10	<10	<10	<10	<10	<10	<10	24
40	Yakima River at Parker	1973-75	47	<20	<20	<20	<20	<20	<20	<20	27
47	Yakima River near Parker	1962-69	10	<10	<10	<10	<10	<10	28	30	27
54	Toppenish Creek near Fort Simcoe	1980-81	14	<10	<10	<10	<10	<10	<10	10	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<10	<10	<10	<10	<10	<10	<10	42
100	Yakima River at Kiona	1962-79	88	<20	<20	<20	<20	<20	<20	20	38
100	Yakima River at Kiona	1980-85	33	<1	<1	<1	<1	<1	7	10	50
					Copper						
4	Yakima River at Cle Elum	1962-70	22	<10	<10	<10	10	20	81	150	18
5	Teanaway River near Cle Elum	1962-66	10	10	10	10	30	118	203	210	42
6	Yakima River near Thorp	1975-75	24	<2	<2	<2	<2	2	3	18	18
7	Wilson Creek at Thrall	1966-70	8	<10	<10	<10	10	40	60	60	36
16	Middle Fork Naches River--Cliffdell	1963-65	6	10	10	25	30	90	120	120	15
21	Naches River near Naches	1963-66	8	10	10	20	20	65	140	140	16
25	Naches River near Yakima	1960-70	18	<5	<5	<5	5	22	111	120	19
26	Naches River near North Yakima	1972-73	23	<2	<2	<2	3	3	5	18	--
32	Yakima River at Union Gap	1979-80	17	<10	<10	<10	<10	10	12	18	32
32	Yakima River at Union Gap	1981-85	26	<1	1	2	2	3	12	100	37
33	North Fork Ahtanum Creek nr Tampico	1980-80	11	3	3	4	10	10	10	10	24
33	North Fork Ahtanum Creek nr Tampico	1981-81	8	1	1	1	1	8	12	12	26
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	2	2	2	5	10	10	10	24
40	Yakima River at Parker	1973-75	46	<2	<2	<2	2	3	5	9	27
47	Yakima River near Parker	1962-70	11	<5	<5	<5	30	80	136	140	27
54	Toppenish Creek near Fort Simcoe	1974-80	12	1	1	3	10	10	14	16	23
54	Toppenish Creek near Fort Simcoe	1981-81	8	<1	<1	<1	1	4	5	5	37
55	North Fork Simcoe Cr nr Fort Simcoe	1974-80	7	<2	<2	2	4	10	10	10	31
100	Yakima River at Kiona	1962-70	11	<5	<5	5	20	150	192	200	40
100	Yakima River at Kiona	1973-80	88	<2	<2	<2	2	5	10	30	38
100	Yakima River at Kiona	1981-85	26	<1	<1	2	3	4	9	22	56
399	Yakima River at Kiona	1968-71	39	1	2	3	4	7	11	91	47
					Iron						
32	Yakima River at Union Gap	1979-85	44	19	22	30	40	48	86	200	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	40	53	62	90	142	184	240	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	40	40	60	84	190	210	210	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	30	98	130	230	462	490	530	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	60	60	68	93	125	140	140	31
100	Yakima River at Kiona	1975-85	57	10	14	20	30	50	100	200	38
399	Yakima River at Kiona	1979-71	9	31	31	56	81	122	450	450	--
					Lead						
6	Yakima River near Thorp	1975-75	24	<2	2	7	10	18	28	400	18
26	Naches River near North Yakima	1972-73	23	<2	<2	<2	2	4	6	6	19
32	Yakima River at Union Gap	1980-85	42	<1	<1	<1	1	2	7	28	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<1	<1	<1	<1	1	2	13	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	1	1	24
40	Yakima River at Parker	1973-75	47	<2	<2	2	4	11	24	39	27
54	Toppenish Creek near Fort Simcoe	1980-81	22	<1	<1	<1	<1	1	2	4	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	3	3	42
100	Yakima River at Kiona	1973-79	78	<2	<2	3	6	11	20	300	38
100	Yakima River at Kiona	1980-85	39	<1	<1	<1	1	2	5	10	50
399	Yakima River at Kiona	1968-71	35	3	6	10	15	21	65	100	--

Table 54.--Summary of dissolved major-metal and trace-element data in the Yakima River basin, Washington, 1953-85 water years--Continued

Map reference number	Site name	Water-year period	Number of samples	Minimum value (μg/L)	Value (μg/L) at indicated percentile 10	25	50 (median)	75	90	Maximum value (μg/L)	Minimum hardness (mg/L)
	Manganese										
32	Yakima River at Union Gap	1979-85	45	<10	7	8	10	16	22	50	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	5	6	7	10	15	34	70	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	6	6	10	18	20	40	40	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	9	10	10	18	20	28	33	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	4	4	6	10	20	22	22	31
100	Yakima River at Kiona	1975-85	59	<10	<10	4	8	20	30	50	38
	Mercury										
32	Yakima River at Union Gap	1979-85	45	<.1	<.1	<.1	<.1	.1	.2	.3	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<.1	<.1	<.1	<.1	.2	.4	.5	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<.1	<.1	<.1	<.1	.1	.3	.3	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	<.1	<.1	<.1	.1	.2	.3	.7	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<.1	<.1	<.1	.1	.4	.4	.4	31
100	Yakima River at Kiona	1975-85	60	<.1	<.1	<.1	<.1	.1	.2	.5	38
399	Yakima River at Kiona	1970-71	4	1	1	1	1	2.1	2.5	2.5	--
	Nickel										
32	Yakima River at Union Gap	1980-85	42	<1	<1	<1	1	2	4	46	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<1	<1	<1	2	2	7	8	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	1	1	2	2	4	4	4	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	<1	<1	<1	1	2	4	11	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	1	1	2	2	4	5	5	31
100	Yakima River at Kiona	1980-85	39	<1	<1	<1	1	3	6	10	38
	Selenium										
32	Yakima River at Union Gap	1979-85	38	<1	<1	<1	<1	<1	<1	<1	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	<1	<1	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	<1	<1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	<1	<1	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	<1	<1	31
100	Yakima River at Kiona	1975-85	53	<1	<1	<1	<1	<1	<1	4	38
	Silver										
32	Yakima River at Union Gap	1979-85	38	<1	<1	<1	<1	<1	<1	<1	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	<1	<1	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	<1	<1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	<1	<1	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	<1	<1	31
100	Yakima River at Kiona	1978-85	41	<1	<1	<1	<1	<1	<1	1.0	38
	Zinc										
4	Yakima River at Cle Elum	1962-66	10	<50	<50	<50	50	50	95	100	18
4	Yakima River at Cle Elum	1967-70	12	<20	<20	<20	<20	10	10	10	20
5	Teanaway River near Cle Elum	1962-66	10	<50	<50	<50	50	62	100	100	42
6	Yakima River near Thorp	1975-75	24	<20	<20	<20	<20	20	40	70	18
7	Wilson Creek at Thrall	1967-70	6	<20	<20	<20	<20	<20	20	20	36
16	Middle Fork Naches River--Cliffdell	1963-65	6	<50	<50	<50	<50	100	100	100	15
21	Naches River near Naches	1963-66	8	<50	<50	<50	<50	88	500	500	16
25	Naches River near Yakima	1962-66	9	<50	<50	<50	<50	55	100	100	19
25	Naches River near Yakima	1967-70	7	<10	<10	<10	<10	<10	10	10	21
32	Yakima River at Union Gap	1979-85	45	<3	<3	<3	5	10	13	21	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<3	<3	<3	6	10	11	70	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<3	<3	<3	<3	4	5	5	24
40	Yakima River at Parker	1973-75	46	<20	<20	<20	<20	20	30	80	27
47	Yakima River near Parker	1962-65	8	<50	<50	<50	<50	75	400	400	27
54	Toppenish Creek near Fort Simcoe	1980-81	22	<3	<3	<3	<3	7	18	26	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<3	<3	<3	<3	8	13	13	42
100	Yakima River at Kiona	1962-65	8	<50	<50	<50	<50	50	100	100	43
100	Yakima River at Kiona	1968-76	70	<20	<20	<20	<20	20	30	300	38
100	Yakima River at Kiona	1977-85	51	<3	<3	<3	4	8	10	30	50
399	Yakima River at Kiona	1968-71	37	3	7	12	20	60	213	760	--

Table 55.--Summary of dissolved major-metal and trace-element concentrations exceeding water-quality criteria, regulations, or standards in the Yakima River basin, Washington, 1953-85 water years

[Statistical summaries of constitutent concentrations for selected sites are listed in table 54. Results for those sites where all of the observations met U.S. Environmental Protection Agency (1986) criteria, regulations, or State standards (arsenic, barium, boron, nickel, selenium) are not shown in this table. "--" = no standard or criteria; Exceedances were determined using measured water hardness unless noted otherwise; the listed acute and chronic criteria assume a water hardness of 50 milligrams per liter as calcium carbonate; * = exceedences computed using an estimated hardness equal to the minimum hardness for the period of record]

Map-reference number	Site name	Number of observations	Number of observations not meeting criteria and regulations: Freshwater aquatic life, Acute	Freshwater aquatic life, Chronic	Human health (drinking water)
Dissolved cadmium criteria or standards: Acute: 1-hour average 1.8 micrograms per liter once in 3 years. Chronic: 4-day average 0.66 micrograms per liter once in 3 years. Drinking water: 0.01 milligrams per liter (National Primary Drinking Water Regulation).					
32	Yakima River at Union Gap	36	1	3	0
33	North Fork Ahtanum Creek nr Tampico	14	0	3	0
54	Toppenish Creek near Fort Simcoe	14	1	1	0
100	Yakima River at Kiona	51	2	9	0
Dissolved chromium criteria or standards: Acute: 1-hour average 16 micrograms per liter once in 3 years. Chronic: 4-day average 11 micrograms per liter once in 3 years. Drinking water: 0.05 milligrams per liter (National Primary Drinking Water Regulation).					
21	Naches River near Naches	8	1	1	0
47	Yakima River near Parker	10	1	1	0
100	Yakima River at Kiona	121	1	1	0
399	Yakima River at Kiona	3	1	1	0
Dissolved copper criteria or standards: Acute: 1-hour average 9.2 micrograms per liter once in 3 years. Chronic: 4-day average 6.5 micrograms per liter once in 3 years. Drinking water: 1 milligram per liter (National Secondary Drinking Water Regulation).					
4	Yakima River at Cle Elum	22	12	12	0
5	Tenaway River near Cle Elum	10	7	9	0
6	Yakima River near Thorp	24	1	1	0
7	Wilson Creek at Thrall	8	3	3	0
16	Middle Fork Naches River near Cliffdell	6	6	6	0
17	Bumping River at American River	3	3	3	0
18	American River near Nile	4	3	3	0
21	Naches River near Naches	8	8	8	0
24	Naches River at Naches	1	1	1	0
25	Naches River near Yakima	18	10	10	0
26	Naches River near North Yakima	23	*3	*5	0
32	Yakima River at Union Gap	43	3	4	0
33	North Fork Ahtanum Creek nr Tampico	19	2	3	0
34	North Fork Ahtanum Creek at Tampico	2	0	1	0
35	South Fork Ahtanum Creek nr Tampico	7	0	1	0
40	Yakima River at Parker	46	*3	*9	0
47	Yakima River near Parker	11	7	7	0
54	Toppenish Creek near Fort Simcoe	20	1	1	0
55	North Fork Simcoe Cr nr Fort Simcoe	7	2	2	0
100	Yakima River at Kiona	125	10	16	0
399	Yakima River at Kiona	39	1	7	0
Dissolved iron criteria or standards: Chronic: 1000 micrograms per liter. Drinking water: 0.3 milligrams per liter (National Secondary Drinking Water Regulation).					
54	Toppenish Creek near Fort Simcoe	22	--	0	12
399	Yakima River at Kiona	9	--	0	1
Dissolved manganese criteria or standards: Drinking water: 0.05 milligrams per liter (National Secondary Drinking Water Regulation).					
32	Yakima River at Union Gap	45	--	--	1
33	North Fork Ahtanum Creek nr Tampico	22	--	--	1
100	Yakima River at Kiona	59	--	--	2

Table 55.--Summary of dissolved major-metal and trace-element concentrations exceeding water-quality criteria, regulations, or standards in the Yakima River basin, Washington, 1953-85 water years

Map-reference number	Site name	Number of observations	Number of observations not meeting criteria and regulations: Freshwater aquatic life, Acute	Freshwater aquatic life, Chronic	Human health (drinking water)
Dissolved zinc criteria or standards: Acute: 1-hour average 65 micrograms per liter once in 3 years. Chronic: 4-day average 59 micrograms per liter once in 3 years. Drinking water: 5 milligrams per liter (National Secondary Drinking Water Regulation).					
4	Yakima River at Cle Elum	22	1	1	0
16	Middle Fork Naches River near Cliffdell	6	2	2	0
17	Bumping River at American River	3	2	2	0
18	American River near Nile	4	1	1	0
25	Naches River near Yakima	16	1	1	0
47	Yakima River near Parker	8	1	1	0
100	Yakima River at Kiona	129	2	2	0
399	Yakima River at Kiona	37	7	*9	0
Dissolved mercury criteria or standards: Acute: 1-hour average 2.4 micrograms per liter once in 3 years. Chronic: 4-day average 0.012 micrograms per liter once in 3 years. Drinking water: 0.002 milligrams per liter (National Primary Drinking Water Regulation).					
32	Yakima River at Union Gap	45	0	20	0
33	North Fork Ahtanum Creek nr Tampico	22	0	10	0
34	North Fork Ahtanum Creek at Tampico	1	0	1	0
35	South Fork Ahtanum Creek nr Tampico	7	0	2	0
54	Toppenish Creek near Fort Simcoe	22	0	15	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	0	4	0
100	Yakima River at Kiona	60	0	16	0
399	Yakima River at Kiona	4	1	4	1
Dissolved lead criteria or standards: Acute: 1-hour average 34 micrograms per liter once in 3 years. Chronic: 4-day average 1.3 micrograms per liter once in 3 years. Drinking water: 0.05 milligrams per liter (National Primary. Drinking Water Regulation).					
6	Yakima River near Thorp	24	7	23	1
26	Naches River near North Yakima	23	*0	*13	0
32	Yakima River at Union Gap	42	0	19	0
33	North Fork Ahtanum Creek nr Tampico	22	0	5	0
34	North Fork Ahtanum Creek at Tampico	2	0	1	0
35	South Fork Ahtanum Creek nr Tampico	7	0	1	0
36	South Fork Ahtanum Creek at Tampico	1	0	1	0
39	Main Canal near Parker	1	0	1	0
40	Yakima River at Parker	47	1	34	0
52	Wanity Slough at Rocky Ford Road	1	0	1	0
54	Toppenish Creek near Fort Simcoe	22	0	6	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	0	1	0
56	South Fork Simcoe Cr nr Fort Simcoe	1	0	1	0
64	Satus Creek above Logy Cr	1	0	1	0
65	Logy Creek near Toppenish	1	0	1	0
100	Yakima River at Kiona	117	2	64	4
399	Yakima River at Kiona	35	*7	*35	4
Dissolved silver criteria or standards: Acute: 1-hour average 1.2 micrograms per liter at any time. Drinking water: 0.05 milligrams per liter (National Primary Drinking Water Regulation).					
100	Yakima River at Kiona	41	1	--	0

Table 56.--Summary of total recoverable and total major-metal and trace-element data in the Yakima River basin, Washington, 1953-85 water years

[Total recoverable and total are expressions of less than 95 percent and greater than or equal to 95 percent recoveries, respectively; µg/L = micrograms per liter; mg/L = milligrams per liter; data are not necessarily representative of monthly variations and should not be used inter- and intra-site comparisons; hardness in milligrams per liter as calcium carbonate]

Map reference number	Site name	Water-year period	Number of samples	Minimum value (µg/L)	Value, in µg/L, at indicated percentile: 10	25	50 (median)	75	90	Maximum value (µg/L)	Minimum hardness (mg/L)
	Total arsenic										
32	Yakima River at Union Gap	1979-82	26	1	1	1	2	2	3	3	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	1	1	2	3	4	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	1	1	2	4	4	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	1	2	10	14	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	1	3	6	6	3
100	Yakima River at Kiona	1975-82	41	<1	1	2	3	3	4	18	38
	Total recoverable barium										
32	Yakima River at Union Gap	1979-82	26	<100	<100	<100	<100	100	100	200	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<100	<100	<100	<100	100	100	100	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<100	<100	<100	<100	<100	<100	<100	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<100	<100	<100	<100	<100	<100	100	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<100	<100	<100	<100	<100	<100	<100	31
100	Yakima River at Kiona	1978-82	29	<100	<100	<100	<100	100	200	400	38
	Total recoverable boron										
32	Yakima River at Union Gap	1980-81	24	9	10	20	55	202	360	370	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	6	8	18	60	202	330	370	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	6	6	7	20	50	80	80	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	7	8	18	40	220	344	380	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	2	2	8	10	45	60	60	31
100	Yakima River at Kiona	1980-82	21	20	30	35	120	275	374	410	38
	Total recoverable cadmium										
32	Yakima River at Union Gap	1980-82	24	<1	<1	<1	<1	1	1	3	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	4	6	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	1	1	1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	1	1	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	1	1	42
100	Yakima River at Kiona	1975-79	19	<2	<2	<2	<2	<2	<2	<2	44
100	Yakima River at Kiona	1980-82	21	<1	<1	<1	<1	<1	1	2	50
	Total recoverable chromium										
7	Wilson Creek at Thrall	1967-70	6	<10	<10	<10	<10	<10	10	10	36
32	Yakima River at Union Gap	1980-82	24	<10	<10	<10	<10	10	20	20	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<10	<10	<10	<10	10	15	20	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<10	<10	<10	<10	20	20	20	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<10	<10	<10	<10	10	20	20	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<10	<10	<10	<10	20	20	20	42
100	Yakima River at Kiona	1965-79	23	<20	<20	<20	<20	<20	<20	20	38
100	Yakima River at Kiona	1980-82	21	<10	<10	<10	<10	10	20	30	50
	Total recoverable copper										
32	Yakima River at Union Gap	1979-82	33	<2	3	5	8	12	26	39	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	2	3	4	5	7	32	90	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	3	3	3	5	10	38	38	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	2	3	4	5	9	18	67	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	3	3	4	6	9	12	12	42
100	Yakima River at Kiona	1975-78	16	<20	<20	<20	<20	<20	36	70	44
100	Yakima River at Kiona	1979-82	32	<2	3	6	8	11	14	23	50
399	Yakima River at Kiona	1970-71	4	5	5	5	6	7	8	8	--
	Total recoverable iron										
4	Yakima River at Cle Elum	1953-65	156	<10	<10	<10	20	58	116	230	17
5	Teanaway River near Cle Elum	1962-65	30	30	50	60	80	130	380	700	42
16	Middle Fork Naches River Cliffdell	1963-65	33	10	20	35	70	120	236	480	15
17	Bumping River at American River	1963-64	39	<10	10	30	40	70	80	110	12
18	American River near Nile	1963-64	35	<10	<10	20	40	50	190	260	14
19	Rattlesnake Creek near Nile	1963-64	30	20	31	40	50	100	445	810	20
21	Naches River near Naches	1963-65	60	20	31	60	100	150	358	660	16
23	Tieton River at Oak Cr Game Range	1963-65	49	60	80	140	200	325	500	820	22
24	Naches River at Naches	1959-60	20	30	31	70	130	180	245	250	21
25	Naches River near Yakima	1960-65	56	10	30	50	115	200	384	680	19
26	Naches River near North Yakima	1960-65	57	20	40	55	120	205	376	680	19
32	Yakima River at Union Gap	1979-82	32	270	363	525	950	1,100	2,780	5,900	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	140	280	300	480	935	3,910	17,000	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	470	470	570	640	1,900	7,100	7,100	24
54	Toppenish Creek near Fort Simcoe	1980-81	21	340	456	530	700	945	1,320	6,800	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	510	510	570	750	1,675	2,500	2,500	31
100	Yakima River at Kiona	1953-82	150	<10	<10	<10	30	618	1,300	18,000	38
399	Yakima River at Kiona	1968-71	26	47	67	295	505	795	4,310	94,400	--
451	Little Naches River near Cliffdell	1963-65	33	10	20	35	70	120	236	480	15

Table 56.--Summary of total recoverable and total major-metal and trace-element data in the Yakima River basin, Washington, 1953-85 water years--Continued

Map reference number	Site name	Water-year period	Number of samples	Minimum value (µg/L)	Value, in µg/L, at indicated percentile 10	25	50 (median)	75	90	Maximum value (µg/L)	Minimum hardness (mg/L)
	Total recoverable lead										
32	Yakima River at Union Gap	1979-82	33	<1	<1	2	5	8	39	97	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<1	<1	2	4	7	11	20	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	1	3	5	5	5	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	<1	<1	2	4	6	11	36	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	1	1	2	2	6	8	8	42
100	Yakima River at Kiona	1975-77	12	<200	<200	<200	<200	<200	<200	<200	44
100	Yakima River at Kiona	1978-82	34	<1	1	3	4.0	9	14	78	50
	Total recoverable manganese										
32	Yakima River at Union Gap	1979-82	32	20	20	30	35	40	70	470	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	10	13	20	20	30	71	360	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	20	20	20	30	40	150	150	24
54	Toppenish Creek near Fort Simcoe	1980-81	21	20	20	25	30	45	50	100	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	20	20	20	25	45	60	60	31
100	Yakima River at Kiona	1975-82	48	<10	30	42	60	80	181	420	38
147	Domerie Creek above Roslyn Intake	1967-69	17	<80	<80	<80	<80	<80	<80	<80	24
	Total recoverable mercury										
6	Yakima River near Thorp	1975-75	24	<.5	<.5	<.5	<.5	<.5	<.5	<.5	18
26	Naches River near North Yakima	1972-73	24	<.5	<.5	<.5	<.5	<.5	<.5	.6	19
32	Yakima River at Union Gap	1979-82	33	<.1	<.1	.1	.3	.4	.6	.7	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<.1	.1	.1	.2	.4	.6	1.3	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<.1	<.1	.1	.1	.7	1.5	1.5	24
40	Yakima River at Parker	1973-75	47	<.5	<.5	<.5	<.5	<.5	<.5	1.3	27
54	Toppenish Creek near Fort Simcoe	1980-81	22	<.1	<.1	.1	.3	.4	.6	.6	34
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<.1	<.1	.1	.1	.7	1.0	1.0	42
100	Yakima River at Kiona	1973-77	70	<.5	<.5	<.5	<.5	<.5	<.5	4.1	38
100	Yakima River at Kiona	1978-82	36	<.1	<.1	<.1	.2	.4	.6	.8	50
	Total recoverable nickel										
32	Yakima River at Union Gap	1980-82	30	1	2	4	6	6	16	21	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	<1	<1	1	4	8	10	15	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	1	6	7	8	8	24
54	Toppenish Creek near Fort Simcoe	1980-81	22	<1	<1	2	4	6	13	470	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	3	4	9	21	21	31
100	Yakima River at Kiona	1980-82	27	<1	2	3	4	7	15	18	38
	Total selenium										
32	Yakima River at Union Gap	1979-82	26	<1	<1	<1	<1	<1	<1	1	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	<1	1	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	<1	<1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	<1	1	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	<1	<1	31
100	Yakima River at Kiona	1975-82	41	<1	<1	<1	<1	<1	<1	1	38
	Total recoverable silver										
32	Yakima River at Union Gap	1979-82	28	<1	<1	<1	<1	<1	1	3	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	14	<1	<1	<1	<1	<1	1	1	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	<1	<1	<1	<1	<1	<1	<1	24
54	Toppenish Creek near Fort Simcoe	1980-81	14	<1	<1	<1	<1	<1	<1	1	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	<1	<1	<1	<1	<1	<1	<1	31
100	Yakima River at Kiona	1978-82	31	<1	<1	<1	<1	<1	<1	2	38
	Total recoverable zinc										
32	Yakima River at Union Gap	1979-82	32	<10	10	20	20	30	40	50	32
33	North Fork Ahtanum Creek nr Tampico	1980-81	22	10	10	10	20	30	80	90	24
35	South Fork Ahtanum Creek nr Tampico	1980-80	7	10	10	20	20	30	30	30	24
54	Toppenish Creek near Fort Simcoe	1980-81	21	10	10	10	20	30	38	40	23
55	North Fork Simcoe Cr nr Fort Simcoe	1980-80	6	20	20	20	20	30	30	30	31
100	Yakima River at Kiona	1975-82	48	<20	<20	20	20	30	70	160	38

Table 57.--Summary of total and total-recoverable major-metal and trace-element concentrations exceeding water-quality criteria, regulations, or standards in the Yakima River basin, Washington, 1953-85 water years

[Statistical summaries of constitutent concentrations for selected sites are listed in table 56. Results for those sites where all of the observations met U.S. Environmental Protection Agency (1986) criteria, regulations, or State standards (arsenic, barium, boron, and selenium) are not shown in this table. "--" = no standard or criteria; exceedances were determined using measured water hardness unless noted otherwise; the listed acute and chronic criteria assume a water hardness of 50 milligrams per liter as calcium carbonate; * = exceedances computed using an estimated hardness equal to the minimum hardness for the period of record]

Total recoverable cadmium, water-quality standard:
Acute: 1-hour average 1.8 micrograms per liter once in 3 years. Chronic: 4-day average 0.66 micrograms per liter once in 3 years. Drinking water: 0.01 milligrams per liter (National Primary Drinking Water Regulation).

Map-reference number	Site name	Number of observations	Number of observations not meeting criteria and regulations: Freshwater aquatic life, Acute	Freshwater aquatic life, Chronic	Human health (drinking water)
32	Yakima River at Union Gap	24	1	9	0
33	North Fork Ahtanum Creek nr Tampico	14	2	2	0
54	Toppenish Creek near Fort Simcoe	14	1	1	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	0	1	0
100	Yakima River at Kiona	40	1	2	0
399	Yakima River at Kiona	1	0	*1	0

Total recoverable chromium, water-quality standard:
Acute: 1-hour average 16 micrograms per liter once in 3 years. Chronic: 4-day average 11 micrograms per liter once in 3 years. Drinking water: 0.05 milligrams per liter (National Primary Drinking Water Regulation).

Map-reference number	Site name	Number of observations	Acute	Chronic	Human health (drinking water)
32	Yakima River at Union Gap	24	4	5	0
33	North Fork Ahtanum Creek nr Tampico	14	1	1	0
35	So Fk Ahtanum Cr nr Tampico	7	2	2	0
54	Toppenish Creek near Fort Simcoe	14	2	2	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	2	2	0
100	Yakima River at Kiona	44	4	4	0

Total recoverable copper, water-quality standard:
Acute: 1-hour average 9.2 micrograms per liter once in 3 years. Chronic: 4-day average 6.5 micrograms per liter once in 3 years. Drinking water: 1 milligram per liter (National Secondary Drinking Water Regulation).

Map-reference number	Site name	Number of observations	Acute	Chronic	Human health (drinking water)
32	Yakima River at Union Gap	33	14	23	0
33	North Fork Ahtanum Creek nr Tampico	22	9	15	0
35	So Fk Ahtanum Cr nr Tampico	7	4	4	0
54	Toppenish Creek near Fort Simcoe	22	5	9	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	1	3	0
100	Yakima River at Kiona	48	5	9	0
399	Yakima River at Kiona	4	0	2	0

Total recoverable iron, water-quality standard:
Chronic: 1,000 micrograms per liter. Drinking water: 0.3 milligrams per liter (National Secondary Drinking Water Regulation).

Map-reference number	Site name	Number of observations	Acute	Chronic	Human health (drinking water)
5	Teanaway River near Cle Elum	30	--	0	5
16	Midddle Fork Naches River Cliffdell	33	--	0	2
19	Rattlesnake Creek near Nile	30	--	0	4
21	Naches River near Naches	60	--	0	6
23	Tieton River at Oak Cr Game Range	49	--	0	14
25	Naches River near Yakima	56	--	0	5
26	Naches River near North Yakima	57	--	0	8
32	Yakima River at Union Gap	32	--	14	31
33	North Fork Ahtanum Creek nr Tampico	22	--	4	18
34	No Fk Ahtanum Cr at Tampico	1	--	0	1
35	So Fk Ahtanum Cr nr Tampico	7	--	2	7
54	Toppenish Creek near Fort Simcoe	21	--	5	21
55	North Fork Simcoe Cr nr Fort Simcoe	6	--	2	6
100	Yakima River at Kiona	150	--	23	48
399	Yakima River at Kiona	26	--	4	20
451	Little Naches River near Cliffdell	33	--	0	2

Total recoverable manganese, water-quality standard:
Drinking water: 0.05 milligrams per liter (National Secondary Drinking Water Regulation).

Map-reference number	Site name	Number of observations	Acute	Chronic	Human health (drinking water)
32	Yakima River at Union Gap	32	--	--	6
33	North Fork Ahtanum Creek nr Tampico	22	--	--	3
35	South Fork Ahtanum Creek nr Tampico	7	--	--	1
54	Toppenish Creek near Fort Simcoe	21	--	--	6
55	North Fork Simcoe Cr nr Fort Simcoe	6	--	--	1
100	Yakima River at Kiona	48	--	--	36

Table 57.--Summary of total and total-recoverable major-metal and trace-element concentrations exceeding water-quality criteria, regulations, or standards in the Yakima River basin, Washington, 1953-85 water years--Continued

Map-reference number	Site name	Number of observations	Number of observations not meeting criteria and regulations: Freshwater aquatic life, Acute	Freshwater aquatic life, Chronic	Human health (drinking water)
Total recoverable lead, water-quality standard: Acute: 1-hour average 34 micrograms per liter once in 3 years. Chronic: 4-day average 1.3 micrograms per liter once in 3 years. Drinking water: 0.05 milligrams per liter (National Primary Drinking Water Regulation).					
32	Yakima River at Union Gap	33	3	29	3
33	North Fork Ahtanum Creek nr Tampico	22	0	20	0
34	North Fork Ahtanum Creek at Tampico	1	0	1	0
35	South Fork Ahtanum Creek nr Tampico	7	0	5	0
54	Toppenish Creek near Fort Simcoe	22	0	19	0
55	North Fork Simcoe Cr nr Fort Simcoe	6	0	5	0
100	Yakima River at Kiona	46	0	24	0
387	Yakima River at Hwy 224 nr Richland	1	0	*1	0
388	Naches River at Yakima water intake	1	0	*1	0
389	Naches River at mouth near Yakima	1	0	1	0
399	Yakima River at Kiona	4	0	4	0
Total recoverable zinc, water-quality standard: Acute: 1-hour average 65 micrograms per liter once in 3 years. Chronic: 4-day average, 59 micrograms per liter once in 3 years. Drinking water: 5 milligrams per liter (National Secondary Drinking Water Regulation).					
33	North Fork Ahtanum Creek nr Tampico	22	2	2	0
100	Yakima River at Kiona	48	5	5	0
Total recoverable mercury, water-quality standard: Acute: 1-hour average 2.4 micrograms per liter once in 3 years. Chronic: 4-day average 0.012 micrograms per liter once in 3 years. Drinking water: 0.002 milligrams per liter (National Primary Drinking Water Regulation).					
26	Naches River near North Yakima	24	0	1	0
32	Yakima River at Union Gap	33	0	26	0
33	North Fork Ahtanum Creek nr Tampico	22	0	18	0
34	No Fk Ahtanum Cr at Tampico	1	0	1	0
35	So Fk Ahtanum Cr nr Tampico	7	0	4	0
36	So Fk Ahtanum Cr at Tampico	1	0	1	0
40	Yakima R at Parker	47	0	1	0
54	Toppenish Creek near Fort Simcoe	22	0	13	0
100	Yakima River at Kiona	106	0	31	0
386	Yakima R at Ellensburg water intake	1	0	*1	0
387	Yakima River at Hwy 224 nr Richland	1	0	*1	0
388	Naches River at Yakima water intake	1	0	*1	0
399	Yakima River at Kiona	1	0	*1	0
Total recoverable nickel, water-quality standard: Acute: 1-hour average 790 micrograms per liter once in 3 years. Chronic: 4-day average 88 micrograms per liter once in 3 years.					
54	Toppenish Creek near Fort Simcoe	22	0	1	--
Total recoverable silver, water-quality standard: Acute: 1-hour average 1.2 micrograms per liter at any time. Drinking water: 0.05 milligrams per liter (National Primary Drinking Water Regulation).					
32	Yakima River at Union Gap	28	3	--	0
33	North Fork Ahtanum Creek nr Tampico	14	2	--	0
54	Toppenish Creek near Fort Simcoe	14	1	--	0
100	Yakima River at Kiona	31	1	--	0

Table 58.--Summary of trace-organic-compound determinations showing maximum concentrations and the number of determinations above the minimum reporting level, Yakima River basin, Washington, 1968-83 water years

["RL" = minimum analytical reporting level; "--" indicates no determination above reporting level; 2,4-D = 2,4-dichlorophenoxyacetic acid; DDT = dichlorodiphenyltrichloroethane; DDD = dichlorodiphenyldichloroethane; DDE = dichlorodiphenyldichloroethylene; 2,4,5-T = trichlorophenoxyacetic acid; PCB = polychlorinated biphenyls; μg/L = micrograms per liter; μg/kg = micrograms per kilogram; mg/kg = milligrams per kilogram; μg/g = micrograms per gram; wt = weight; values in parenthesis are the site's map reference number; data retrieved from U.S. Environmental Protection Agency's Computer Storage and Retrieval System in 1986 water year]

Type of analysis	Maximum constituent concentration and number of determinations above RL — Site name and map reference number									
	DID 18 Drain at Sunny-side (86)	Sul-phur Creek nr Sunny-side (91)	Yak-ima River at Kiona (100)	Yakima River at Ellens-burg Intake (386)	Yakima River near Rich-land (387)	Naches River at Yakima Intake (388)	Naches River at mouth (389)	Yak-ima River at Kiona (399)	Yakima River at Gran-ger (424)	Yakima River near Birch-field Drain (464)
WATER ANALYSIS										
HERBICIDES										
2,4-D, dissolved (μg/L)	--	--	0.71	--	--	--	--	--	--	--
Number of determinations	0	0	4	0	0	0	0	0	0	0
2,4-D, total (μg/L)	--	.10	.71	--	--	--	--	--	--	--
Number of determinations	0	1	27	0	0	0	0	0	0	0
2,4,5-T, total (μg/L)	--	--	.01	--	--	--	--	--	--	--
Number of determinations	0	0	4	0	0	0	0	0	0	0
INSECTICIDES										
Aldrin, total (μg/L)	--	--	--	--	--	--	--	.001	--	--
Number of determinations	0	0	0	0	0	0	0	3	0	0
Alpha hexachlorocyclohexane, total (μg/L)	--	--	--	--	.004	.002	.004	--	--	--
Number of determinations	0	0	0	0	1	1	1	0	0	0
Beta hexachlorocyclohexane, total (μg/L)	--	--	--	--	.012	--	--	--	--	--
Number of determinations	0	0	0	0	1	0	0	0	0	0
DDT, dissolved (μg/L)	--	--	.01	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
DDT, suspended (μg/L)	--	--	.01	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
DDT, total (μg/L)	.10	.02	.04	--	--	--	--	.009	--	--
Number of determinations	1	1	18	0	0	0	0	11	0	0
DDD, total (μg/L)	.03	--	.02	--	--	--	--	.009	--	--
Number of determinations	1	0	10	0	0	0	0	12	0	0
DDE, suspended (μg/L)	--	--	.01	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
DDE, total (μg/L)	.05	.01	.02	--	--	--	--	.005	--	--
Number of determinations	1	1	13	0	0	0	0	15	0	0
Diazinon, dissolved (μg/L)	--	--	0.02	--	--	--	--	--	--	--
Number of determinations	0	0	7	0	0	0	0	0	0	0
Diazinon, total (μg/L)	--	.01	.07	--	--	--	--	--	--	--
Number of determinations	0	1	8	0	0	0	0	0	0	0
Dieldrin, dissolved (μg/L)	--	--	0.01	--	--	--	--	--	--	--
Number of determinations	0	0	4	0	0	0	0	0	0	0
Dieldrin, total (μg/L)	.04	.02	1	--	--	--	--	.016	--	--
Number of determinations	1	1	15	0	0	0	0	9	0	0
Endosulfan, total (μg/L)	--	--	.01	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
Endrin, total (μg/L)	--	--	--	--	--	--	--	.003	--	--
Number of determinations	0	0	0	0	0	0	0	3	0	0
Heptachlor, total (μg/L)	--	--	--	--	--	--	--	.001	--	--
Number of determinations	0	0	0	0	0	0	0	3	0	0
Heptachlor epoxide, total (μg/L)	--	--	--	--	--	--	--	.001	--	--
Number of determinations	0	0	0	0	0	0	0	3	0	0
Lindane, total (μg/L)	.01	--	--	--	--	--	--	.002	--	--
Number of determinations	1	0	0	0	0	0	0	5	0	0
Parathion, dissolved (μg/L)	--	--	.02	--	--	--	--	--	--	--
Number of determinations	0	0	2	0	0	0	0	0	0	0
Parathion, total (μg/L)	--	--	.02	--	--	--	--	--	--	--
Number of determinations	0	0	2	0	0	0	0	0	0	0
PCBs AND RELATED COMPOUNDS										
PCB, suspended (μg/L)	--	--	.10	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
PCB, total (μg/L)	--	--	.10	--	--	--	--	--	--	--
Number of determinations	0	0	1	0	0	0	0	0	0	0
PHTHALATE ESTERS										
Di-n-octyl phthalate, total (μg/L)	--	--	--	0.2	--	26	52	--	--	--
Number of determinations	0	0	0	1	0	1	1	0	0	0
Bis(2-ethyl hexyl) phthalate, total (μg/L)	--	--	--	1.2	--	--	--	--	--	--
Number of determinations	0	0	0	1	0	0	0	0	0	0
POLYCYCLIC AROMATICS										
Napthalene, total (μg/L)	--	--	--	.1	--	--	--	--	--	--
Number of determinations	0	0	0	1	0	0	0	0	0	0
BED SEDIMENT										
INSECTICIDES										
Chlordane (μg/kg)	--	19	--	--	--	--	--	--	--	--
Number of determinations	0	1	0	0	0	0	0	0	0	0
Alpha hexachlorocyclohexane (μg/kg)	--	--	--	--	15	--	--	--	--	--
Number of determinations	0	0	0	0	1	0	0	0	0	0
Beta hexachlorocyclohexane (μg/kg)	--	--	--	--	6	--	--	--	--	--
Number of determinations	0	0	0	0	1	0	0	0	0	0
DDT (μg/kg)	55	90	24	--	--	--	--	--	--	--
Number of determinations	1	1	7	0	0	0	0	0	0	0
p,p' DDT (μg/kg)	--	--	20	--	--	--	4	--	--	--
Number of determinations	0	0	2	0	0	0	1	0	0	0
DDD (μg/kg)	15	34	15	--	--	--	--	--	--	--
Number of determinations	1	1	5	0	0	0	0	0	0	0
p,p' DDD (μg/kg)	--	--	6.79	--	11	--	--	--	--	--
Number of determinations	0	0	3	0	1	0	0	0	0	0
DDE (μg/kg)	20	87	26	--	--	--	--	--	--	--
Number of determinations	1	1	7	0	0	0	0	0	0	0
p,p' DDE (μg/kg)	--	--	2.08	--	13	--	5	--	--	--
Number of determinations	0	0	1	0	1	0	1	0	0	0
Dieldrin (μg/kg)	2	14	1.14	--	--	--	--	--	--	--
Number of determinations	1	1	3	0	0	0	0	0	0	0
Endrin (μg/kg)	--	.60	--	--	--	--	--	--	--	--
Number of determinations	0	1	0	0	0	0	0	0	0	0
Heptachlor epoxide (μg/kg)	--	.10	--	--	--	--	--	--	--	--
Number of determinations	0	1	0	0	0	0	0	0	0	0

Table 58.--Summary of trace-organic-compound determinations showing maximum concentrations and the number of determinations above the minimum reporting level, Yakima River basin, Washington, 1968-83 water years--Continued

Type of analysis	DID 18 Drain at Sunny-side (86)	Sul-phur Creek nr Sunny-side (91)	Yak-ima River at Kiona (100)	Yakima River at Ellens-burg Intake (386)	Yakima River near Rich-land (387)	Naches River at Yakima Intake (388)	Naches River at mouth (389)	Yak-ima River at Kiona (399)	Yakima River at Gran-ger (424)	Yakima River near Birch-field Drain (464)
	Maximum constituent concentration and number of determinations above RL — Site name and map reference number									
BED SEDIMENT--Continued										
PCBs										
Aroclor 1254 PCB (μg/kg)	--	--	--	--	--	51	--	--	--	--
Number of determinations	0	0	0	0	0	1	0	0	0	0
PCB (μg/kg)	--	23	--	--	--	--	--	--	--	--
Number of determinations	0	1	0	0	0	0	0	0	0	0
PHENOLS AND CRESOLS										
Phenolics (μg/kg)	--	--	--	--	170	130	--	--	--	--
Number of determinations	0	0	0	0	1	1	0	0	0	0
PHTHALATE ESTERS										
Diethyl phthalate (μg/kg)	--	--	--	--	300	200	200	--	--	--
Number of determinations	0	0	0	0	1	1	1	0	0	0
Di-n-octyl phthalate (μg/kg)	--	--	--	--	200	200	--	--	--	--
Number of determinations	0	0	0	0	1	1	0	0	0	0
Bis(2-ethyl hexyl) phthalate (μg/kg)	--	--	--	--	--	--	200	--	--	--
Number of determinations	0	0	0	0	0	0	1	0	0	0
TISSUE ANALYSIS										
INDUSTRIAL SOLVENT USED IN PESTICIDES										
Isophorone, tissue, wet wt (mg/kg)	--	--	--	.29	--	--	--	--	--	--
Number of determinations	0	0	0	1	0	0	0	0	0	0
INSECTICIDES										
Alpha hexachlorocyclohexane, tissue, wet wt (mg/kg)	--	--	--	--	--	--	--	--	--	.022
Number of determinations	0	0	0	0	0	0	0	0	0	7
Chlordane cis isomer, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	.05	--
Number of determinations	0	0	0	0	0	0	0	0	5	0
Chlordane trans isomer, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	.01	--
Number of determinations	0	0	0	0	0	0	0	0	2	0
Nonachlor cis isomer, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	.01	--
Number of determinations	0	0	0	0	0	0	0	0	3	0
Nonachlor trans isomer, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	0.01	--
Number of determinations	0	0	0	0	0	0	0	0	3	0
DDT sum, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	--	9.8
Number of determinations	0	0	0	0	0	0	0	0	0	7
DDT, fat, tissue, wet wt (μg/g)	--	--	--	--	--	--	--	--	4.34	--
Number of determinations	0	0	0	0	0	0	0	0	29	0
p,p' DDT in tissue, wet (mg/kg)	--	--	--	--	.18	.05	.09	--	1.03	--
Number of determinations	0	0	0	0	1	1	1	0	24	0
p,p' DDT, fish (μg/kg)	--	--	--	--	--	--	--	--	--	1009
Number of determinations	0	0	0	0	0	0	0	0	0	7
p,p' DDD, tissue, wet wt (mg/kg)	--	--	--	--	.28	.04	.04	--	.80	2.06
Number of determinations	0	0	0	0	1	1	1	0	27	7
p,p' DDE, tissue, wet wt (mg/kg)	--	--	--	.08	1.55	.32	.07	--	3.10	6.7
Number of determinations	0	0	0	1	1	1	1	0	30	7
Dieldrin, tissue, wet wt (mg/kg)	--	--	--	--	--	--	--	--	.17	--
Number of determinations	0	0	0	0	0	0	0	0	20	0
PCBs										
PCB-1248, tissue, wet wt (mg/kg)	--	--	--	--	--	--	--	--	0.05	--
Number of determinations	0	0	0	0	0	0	0	0	2	0
PCB-1254, tissue, wet wt (mg/kg)	--	--	--	--	--	--	--	--	.2	1.25
Number of determinations	0	0	0	0	0	0	0	0	6	7
PCB-1260, tissue, wet wt (mg/kg)	--	--	--	--	--	--	--	--	.3	--
Number of determinations	0	0	0	0	0	0	0	0	9	0
Total PCBs, tissue, (mg/kg)	--	--	--	--	--	--	--	--	--	1.25
Number of determinations	0	0	0	0	0	0	0	0	0	7
PCB, fish, (mg/kg)	--	--	--	--	--	--	--	--	3	--
Number of determinations	0	0	0	0	0	0	0	0	22	0
HALOGENATED ALIPHATICS										
Methylene chloride, tissue, wet wt (mg/kg)	--	--	--	--	.58	.57	--	--	--	--
Number of determinations	0	0	0	0	1	1	0	0	0	0
MONOCYCLIC AROMATICS										
Benzene, tissue, wet wt (mg/kg)	--	--	--	--	.02	.01	.03	--	--	--
Number of determinations	0	0	0	0	1	1	1	0	0	0
PHTHALATE ESTERS										
Diethyl phthalate, tissue, wet (mg/kg)	--	--	--	.12	1	.3	.6	--	--	--
Number of determinations	0	0	0	1	1	1	1	0	0	0
Di-n-butyl phthalate, tissue, wet wt (mg/kg)	--	--	--	--	--	.6	.6	--	--	--
Number of determinations	0	0	0	0	0	1	1	0	0	0
Di-n-octyl phthalate, tissue, wet (mg/kg)	--	--	--	.09	--	--	--	--	--	--
Number of determinations	0	0	0	1	0	0	0	0	0	0
Bis(2-ethyl hexyl) Phthalate, tissua, wet (mg/kg)	--	--	--	1.5	.4	.9	.3	--	--	--
Number of determinations	0	0	0	1	1	1	1	0	0	0
POLYCYCLIC AROMATICS										
Benzo(ghi) perylene, tissue (mg/kg)	--	--	--	--	--	2.2	--	--	--	--
Number of determinations	0	0	0	0	0	1	0	0	0	0
1,1,5,6-Dibanzanthracene, tissue wet (mg/kg)	--	--	--	--	--	1.6	--	--	--	--
Number of determinations	0	0	0	0	0	1	0	0	0	0
Indeno (1,2,3-cd) pyrene, tissue, wet (mg/kg)	--	--	--	--	--	2.2	--	--	--	--
Number of determinations	0	0	0	0	0	1	0	0	0	0

Table 59.--Summary of fecal-coliform-bacteria concentrations that exceeded State standards in the Yakima River basin, Washington, 1968-85 water years

[Based on comparisons of individual determinations made each month at a site to the following State standards: geometric mean shall not exceed 50 for class AA, 100 for class A, and 200 colonies per 100 milliliters for class B streams]

Stream class	Map reference number	Site name	Number of determinations	Number of determinations exceeding State standards
		Class A -- Main stem		
A	354	Yakima River at Ellensburg	17	6
A	364	Yakima River at Thrall-public access	2	1
A	355	Yakima River at Umtanum	18	9
A	320	Yakima River at Harrison Rd Bridge	5	2
A	27	Yakima River near Terrace Heights	28	3
A	322	Yakima River-Terrace Heights Bridge	6	3
A	32	Yakima River at Union Gap	56	26
A	40	Yakima River at Parker	158	45
A	48	Yakima River near Toppenish	31	7
A	337	Yakima River at bridge near Granger	24	23
A	92	Yakima River at Mabton	26	23
A	338	Yakima River at bridge near Mabton	27	25
A	94	Yakima River at Prosser	27	21
A	100	Yakima River at Kiona	190	74
A	101	Yakima River at Van Geisan Bridge	32	11
A	428	Yakima River near Richland	2	1
		Class A -- Tributaries, canals, and drains		
A	7	Wilson Creek at Thrall	23	20
A	24	Naches River at Naches	24	1
A	26	Naches River near North Yakima	22	2
A	29	Wide Hollow Creek at Goodman Road	4	4
A	30	Wide Hollow Creek at Union Gap	4	4
A	36	South Fork Ahtanum Creek at Tampico	4	2
A	37	Ahtanum Creek at Goodman Rd	12	8
A	39	Main Canal near Parker	9	4
A	52	Wanity Slough at Rocky Ford Road	12	12
A	53	Marion Drain near Granger	24	20
A	56	South Fork Simcoe Cr nr Fort Simcoe	4	1
A	58	Mud Lake Drain near Harrah	6	5
A	60	Toppenish Creek at Alfalfa	11	6
A	62	Toppenish Creek near Satus	24	17
A	65	Logy Creek near Toppenish	4	1
A	70	Satus Creek at Satus	24	13
A	71	South Drain near Satus	12	9
A	193	Swauk Creek below Mineral Spring	8	1
A	228	North Fork Manastash Cr--FS Boundary	4	1
A	297	Roza Main Canal at Beam Road	21	8
A	298	Sunnyside Canal at Beam Road	19	13
A	300	KID Coyote Canyon Drain near bottom	2	1
A	307	Chandler Canal--mile 0.6 nr Prosser	4	2
A	308	Chandler Canal--mile 2.8 nr Prosser	4	2
A	311	Satus Drain 302 NW1/4 Sec 34 9N 22E	6	6
A	312	Cherry Cr SE 1/4 Sec 29 T17N R19E	16	15
A	313	Coleman Cr NW 1/4 Sec 20 T17N R19E	6	5
A	319	Cottonwood Canal Drain SE1/4 Sec 28	5	5
A	321	Naches River at Nelson Bridge	7	2
A	323	Drain at Birchfield Road	8	8
A	324	Wide Hollow Creek near Gromore	5	4
A	325	Wide Hollow Cr at W. Washington Ave	6	6
A	326	Wide Hollow Creek at Union Gap STP	14	8
A	327	Ahtanum Creek at mouth	10	9
A	330	Drn DID #3 at South Hill Road	19	8
A	331	Drn DID #3 at Duffy Road	18	13
A	335	Griffin Lake Inlet	29	26
A	336	Griffin Lake Outlet	22	7
A	339	East Toppenish Drain at Wilson Road	6	4
A	340	Sub Drain 35 at Parton Road	6	5
A	341	Marion Drain at Highway 97	3	2
A	342	Wanity Slough at Myers Road	4	4
A	345	South Drain at Highway 22 nr Satus	6	5
A	346	Granger Drain--Hwy 223 abv Granger	27	27
A	347	Spring Creek at Hess Road	5	3
A	348	Snipes Cr at Old Inland Empire Road	5	4
A	350	Wilson Creek at Sanders Road	7	7
A	351	Wilson Creek at Dammon Road	7	7
A	352	Wipple Wasteway at Thrall Road	16	15
A	353	Wilson Creek at Thrall Road	18	16
A	356	Drain DID #3 abv Rendering Plant	17	4

Table 59.--Summary of fecal-coliform-bacteria concentrations that exceeded State standards in the Yakima River basin, Washington, 1968-85 water years--Continued

Stream class	Map reference number	Site name	Number of determin-ations	Number of determinations exceeding State standards
		Class A -- Tributaries, canals, and drains		
A	357	Drain at Elks Golf Course	6	5
A	358	Teanaway River at Highway 10 bridge	10	1
A	359	Swauk Creek near Highway 10 bridge	10	4
A	361	Taneum Creek Anderson's Loafing Shed	10	10
A	362	Manastash Creek at Brown Road Bridge	10	9
A	363	Reecer Creek near mouth	10	4
A	365	Sorenson Creek	5	5
A	505	DID 3 Drain on Needham Feedlot	15	15
A	506	DID 9 Drain at Sunnyside-Mabton Hwy	15	15
A	507	DID 5 Drain along Tear Road	15	15
A	508	Washout Drain at Allen Road	15	15
A	509	DID 18 Drain at Vernita Highway	15	15
A	510	DID 3 at E. 1st St in Sunnyside	3	3
A	511	Snipes Mt. Lateral, trib to DID 3	2	2
A	512	DID 3 Drain at Duffy Road	2	2
A	513	DID 3 nr Yakima Rendering Plant	2	2
A	514	Tributary to DID 3 at Midvale Road	2	2
A	515	DID 3 Drain at South Hill Road	2	2
A	517	DID 3 Drain at Highway 12	2	2
A	518	DID 3 Drain at Outlook Road	2	2
A	519	Trib. to DID 3 Drain at Reeves Road	2	2
A	520	Trib. to DID 9 at Euclid Road	2	2
A	521	Trib. to DID 9, 500 yd N. Stover Rd	2	2
A	522	Trib. to DID 5 Drain at Allen Road	2	2
A	523	Trib. to DID 5 at Alexander Road	2	2
A	525	Washout Drain--Van Belle/Washout Rd	2	2
A	526	DID 17 Drain at Vernita Highway	2	2
A	527	Trib. to DID 18 at Van Belle Road	2	2
A	529	Roza Main Cnl at District Line Road	2	1
A	530	Sunnyside Canal at Maple Grove Road	2	1
A	531	Sunnyside Canal at Highway 12	2	2
A	532	Sunnyside Canal at District Line Road	2	2
A	533	Roza Main Canal at Scoon Road	2	1
A	534	Roza Main Canal at Wilgus Road	2	1
		Class B -- Sulphur Creek		
B	328	Sulphur Cr at North above Sunnyside	28	26
B	329	Sulphur Cr Wasteway at Factory Road	30	27
B	332	Sulphur Cr Wasteway at Duffy Road	28	28
B	333	Sulphur Cr Wasteway at Morse Road	29	29
B	334	Sulphur Cr Wasteway at McGee Road	32	31
B	500	Sulphur Creek at Green Valley Road	15	15
B	501	Sulphur Creek at Duffy Road	15	15
B	502	Sulphur Creek at Alexander Road	15	14
B	503	Sulphur Creek below Sheller Road	15	7
B	504	Sulphur Creek at Sunnyside Canal	10	9
		Class AA		
AA	1	Yakima River above Cle Elum	24	1
AA	156	Hyak Creek--head of Lake Keechelus	53	10
AA	192	Cougar Creek	17	9
AA	195	Swauk Creek at Hurley Creek	16	9
AA	199	Lion Gulch above Liberty Road	20	5
AA	200	Swauk above Williams Creek	22	9
AA	204	Swauk abv Mineral Spring Resort	18	5
AA	206	Hovey Creek above Highway 97	9	1
AA	208	Swauk Creek abv campground-Sec 12	5	1
AA	210	Swauk Creek above Hurley Creek	17	7
AA	217	Swauk Creek	9	4
AA	218	Naneum Creek	11	3
AA	223	North Fork Taneum Creek	9	2
AA	224	South Fork Taneum Creek	10	2
AA	234	North Fork Taneum Cr at Sec 20/19	5	1
AA	251	Clear Creek	7	1
AA	290	Soup Creek NWSE Sec 28 T14N R14E	1	1

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