Water Quality of the Lower Columbia River Basin: Analysis of Current and Historical Water-Quality Data through 1994

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4294

Prepared in cooperation with the
Lower Columbia River Bi-State
Water-Quality Program

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FOREWORD

One of the great challenges faced by the Nation’s water-resource scientists is providing reliable water-quality information to guide the management and protection of our water resources. That challenge is being addressed by Federal, Tribal, State, interstate, and local water-resources agencies, by academic institutions, and by private industry. 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, decision of operational procedures for industrial, wastewater, or water-supply facilities, and refinement of 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 variety of collection and analytical procedures, and the types of water-quality characteristics determined.

The Lower Columbia River Bi-State Water Quality Program, with involvement from private industry, sports and commercial fishing, public ports, environmental groups, municipal, State, Northwest Power Planning Council, and Federal interests, has provided guidance to:

1. Provide a regionally consistent description of water-quality conditions;
2. Define seasonal and 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.

Don Yon, Project Manager
Lower Columbia River Bi-State Water Quality Program

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS

[SI = International System of units, a modernized metric system of measurement]

Factors for converting SI metric units to inch/pound units

Multiply	By	To obtain
	Length	
micrometer (µm)	0.00003937	inch (in)
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot (ft)
	Volume	
milliliter (mL)	0.001057	quart (qt)
liter (L)	1.057	quart
liter	0.2642	gallon (gal)
	Mass	
nanogram (ng)	0.00000000003527	ounce (oz avoirdupois)
microgram (mg)	0.00000003527	ounce
milligram (mg)	0.00003527	ounce
gram (g)	0.03527	ounce
kilogram (kg)	35.27	ounce
	Density	
grams per cubic centimeter (g/cm^3)	0.5780	ounces per cubic inch (oz/in^3)
	Temperature	
degrees Celsius (°C)	([1])	degrees Fahrenheit (°F)
	Concentration, in water	
nanograms per liter (ng/L)	1	parts per trillion (ppt)
micrograms per liter (µg/L)	1	parts per billion (ppb)
milligrams per liter (mg/L)	1	parts per million (ppm)
	Concentration, in sediment	
micrograms per gram (µg/g)	1	parts per million (ppm)

[1] Temperature °F = 1.8 (Temperature °C) + 32

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Abstract

The lower Columbia River Basin includes the river basins draining into the Columbia River below Bonneville Dam—the largest of which is the Willamette River. This report presents the results of a study by the U.S. Geological Survey, done in cooperation with the Lower Columbia River Bi-State Water-Quality Program, to describe the water-quality conditions in the lower Columbia River Basin by interpreting historical data collected and data collected in 1994. Historical water-quality data spanning more than 50 years and comprising more than 200 parameters were collated for interpretation in this report. The U.S. Geological Survey, the Oregon Department of Environmental Quality, and the Washington Department of Ecology collected water-quality data at 10 sites in the lower Columbia River Basin from January to December of 1994. Water-quality constituents measured in 1994 were screened against U.S. Environmental Protection Agency (EPA) and State guidelines.

Arsenic, a human carcinogen, was detected in 15 of 16 samples in the lower Columbia River, but was not detected in any of the sampled tributaries. All 15 arsenic detections had concentrations that exceeded both the EPA ambient water-quality criteria for the protection of human health and the EPA human-health advisories for drinking water. Chromium was detected at all four Columbia River sites—most frequently in the Columbia River at Hayden Island. None of the chromium concentrations detected, however, exceeded water-quality criteria or guidelines.

Measurements of suspended trace-element concentrations (trace-element concentrations associated with the suspended-sediment fraction) showed that the suspended form is the dominant transport phase for aluminum, iron, and manganese, whereas the dissolved form is the dominant transport phase for arsenic, barium, chromium, and copper. On the basis of tributary loads during summer low-flow months, sources of suspended silver, nickel, aluminum, and antimony exist in the lower Columbia River Basin, whereas the sources of suspended zinc and arsenic exist outside of the lower basin.

Twenty organic compounds were detected of the 47 compounds analyzed for this study. None of the organic compounds measured exceeded EPA's ambient water-quality criteria or drinking-water guidelines. The Willamette River at Portland had the largest number of detections, and all 20 compounds were detected at one time or another at that site. The largest concentrations of the agricultural pesticides, atrazine, metolachlor, and simazine were detected in the Willamette River, where they were detected in 93, 86, 93 percent, respectively, of the samples collected. The highest concentrations of atrazine in the Willamette River were associated with the spring application and fall runoff periods.

Both historical and current data showed that the highest water temperatures in the lower Columbia River Basin are present during August. For water years 1977–81 in the Columbia River at Bradwood (river mile 38.9), 75 percent of the daily mean water temperatures during August exceeded 20 degrees Celsius, a “special condition” criterion for the State of Washington. The special condition criterion was exceeded at four sites on the lower Columbia River during July and August, 1994—a period coinciding with season-high air temperatures and low streamflow. Trend tests using data from 1974 to 1994 showed significant ($\rho < 0.05$) upward trends for water temperature at the Columbia River at Warrendale and the Willamette River at Portland.

Concentrations of dissolved oxygen and total dissolved gas were above saturation levels during high stormflows in the lower Columbia River and the Willamette River during 1994. The high concentrations of total dissolved gas in the Columbia River exceeded Oregon and Washington State standards of 110 percent of saturation and were caused by spilling water at the Columbia River dams. Aquatic life in the lower Columbia River Basin was not subjected to low dissolved-oxygen concentrations. Comparison of dissolved-oxygen concentrations in the Willamette River from 1949–58 to 1972–94 showed a significant increase in dissolved-oxygen concentrations during the low-streamflow months of summer.

Trend tests showed significant ($\rho < 0.05$) downward trends from 1973 to 1994 for three constituents at the Columbia River at Warrendale: phosphorus in unfiltered water, total dissolved solids, and specific conductance. These trends may be a consequence of more conservative agricultural practices in the area upstream from Warrendale.

INTRODUCTION

The Columbia River Basin (fig. 1), molded and sculpted through geologic time, has become a dominant landscape feature in the Pacific Northwest. It has witnessed the birth of new mountains, the slow weathering of old ones, the violent eruptions of volcanoes, and some of the most cataclysmic floods in Earth’s history. The basin has been home to Native American peoples for thousands of years and has attracted explorers and settlers from many countries. The Columbia River drains parts of the States of Washington, Idaho, Montana, Wyoming, Nevada, Utah, and Oregon, and the Province of British Columbia, where its headwaters arise. It flows more than 1,200 miles from Columbia Lake to its mouth at the Pacific Ocean. The Columbia River has been both habitat and passageway for salmon and other aquatic life, and has had spiritual and physical significance to Native Americans for centuries. As people industrialized the Pacific Northwest, water use within the basin changed dramatically: hydroelectric projects were completed to provide electricity, navigation channels were constructed to promote commerce, diversion dams were constructed to increase agricultural production through irrigation, reservoirs were constructed to reduce flooding and to provide recreational opportunities, and cities grew along the banks of the basin’s rivers.

Development within the Columbia River Basin has not been without side effects. When Captain Robert Gray discovered the Columbia River in 1792, an estimated 10 to 16 million adult salmon were returning annually to the river; this salmon resource was once considered to be unlimited. Between 1985 and 1990, however, only 1.1 to 2.8 million adults returned each year. Not only has the total number of salmon declined drastically, but the average size of returning adults is markedly smaller for several stocks. An estimated 67 individual stocks have been permanently eliminated, 4 stocks are presently listed as threatened or endangered under the Endangered Species Act, and an additional 72 stocks are thought to be in jeopardy.

Concern about degradation of water quality in the Columbia River Basin began in the late 1800’s (P. Klingeman, Oregon State University, written commun., 1995). Hydropower development, irrigated agriculture, logging, mining, stream channelization, and urbanization are recognized as contributing factors. Hydroelectric and agricultural development have changed the quantity and timing of seasonal runoff, modifying water temperatures

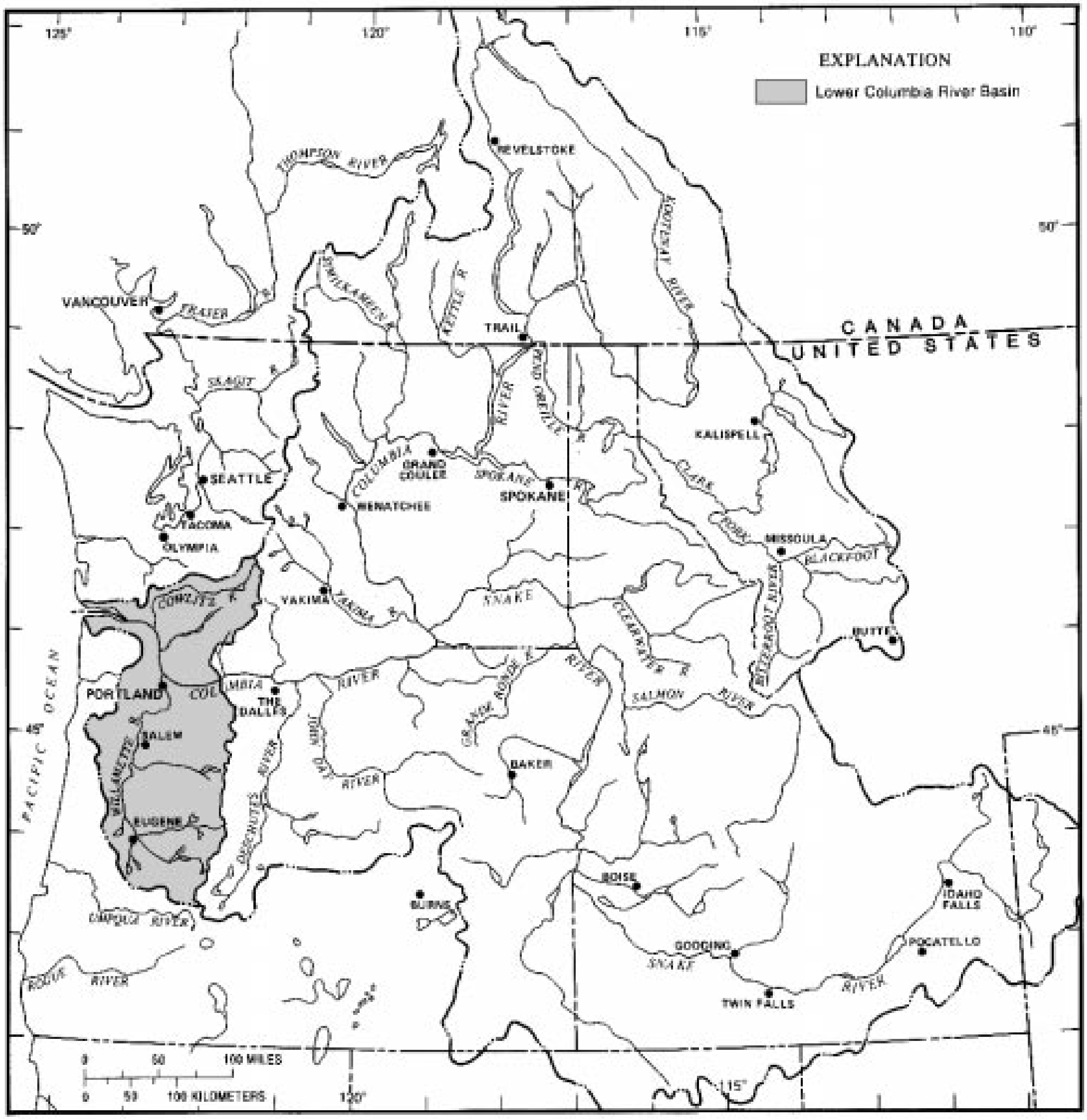

Figure 1. The Columbia River Basin.

and sometimes supersaturating the river water with air, which can cause gas-bubble trauma in fish. Dissolved-oxygen levels, while adequate in the Columbia River, have been depressed in some tributaries by municipal and industrial wastes. The Snake and Willamette Rivers are known to be the major contributors of nitrogen and phosphorus to the Columbia River. Suspended sediment tends to increase in subbasins influenced by logging and agriculture. Toxic chemicals, such as pesticides, polychlorinated biphenyls (PCB), and trace elements, have been found in fish of the Columbia River Basin, resulting in at least one recent human health advisory (Stober and Nakatani, 1992). Radioactivity in the lower Columbia River has historically been of concern, a result of Hanford's eight plutonium production reactors which, one by one, have been closed (Toombs and others, 1983). Additionally, radionuclides have historically been of concern. Unquestionably, today's water managers face a difficult and complex task as they strive to maintain a healthy environment in the basin, while maintaining the livelihood of the people who live in it.

Background

The Lower Columbia River Bi-State Water-Quality Program was initiated in 1990 by the Governors of Oregon and Washington. On the basis of workshops and public comments, the Governors concluded that the study of the lower Columbia River Basin would receive broader support in a Bi-State study framework than as part of the Federal Government's National Estuary Program. The Bi-State study is a 4-year program that is sponsored jointly by the Washington Department of Ecology (WDOE), the Oregon Department of Environmental Quality (ODEQ), the Washington and Oregon Public Port Associations, and the Northwest Pulp and Paper Association. A Bi-State steering committee was created to assist WDOE and ODEQ in administering this program, which will study water quality below Bonneville Dam (river mile [RM] 146.1). The committee is composed of representatives from local governments, industries, Native American Tribes, fishing groups, environmental groups, the general public, public ports, and Federal agencies. On the basis of the water-quality information obtained, the steering committee will evaluate options and provide recommendations for improving and protecting water quality and beneficial uses in the Columbia River. ODEQ and WDOE will also be reviewing data and making their own determinations, in addition to responding to recommendations made by the steering committee.

The Bi-State steering committee identified several major goals for the water-quality program in the lower Columbia River. The goals are as follows:

1. Provide a regionally consistent description of water-quality conditions;
2. Define seasonal and 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.

Within the framework of the Bi-State study, numerous preliminary tasks have been completed to assess water quality in the lower Columbia River (Tetra Tech, Inc., 1993). Preliminary tasks included establishing a library database for isolating data gaps and identifying problem areas. Because water-quality data were sparse, however, the entire lower Columbia River was considered a data gap in 1990. Also important was an inventory of pollutant sources, which included point sources, nonpoint sources (dispersed water-based activities or dispersed land-based activities), and in-place sources (landfill leachate). On the basis of available data, pollutant-loading estimates were made for point sources and were used to identify appropriate analytical suites as well as to aid in the selection of sampling sites for a reconnaissance study. A literature review of physical and hydrologic characteristics of the lower Columbia River was conducted to assist in determining the potential environmental fate of pollutants. Biological indicator species were selected on the basis of existing data for major habitats and biological communities, and from biological exposure (bioaccumulation) and response (community structure) studies. To determine areas that are especially sensitive to pollutants, river miles of the lower Columbia River were characterized according to the various beneficial uses of rivers, such as water supply, recreation, or fish and wildlife.

The lower Columbia River reconnaissance sampling was conducted from September through November 1991 (Tetra Tech, Inc., 1993). Water samples were collected from 45 sites in the lower Columbia River and analyzed for trace elements, nutrients, and other parameters. Nutrient concentrations were not quantified because analytical-method reporting limits for nutrients were higher than the nutrient concentrations in the samples. Aluminum, barium, iron, and lead were the only trace elements that were frequently detected. Analytical-method reporting limits for several trace elements, including lead, mercury, nickel, selenium, and silver, were greater than the U.S. Environmental Protection Agency's (EPA) ambient water-quality criteria, thus hampering identification of trace elements of concern (U.S. Environmental Protection Agency, 1986a). Organic constituents were measured at five sites; in general, semivolatile and volatile organic compounds, pesticides, and PCBs were not detected, with the exception of bis(2-ethylhexyl)phthalate, a common laboratory contaminant. The investigators noted that some of the target organic compounds may have been present at concentrations that were undetectable using the conventional methods employed for the reconnaissance study. Bulk sediment samples were collected at 54 sites in the lower Columbia River and analyzed for trace elements, organic compounds, dioxins and furans, and other miscellaneous parameters. Fish-tissue samples were collected at 18 sites and analyzed for trace elements and organic compounds. Benthic community structure was assessed at 54 sites. All organisms removed from the streambed sediment were enumerated and identified to the lowest practical taxonomic level, generally genus or species.

Supplemental reconnaissance measurements in backwater areas of the Columbia River were made in 1993 (Tetra Tech, Inc., 1994). Backwater areas are hydrologically low-energy areas that promote the settling of fine-grained sediment and associated contaminants. Water samples from 15 backwater sites were analyzed for trace elements, nutrients, bacteria, and other parameters. Water temperatures at several backwater sites exceeded Washington State's temperature standard of 20^{o}C (degrees Celsius). In backwater environments, concentrations of nitrogen and phosphorus approached concentrations that, under proper conditions of light and temperature, have caused nuisance algal blooms in lake environments. Investigators noted that concentrations of aluminum, iron, copper, and lead from unfiltered samples frequently exceeded EPA's ambient water-quality criteria for chronic toxicity to aquatic life. Investigators also concluded that exceedances were principally by trace elements associated with the suspended-sediment fraction. Streambed sediments from the 15 backwater sites also were sampled concurrently for trace elements and organic compounds. On the basis of normalization techniques, some trace elements, such as arsenic in backwater areas and copper in the main stem, may have anthropogenic sources. Pesticides were detected infrequently; the infrequent detection was attributed to the diffuse nature of pesticide inputs from agricultural sources and the lack of local nearshore sources. Polyaromatic hydrocarbons, however, were detected in the vicinity of urban and industrial sources.

Purpose and Scope

Historically, water-quality studies in the lower Columbia River have focused on specific river reaches; many of these studies lack the continuity necessary to assess water quality in a river-basin framework. The Bi-State study has addressed this data gap by initiating an ambient-monitoring program that will assess temporal variations in constituent concentrations and loads in 1994.

The purpose of this report is to describe the water-quality conditions in the lower Columbia River and major tributaries to the extent possible, by:

(1) Examining seasonal variations in concentrations of water-quality constituents in water (filtered and unfiltered) and suspended sediment;

(2) Portraying spatial variations in historical water-quality data;

(3) Determining trends in concentrations of water-quality constituents in water (filtered and unfiltered) and in physical water-quality measurements (for example, water temperature) for sites with adequate historical data;

(4) Analyzing the suitability of surface water for maintenance of aquatic life and protection of human health;

(5) Determining instream loads for selected water-quality constituents and comparing instream loads in major subbasins to instream loads in the Columbia River; and

(6) Listing point sources and, to the extent possible, the associated discharges.

Acknowledgments

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Ralph Ennis	Salmon For All
Nelson Graham	Longview City Manager
Mike Lindberg	Portland City Commissioner
Al Whitford	Longview Fibre Company
Llewellyn Matthews	Northwest Pulp and Paper Association
Rollie Montagne	Port of Portland
Glenn Vanselow	Pacific Northwest Waterways Association
Steve Wille	Southwest Washington Anglers
Elmer Scott, Jr.	Warm Springs Reservation
Wilbur Slockish, Jr.	Native American Tribes
Cyndy deBruler	Columbia River United
Jean R. Cameron	Oregon Environmental Council
Carol Schuler	U.S. Fish and Wildlife Service
Jeremy Buck	U.S. Fish and Wildlife Service
Jim Bergeron	Citizen-at-large
Carol Carver	Citizen-at-large
Stuart McKenzie	U.S. Geological Survey
R. Ted Bottiger	Northwest Power Planning Council
Joyce Cohen	Northwest Power Planning Council
Andy Schaedel	Oregon Department of Environmental Quality (Staff)
Don Yon	Oregon Department of Environmental Quality (Staff)
Bill Young	Oregon Department of Environmental Quality (Staff)
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Brian Offord	Washington Department of Ecology (Staff)
Helen Bresler	Washington Department of Ecology (Staff)
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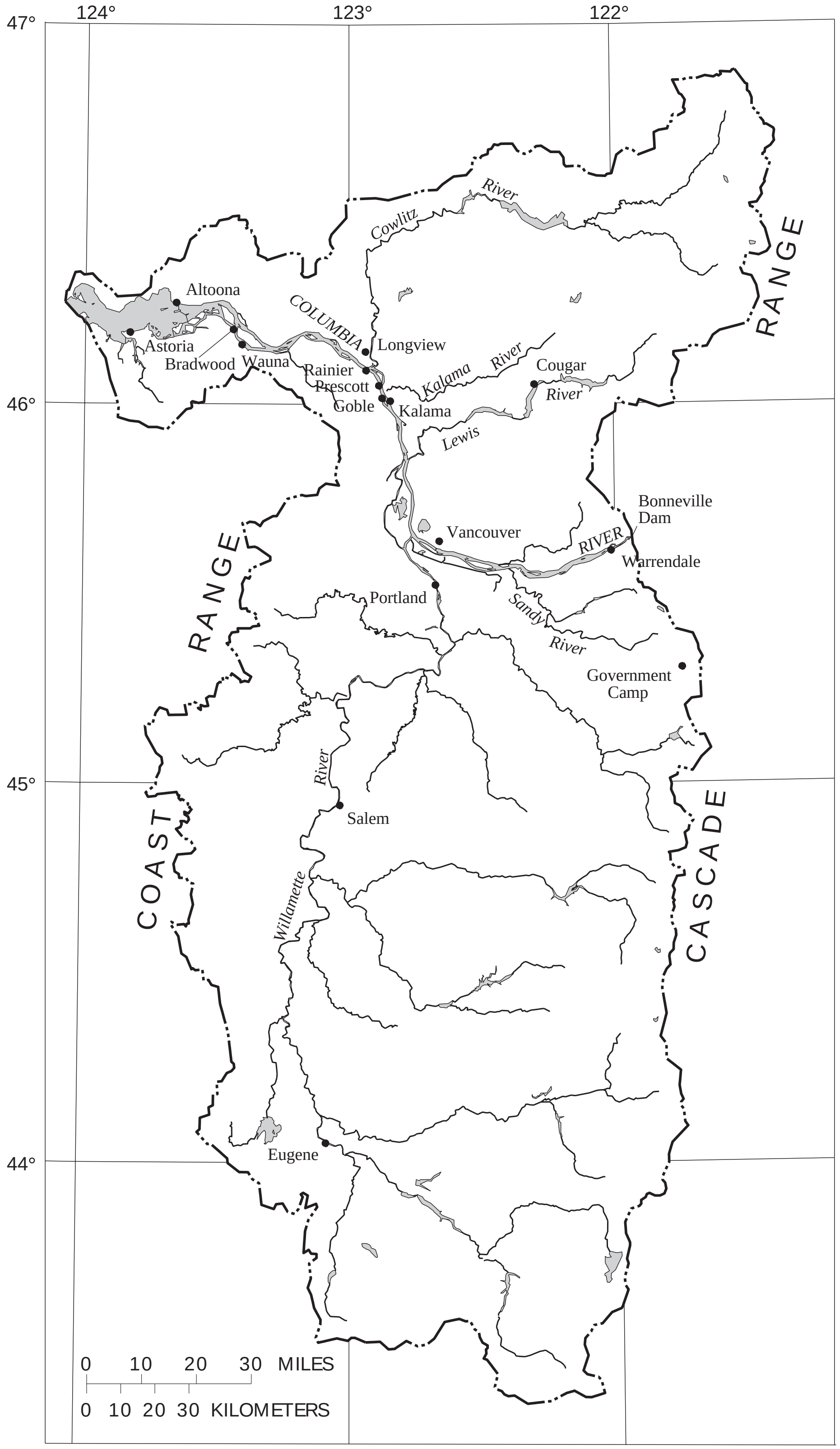
THE LOWER COLUMBIA RIVER BASIN

The Columbia River drains an area of 259,000 square miles and is ranked seventh in length and fourth in streamflow among United States rivers (U.S. Geological Survey, 1981; Saboe, 1991). It flows 1,243 miles from its headwaters in the Canadian Rockies of British Columbia, across the State of Washington, and along the border of Washington and Oregon to its mouth at the Pacific Ocean (fig. 1). There are 11 dams on the Columbia River’s main stem in the United States and 162 dams that form reservoirs with capacities greater than 5,000 acre-feet in the United States and Canadian parts of the basin. The northern and eastern sections of the Columbia River Basin contain mainly sedimentary and metamorphic rocks, whereas the southern, western, and central parts contain mainly igneous rocks.

The lower Columbia River Basin, the subject of this report, drains the area from Bonneville Dam to the mouth of the Columbia River (fig. 2). In the lower basin, the Columbia River flows 146.1 miles and drains an area of about 18,000 square miles, all to the west of the crest of the Cascade Range. The major tributaries and associated drainage areas in the lower Columbia River Basin, in downstream order, are the Sandy River (500 square miles), the



Base from U.S. Geological Survey, 1:100,000, 1986
Universal Transverse Mercator, zone 10

Figure 2. The lower Columbia River Basin, Oregon and Washington.

Willamette River (11,400 square miles), the Lewis River (1,000 square miles), the Kalama River (200 square miles), and the Cowlitz River (2,500 square miles).

Precipitation

Precipitation varies considerably across the lower Columbia River Basin but generally exceeds that in the rest of the Columbia River Basin. The Cascade Range creates a rain shadow which is responsible for the greater quantities of precipitation in the lower Columbia River Basin. Historically, mean annual precipitation in the lower Columbia River Basin ranged from 113 inches at Cougar, Washington, to about 37 inches at Portland, Oregon (fig. 3) and was generally higher in the mountains (Cougar and Government Camp) and on the coast (Astoria) than in the valleys (Portland and Eugene). Intrasite variations in annual precipitation can be large depending on meteorological conditions. For example, annual precipitation at Cougar ranged from as little as 78.27 inches in 1952 to as much as 141.84 inches in 1983 (Earth-Info, Inc., 1993). The annual precipitation at Portland for the 1994 water year (WY) was 36.32 inches (Oregon Climate Service, 1994), which is similar to the mean annual precipitation.

Most of the precipitation in the lower Columbia River Basin falls from November through March. The mean monthly precipitation during this period, in Portland, Eugene, and Cougar was 66, 70, and 71 percent, respectively, of the mean annual precipitation (fig. 4).

Streamflow Conditions

The Willamette River is the major tributary of the lower Columbia River. It drains 65 percent of the area within the lower Columbia River Basin. On the basis of mean annual streamflow for the period 1928–65 (Orem, 1968), the Willamette River's discharge represented 17 percent of the streamflow in the Columbia River at Vancouver, Washington, which is located 0.5 miles upstream from the confluence of the Willamette and Columbia Rivers. For those same years, the Willamette River's contribution to the Columbia River's total streamflow at its mouth near Astoria, Oregon, averaged 13 percent. Compared with other lower Basin tributaries during the period 1928–65, the Willamette River streamflow represented 58 percent of the increase in Columbia River streamflow between Vancouver and the mouth.

Streamflow in the main stem of the lower Columbia River is affected by spring snowmelt, winter rainstorms, and regulation by many dams. In addition to the dams on the main stem of the Columbia River and the many other dams on tributaries above Bonneville Dam, there are 17 reservoirs in the Willamette River Basin, 3 reservoirs in the Lewis River Basin, and 2 reservoirs in the Cowlitz River Basin. Daily flood-control regulation is generally required during the spring snowmelt season. Outflows and forebay levels at Grand Coulee Dam are specified by the U.S. Army Corps of Engineers between May and June in order to provide storage capacity to dampen peak flows. During the 1993 WY, for example, the regulated peak flow at The Dalles during the snowmelt season was 382,000 ft^3/s (cubic feet per second), while the unregulated peak flow would have been 602,000 ft^3/s. Local flooding in the lower Columbia River begins when streamflow reaches about 450,000 ft^3/s (Columbia River Water Management Group, 1994).

In the Willamette River Basin, reservoirs are operated by the U.S. Army Corps of Engineers. They reach minimum flood-control elevations between November 1 and 15 in reservoirs not generating power and by November 30 in reservoirs generating power. Much of the runoff during February and March is due to rainfall. At the higher elevations, however, precipitation occurs as snow, and runoff is often delayed until the spring snowmelt. During floods, water is held in reservoirs until downstream discharges from unregulated streams have subsided and then released at a rate that does not exceed established flood-regulation goals. The well-defined limits of the flood season allow winter storm runoff and spring snowmelt runoff to be impounded and subsequently released during low water conditions in summer and early fall (U.S. Army Corps of Engineers, 1989). Releases during summer and fall are made to satisfy requirements for fisheries, irrigation, navigation, and pollution abatement.

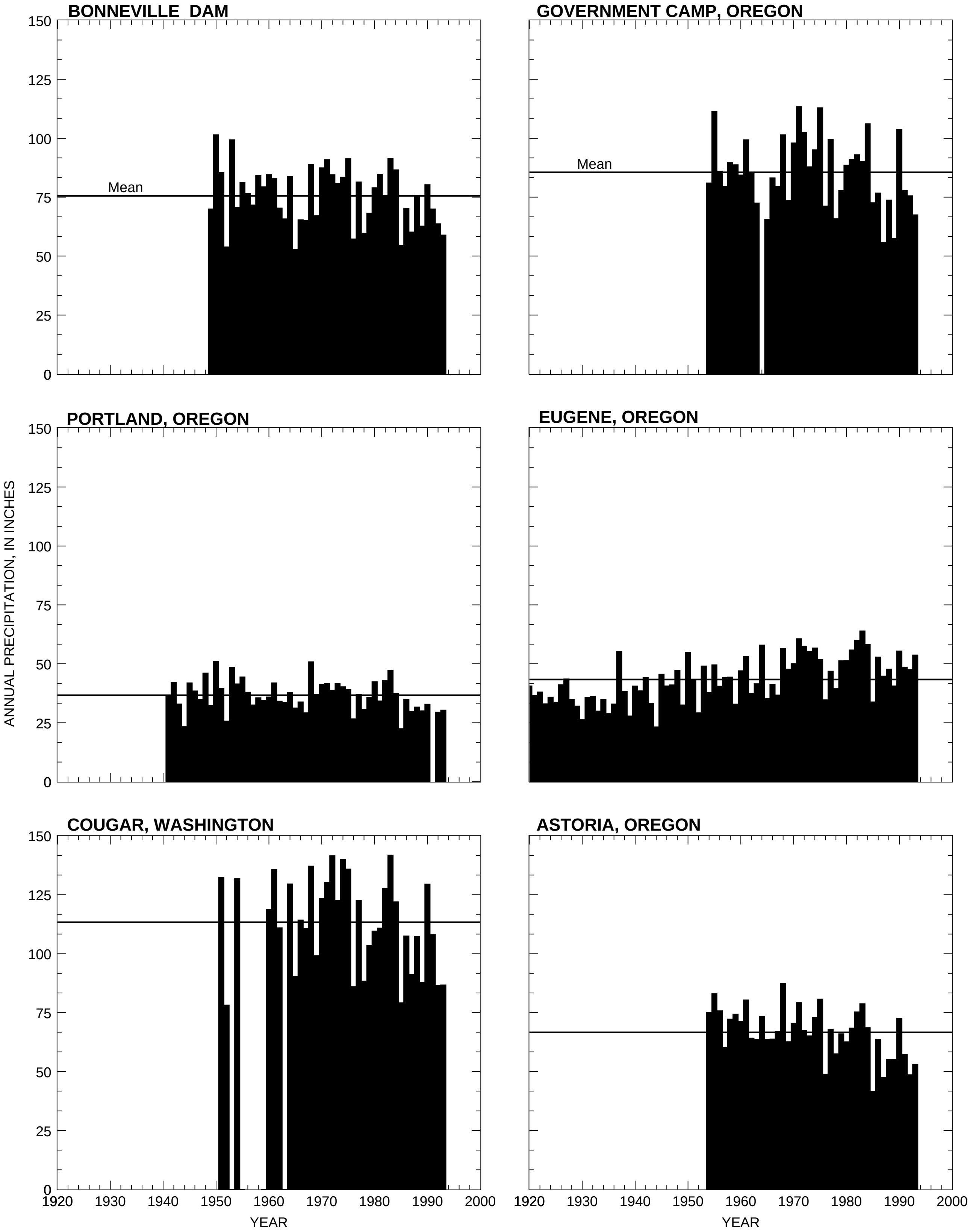


Figure 3. Annual and mean annual precipitation at Bonneville Dam, Government Camp, Portland, Eugene, Cougar, and Astoria, lower Columbia River Basin, Oregon and Washington, 1920–93.

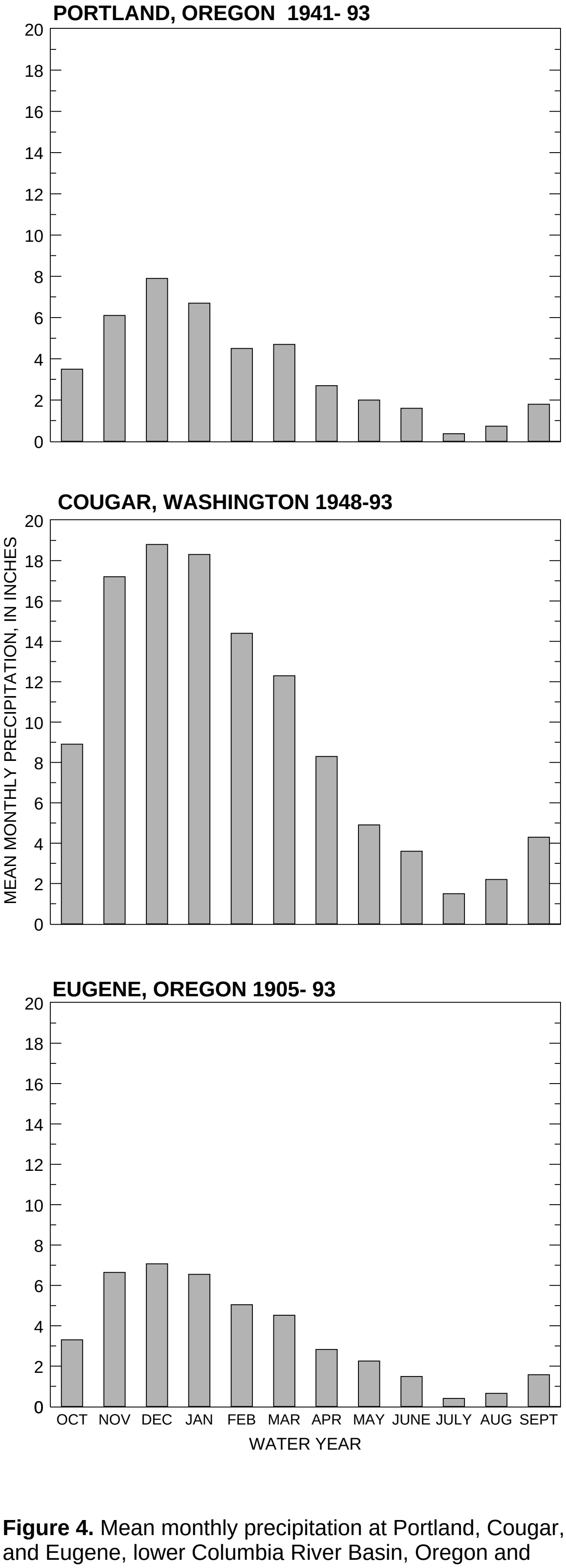


Figure 4. Mean monthly precipitation at Portland, Cougar, and Eugene, lower Columbia River Basin, Oregon and Washington.

In the Columbia River, streamflow is typically high in spring during the snowmelt season. Although winter streamflows are high because of winter rains, they are generally not as high as during snowmelt. Streamflows peaked as a result of spring snowmelt during the months of April, May, and June for the 1956 WY and during June for the 1967 WY (fig. 5). There was, however, no spring peak in the 1977 WY. The 1956, 1967, and 1977 WY’s represent, respectively, the high-flow (351,000 ft^3/s), median-flow (259,000 ft^3/s), and low-flow (153,000 ft^3/s) water years for the period 1928–84 (fig. 6)—based on mean daily streamflow in the Columbia River at mouth (Orem, 1968; U.S. Geological Survey, 1972–75, 1976–80, 1981–84). Peak daily mean streamflows during snowmelt seasons have ranged from 917,000 ft^3/s during June of 1948 to only 179,800 ft^3/s during May of 1977.

The spring snowmelt season usually coincides with the major streamflows of the year. During 1967, a year of median streamflow, more than 40 percent of the annual streamflow in the Columbia River at Vancouver was discharged from April through June during the spring snowmelt period (table 1). During the 1994 WY, however, spring snowmelt runoff was notably less than during the 1967 median streamflow year (fig. 7). The annual mean streamflow (172,100 ft^3/s) measured in the Columbia River at Beaver Army Terminal near Quincy for the 1994 WY is among the lowest 10 percent for the period 1928–85.

The Willamette River’s seasonal streamflow pattern is different from that of the Columbia River. In 1967, the Willamette River discharged only 16 percent of its annual streamflow during spring and 64 percent during the December through March winter months (table 1). In contrast, 41 percent of the streamflow in the Columbia River at Vancouver was discharged during spring and only 24 percent during winter. The 1994 hydrographs for the Columbia and Willamette Rivers (fig. 8) illustrate the same seasonal streamflow patterns—peak flows on the Columbia River were during May and June, and on the Willamette River, rainstorm-driven peaks were measured from January through April and again from November through December.

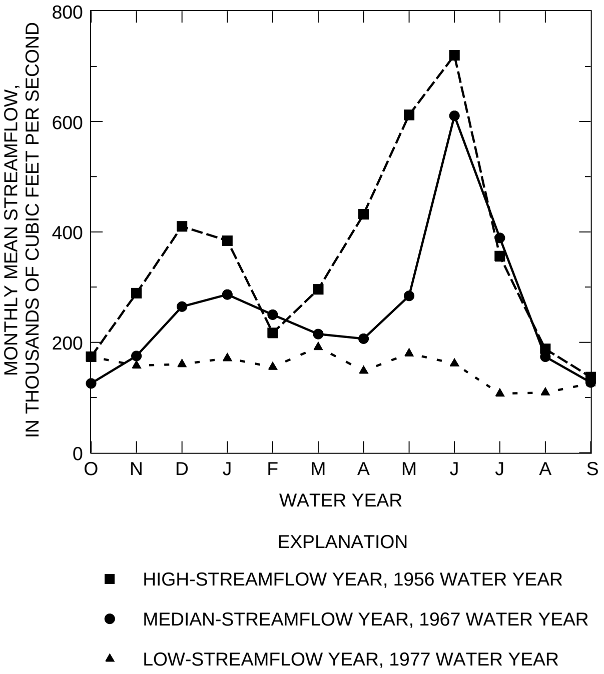


Figure 5. Estimated monthly mean streamflow in the Columbia River at mouth near Astoria for the low-, median-, and high-streamflow years, lower Columbia River Basin, Oregon.

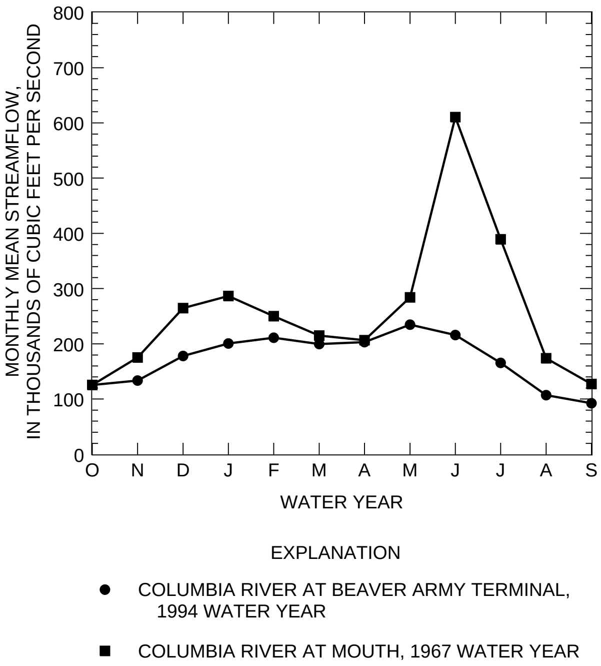


Figure 7. Estimated monthly mean streamflow in the Columbia River at mouth near Astoria, 1967 water year, and Columbia River at Beaver Army Terminal near Quincy, 1994 water year, lower Columbia River Basin, Oregon and Washington.

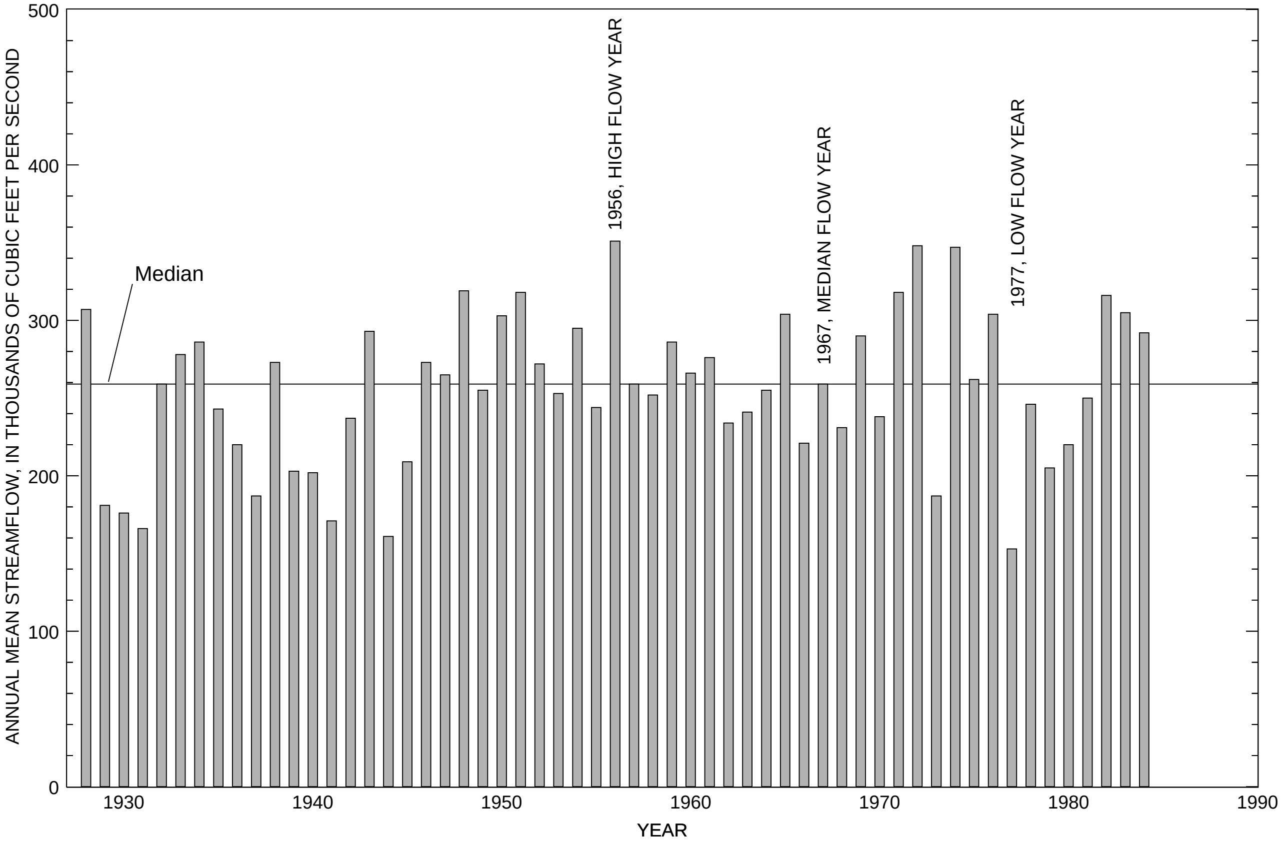


Figure 6. Annual mean streamflow and median annual streamflow for the Columbia River at mouth, 1928–84. (Data from Orem, 1968; U.S. Geological Survey, 1972-75, 1975-80, 1981-84.)

Table 1. Summary statistics for seasonal variations in streamflow at selected sites, lower Columbia River Basin, Oregon and Washington, 1967 water year

[Streamflow reported in thousands of cubic feet per second; Vancouver, Columbia River at Vancouver; Willamette, Willamette River at Portland; St. Helens, Columbia River at St. Helens; Longview, Columbia River at Longview; Astoria, Columbia River at mouth near Astoria; data are for the 1967 water year, a median-streamflow year for the period 1928–85; Fall, October to November; Winter, December to March; Spring, April to June; Summer, July to September]

Site name	Percent of the annual streamflow				Mean monthly streamflow			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Vancouver	9	24	41	26	105	146	332	213
Willamette	14	64	16	6	27.0	65.0	19.6	7.5
St. Helens	10	30	37	23	138	219	356	221
Longview	10	32	36	22	144	239	368	224
Astoria	10	32	35	23	150	254	367	233

Land and Water Use

Major land-use categories[1] in the lower Columbia River Basin include forest land (74 percent) and agricultural land (17 percent) (table 2). Urban lands comprise a relatively small part (5 percent) of the basin, but are significant to water use and water quality. Intensive water use by cities and some agricultural areas makes these land uses of primary importance to water-quality issues. Most of the agricultural land in the lower Columbia River Basin is in the Willamette River Basin (fig. 9). Although the Willamette River Basin makes up 65 percent of the area in the lower Columbia River Basin, it contains 89 percent of the lower basin's agricultural land.

Population in the lower Columbia River Basin was about 2,344,800 in 1990 (T.M. Broad and C.A. Collins, USGS, unpub. data, 1993), with more than 80 percent residing in the Willamette River Basin. As a result, the Willamette River Basin ranks high in terms of water use in the lower Columbia River Basin (table 3), accounting for more than 60 percent of the surface-water and ground-water withdrawals in the lower Columbia River Basin. Commercial[2], industrial[3], livestock, and irrigation withdrawals in the Willamette River Basin are large in comparison to other subbasins in the lower Columbia River Basin. In the Willamette River Basin, for example, industrial and irrigation withdrawals, respectively, represent 55 and nearly 87 percent of the total industrial and irrigation withdrawals in the lower Columbia River Basin.

Point Sources

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 Columbia River or into one of its 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 sources are usually more easily identified and controlled. In addition, point sources include combined-sewer overflows (CSO), which usually occur in the winter in the Willamette River and the Columbia Slough, which drains to the lower Willamette River. Between RM 0 and 25 in the Willamette River, there are a total of 38 CSOs and another 13 in the first 10 river miles of the Columbia Slough (Warner and others, 1992).

One hundred and two point sources were identified as directly connected to the main stem or located within the first 16 river miles of tributaries (table 46, at back of report). These sources are

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[1] Land-use data are from the EPA's 1980 land-use and land-cover digital data (U.S. Environmental Protection Agency, 1994a), which uses the Anderson classification system of land use and land cover (Anderson and others, 1976).

[2] Water used for motels, hotels, restaurants, office buildings, and other commercial facilities, and institutions, both civilian and military.

[3] Water used in processing, washing, cooling in facilities that manufacture products such as steel, chemical and allied products, paper and allied products, and petroleum refining.

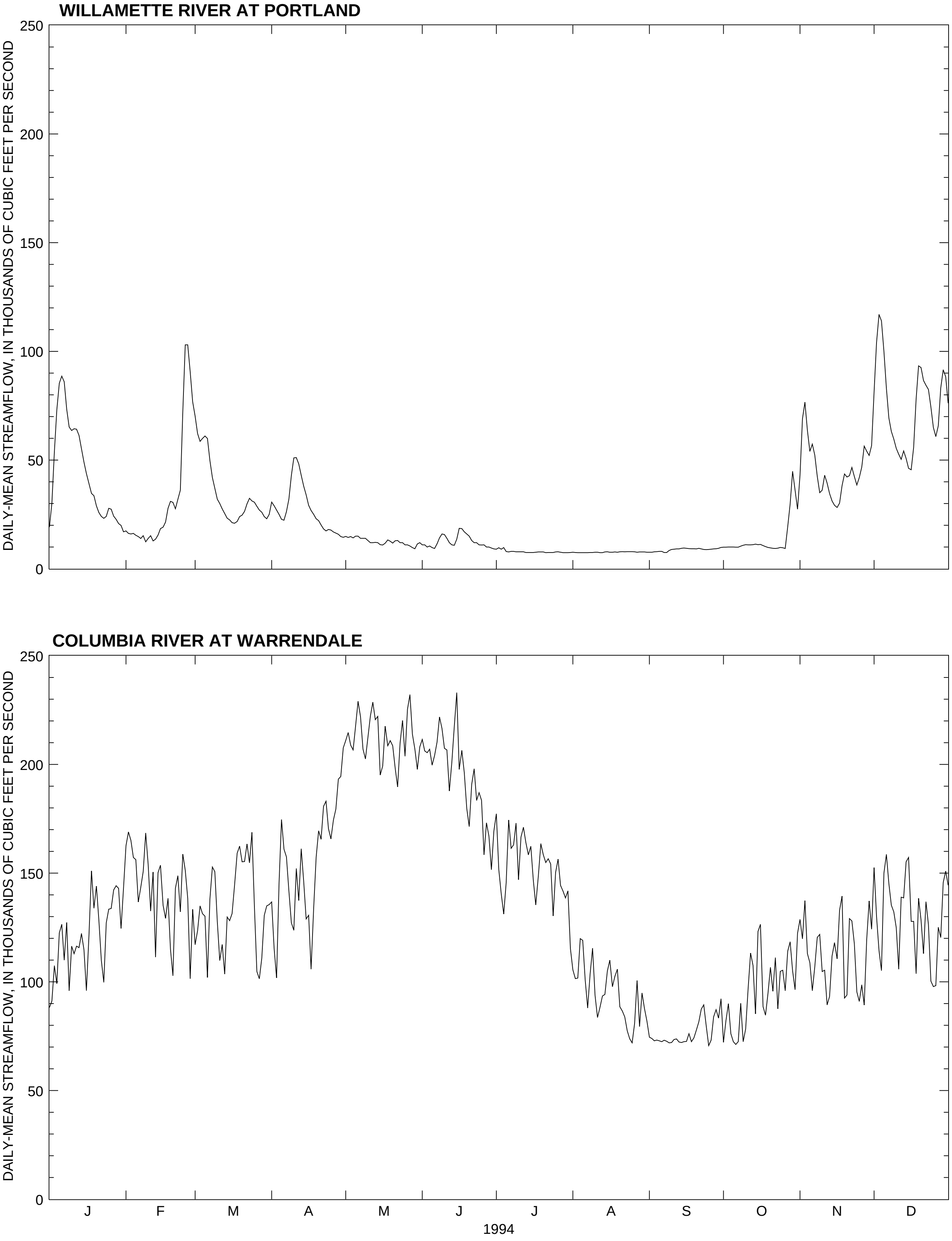


Figure 8. Streamflows in the Willamette River at Portland and Columbia River at Warrendale, lower Columbia River Basin, Oregon and Washington, 1994. (Data for the Columbia River at Warrendale are outflow from Bonneville Dam from the U.S. Army Corps of Engineers.)

Table 2. Percentage of land in specific land-use and land-cover categories, lower Columbia River Basin, Oregon and Washington, 1980
[Land-use percentages from U.S. Environmental Protection Agency, 1994a; %, percent]

Area name	Urban land	Agricultural land	Forest land	Water bodies and wetlands	Other land	Total land area (square miles)
Lower Columbia River Basin	5 %	17 %	74 %	3 %	1 %	17,670
Willamette River Basin (Hydrologic Units 17090001–17090012)	5 %	23.5 %	69.5 %	1 %	1 %	11,426
Non-Willamette areas of the lower Columbia River Basin (Hydrologic Units 17080001–17080006)	4 %	5 %	83 %	5 %	3 %	6,244

facilities that have National Pollutant Discharge Elimination System (NPDES) permits to discharge wastewater. These facilities were classified according to their primary function in order to examine the pollution contributions of different types of industries and their resulting wastewater (table 4). The largest category of point sources is domestic facilities, which are primarily sewage-treatment plants. The locations of these facilities are shown in figure 10. All other point sources are shown in figure 11.

ODEQ and WDOE issue and enforce the NPDES permits in Oregon and Washington. These permits specify the discharge limits that must not be exceeded during the operation of the facility and the frequency and type of monitoring that must be performed. The information in table 46 (at back of report) was obtained from the permit files of ODEQ and from the permits database of WDOE. Information on point sources that discharge directly into the Columbia River came from a report done by Tetra Tech, Inc. for the Lower Columbia River Bi-State Program (Tetra Tech, Inc., 1992). The permit levels for effluent discharge shown in table 46 (at back of report) represent average or maximum permitted effluent quantities and do not necessarily represent actual discharges. Caution should be taken in comparing values in the table because the time frame that the levels are based on differs with each facility. For some facilities, limits have not been set on flow, and levels are based on the “average dry-weather design flow” to the facility. Facilities that are classified as “industrial” by ODEQ or WDOE have limits on the concentrations of selected constituents in their discharge and not on their discharge rate. Likewise, facilities that discharge stormwater do not have flow limits.

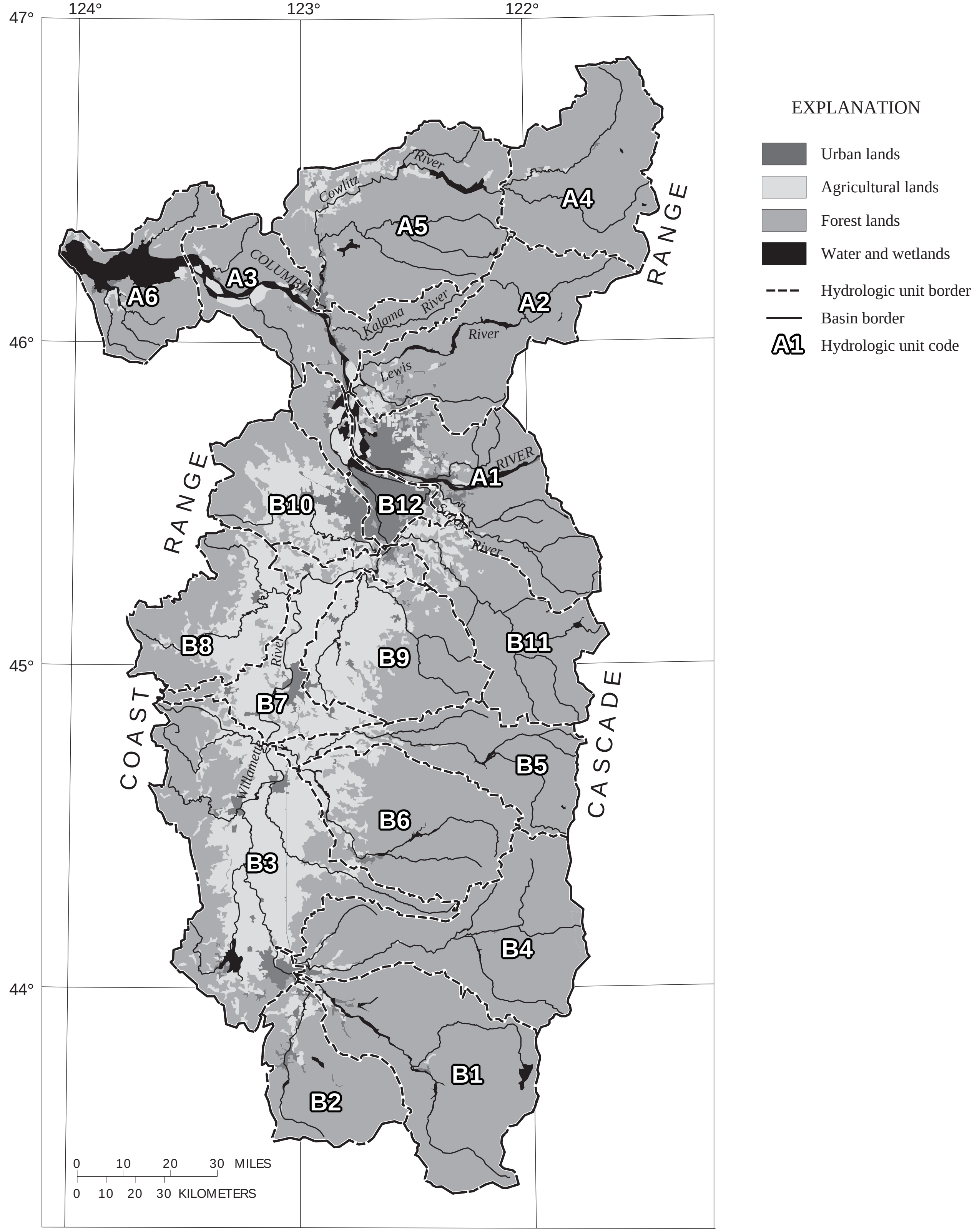
Figure 10 shows only those facilities classified as domestic. The largest sources of effluent volume are the Portland (Columbia Boulevard) and Vancouver (East and West) sewage-treatment plants, which serve the largest populations within 16 river miles of the lower Columbia River. Figure 12 shows facilities that fall in the next three largest categories: chemical plants, seafood processing plants, and other miscellaneous facilities, respectively. The largest sources of effluent volume for these categories are Elf Atochem North America, Inc., an inorganic chemical manufacturer in Portland, and Chevron Chemical Company, a fertilizer plant in St. Helens.

DATA SOURCES AND METHODS OF ANALYSIS

The purposes of this study include examining the spatial and temporal variations in water-quality constituent concentrations, loads, and trends in the lower Columbia River Basin and describing the suitability of surface water for the preservation of aquatic life and the protection of human health. In order to meet these goals, it was necessary not only to collect water-quality data, but also to compile and analyze data that had been previously collected. The current and past data were then related in a common framework in an effort to understand the water quality of the River.

Table 3. Water use in the lower Columbia River Basin, Oregon and Washington, 1990 water year
[Mgal/d, million gallons per day; --, no data; water-use data from Broad and Collins, USGS, unpub. data, 1993]

Hydrologic unit or subbasin name	Population (in thousands)	Total withdrawals (Mgal/d)	Selected withdrawals (Mgal/d)					Wastewater treatment releases (Mgal/d)	Hydroelectric power (Mgal/d)
			Public supply water	Commercial withdrawls and deliveries	Industrial withdrawls and deliveries	Livestock	Irrigation		
Lower Columbia-Sandy, Oregon	31	170	120	45	0.4	0.1	1.2	5.9	100,000
Lower Columbia-Sandy, Washington	210	136.5	29.7	4.1	90.4	.91	13.7	55	0
Willamette River Subbasin. Oregon (including Lower Willamette Unit)	1,927.6	1,100	170	235	220	3.7	358.4	4.8	20,000
Lewis, Washington	36.2	19	.98	.14	.01	0	14.7	.32	9,983
Lower Columbia-Clatskanie, Oregon	21.4	92	2.1	13	60	--	1.3	36	0
Lower Columbia-Clatskanie, Washington	49.9	26.7	6.2	.55	13.5	.16	5.9	44	0
Cowlitz River Subbasin, Washington	44.4	164	4.5	.37	17.3	1.2	16.8	2.4	1,950
Lower Columbia (estuary), Oregon	22.7	52	7.2	45	1.2	.1	.3	4.7	0
Lower Columbia (estuary), Washington	1.57	.18	.13	0	0	0	0	.3	0
Total	2,344.8	1,760.4	340.8	343.2	402.8	6.2	412.3	153.4	131,933



Land Use from U.S. Environmental Protection Agency, 1994

Figure 9. Land use and land cover by hydrologic units, lower Columbia River Basin, Oregon and Washington, 1980.

Table 4. Inventory of point-source classifications, lower Columbia River Basin, Oregon and Washington

Source classification	Number of facilities
Domestic	39
Chemical	12
Wood products and wood treatment	11
Miscellaneous	10
Seafood processing	8
Paper and pulp	5
Aluminum	4
Boat yard	3
Fish hatchery	3
Remediation (site cleanup)	3
Power generating	2
Tank farm (storage)	2

Current and Historical Sources of Data

Data collected in 1994 are referred to as current data, and data collected before 1994 are referred to as historical data. Current data were collected by the USGS, ODEQ, and WDOE, whereas historical data span a longer timeframe and were collected by many agencies.

Historical Data

Water-quality data for more than 200 parameters collected from streams in the lower Columbia River Basin over more than 50 years were collated for interpretation in this report. These data are from three sources: EPA's STOrage and RETreival (STORET) database, USGS's National Water Information System (NWIS) database, and Tetra Tech, Inc. synoptic studies. The retrievals were confined to the hydrologic units inside the lower Columbia River Basin (table 5). The STORET retrieval consisted of data from non-USGS agencies including EPA, U.S. Forest Service, ODEQ, and WDOE; the NWIS retrieval consisted only of USGS data.

Water-quality data of particular relevance were collected at the following three fixed sites in the lower Columbia River Basin as part of the USGS's NAtional Stream Quality Accounting Network (NASQAN):

Columbia River at Warrendale (RM 141.0 — 1973 to October 1993) Willamette River at Portland (RM 12.8—October 1974 to current year) Columbia River at Beaver Army Terminal (RM 53.8—November 1990 to current year).

In 1992, the NASQAN site at Warrendale was moved to Beaver Army Terminal to obtain a better accounting of constituents leaving the Columbia River Basin. Prior to discontinuing data collection at Warrendale, however, the NASQAN program funded the sampling of concurrent data in 1992 from Warrendale and Beaver Army Terminal. As a result of Bi-State interest in the lower Columbia River Basin, the NASQAN program funded continued operation of the Warrendale site through October 1993. The NASQAN suite of constituents measured at the Warrendale and Beaver Army Terminal sites is not extensive. More constituents were measured during 1993–95 at the Willamette River site, however, because of other USGS programs sampling there. The sampling was partially funded by the USGS's National Water Quality Assessment (NAWQA) program (1993–95) in the Willamette Basin (Leahy and Thompson, 1994), and by a Willamette State Study cooperative program (1993–95) between the USGS and ODEQ. NASQAN samp-ling at these three sites was done once every 2 months, but sampling at the Willamette River site was done once a month during 1993–95 because of the other programs. Few samples were collected for priority pollutant trace elements and organic compounds.

Through the Bi-State Program, Tetra Tech, Inc. performed two synoptic studies on the lower Columbia River. A reconnaissance survey of the main stem during September to November 1991 was implemented to make a preliminary assessment of water-quality conditions and to direct future Bi-State studies (Tetra Tech, Inc., 1993). Four environmental media (water, streambed sediments, fish tissue, and benthic organisms) were sampled. For this report, however, interpretation of historical data was restricted to the 45 sites for which the water column was sampled. Due to high method reporting limits and data flagged as "unusable," only selected parameters (pH, turbidity, dissolved oxygen

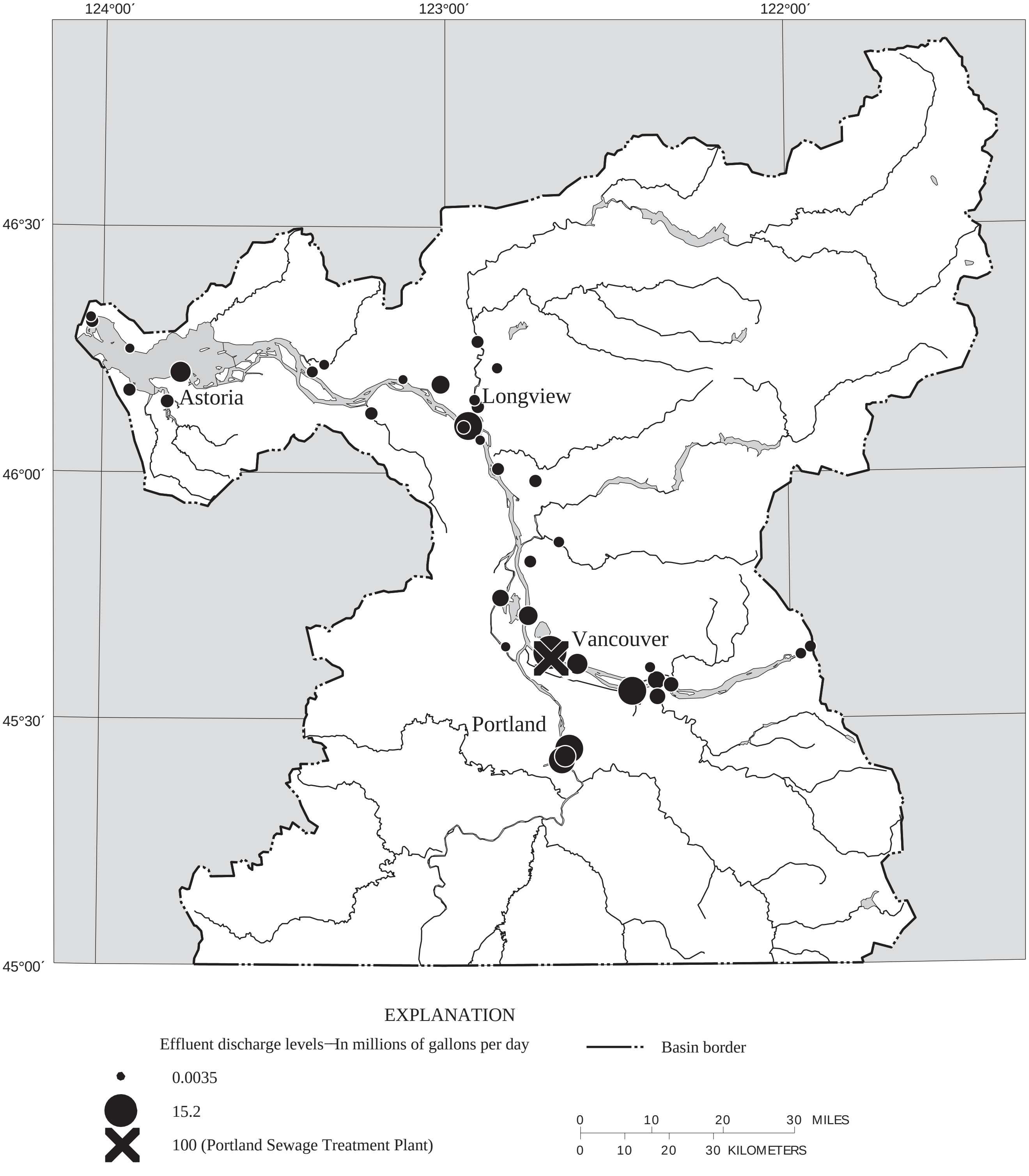


Figure 10. Point-source domestic discharges, lower Columbia River Basin, Oregon and Washington, 1994.

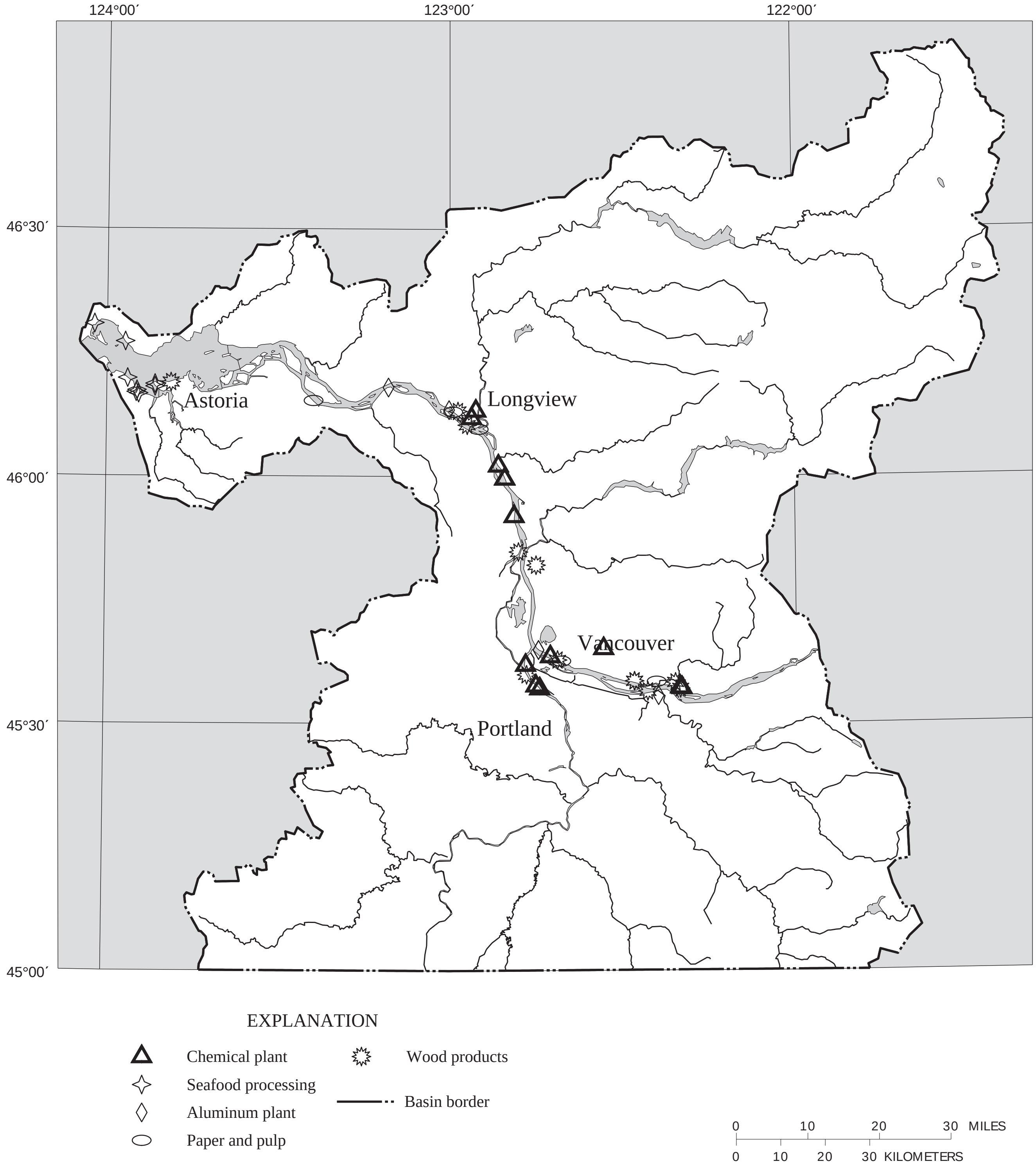


Figure 11. Locations of point sources other than domestic discharge, lower Columbia River Basin, Oregon and Washington, 1994.

Figure 11. Locations of point sources other than domestic discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued.

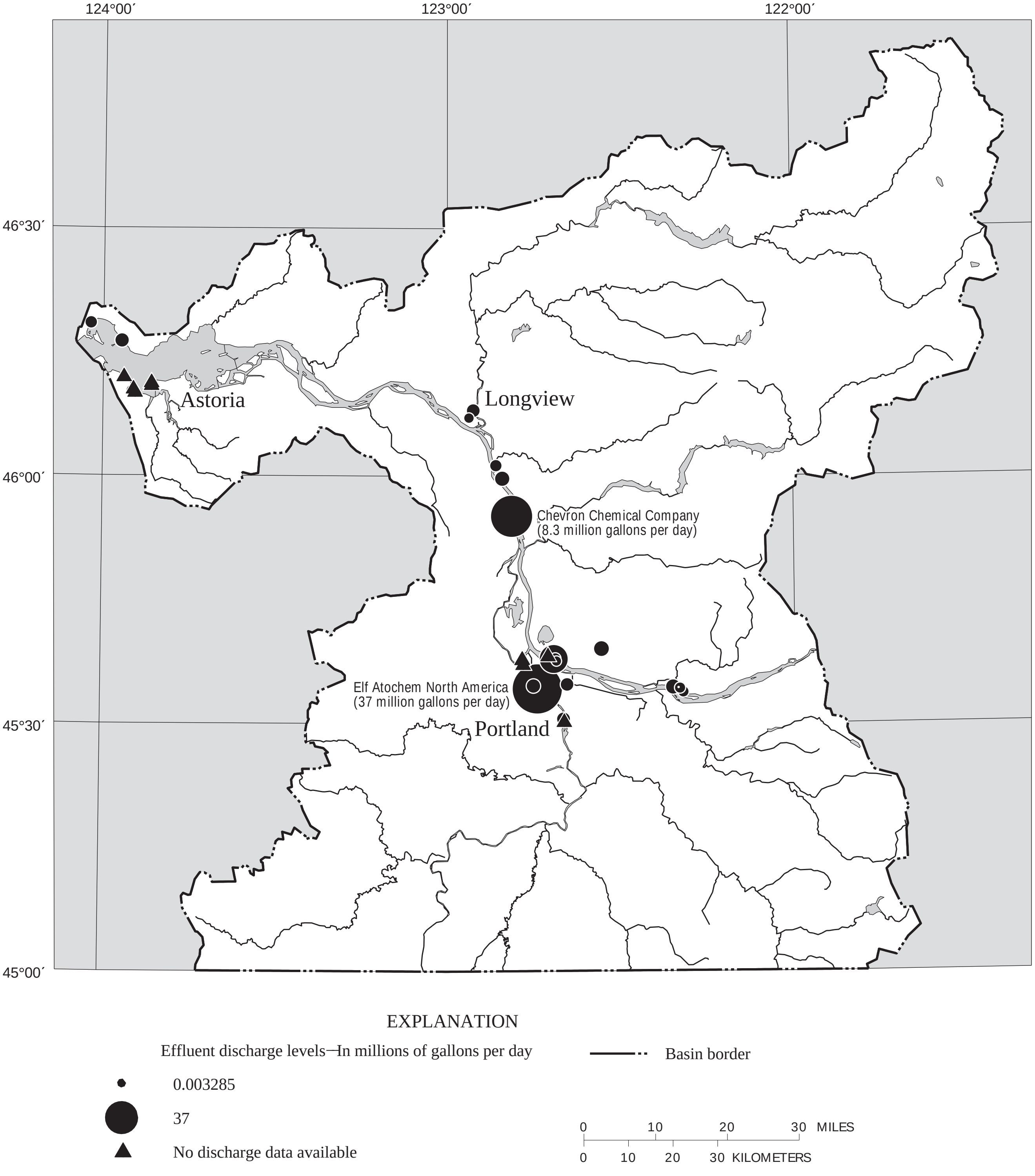


Figure 12. Point-source discharges for chemical, seafood processing, and other miscellaneous facilities, lower Columbia River Basin, Oregon and Washington, 1994.

Table 5. Hydrologic units included in historical data retrievals and subbasin units used for analysis of historical data, lower Columbia River Basin, Oregon and Washington

[Historical data was retrieved for all hydrologic units except 17080004; hydrologic unit descriptions from U.S. Geological Survey, 1982]

Hydrologic unit	Hydrologic unit name	Subbasin or unit name used for analysis of historical data
17080001	Lower Columbia-Sandy, Oregon, Washington	Lower Columbia-Sandy, Oregon
17080001	Lower Columbia-Sandy, Oregon, Washington	Lower Columbia-Sandy, Washington
17080002	Lewis, Washington	Lewis River Subbasin
17080003	Lower Columbia-Clatskanie, Oregon, Washington	Lower Columbia-Clatskanie
17080004	Upper Cowlitz, Washington	Cowlitz River Subbasin
17080005	Lower Cowlitz, Washington	Cowlitz River Subbasin
17080006	Lower Columbia, Oregon, Washington	Lower Columbia (estuary) Unit
17090001	Middle Fork Willamette, Oregon	Willamette River Subbasin
17090002	Coast Fork Willamette, Oregon	Willamette River Subbasin
17090003	Upper Willamette, Oregon	Willamette River Subbasin
17090004	McKenzie, Oregon	Willamette River Subbasin
17090005	North Santiam, Oregon	Willamette River Subbasin
17090006	South Santiam, Oregon	Willamette River Subbasin
17090007	Middle Willamette, Oregon	Willamette River Subbasin
17090008	Yamhill, Oregon	Willamette River Subbasin
17090009	Molalla-Pudding, Oregon	Willamette River Subbasin
17090010	Tualatin, Oregon	Willamette River Subbasin
17090011	Clackamas, Oregon	Willamette River Subbasin
17090012	Lower Willamette, Oregon	Lower Willamette Unit

temperature, specific conductance, salinity, total suspended solids, chloride, sulfate, hardness, fecal-coliform bacteria, and enterococcal bacteria) were examined. In 1993, a second synoptic study was performed to supplement the 1991 data (Tetra Tech, Inc., Redmond, Washington, unpub. data, 1994). During this survey, water, streambed-sediment, and fish-tissue samples were collected in backwater areas (locations isolated from the main river current with an outlet to the main channel, for example, sloughs and back channels) of the lower Columbia River. The interpretation for the present report was limited to the 15 sites for which the water column was sampled. The parameters of interest were mainly physical properties, nutrients, bacteria, and trace elements.

Historical water-quality data were categorized into eight constituent groups: (1) major ions; (2) water temperature and pH; (3) dissolved oxygen; (4) nutrients, including those constituents containing nitrogen and phosphorus; (5) trace elements; (6) organic compounds, including organic carbon, pesticides, and priority organic pollutants as identified by the EPA (U.S. Environmental Protection Agency, 1995); (7) suspended-sediment concentrations in water; and (8) bacteria, including fecal coliform and enterococci. The number of historical determinations for each of these groups is shown in figure 13. Data from the Willamette River Basin are also shown separately in the figure to illustrate the fact that most of the historical data that are available for the lower Columbia River Basin comes from the Willamette River Basin. Table 6 provides an overview of the sites with the most determinations, by constituent group, in the basin. From this table, it can be seen that the Bull Run Watershed (Portland’s drinking-water source) has been frequently sampled in the past.

Table 6. Sites that have the most water-quality determinations from 1939–93, lower Columbia River Basin, Oregon and Washington

[Listed are the five sites with the most water-quality data values for each constituent group; USFS, U.S. Forest Service; EPA, U.S. Environmental Protection Agency; ODEQ, Oregon Department of Environmental Quality; USGS, U.S. Geological Survey; NA, not available; sources of data: EPA's STOrage and RETrieval System, USGS's National Water Inventory System, Tetra Tech, Inc., 1993; and Tetra Tech, Inc., Redmond, Washington, unpub. data, 1994]

Site number	Site name	Sampling agency	Number of data values
	Major Ions		
4527001220900	Bull Run Reservoir at Headworks	USFS, EPA	12,647
4526001220200	Fox Creek	USFS	10,026
4533491224317	Willamette S.I. Monitor	EPA	6,310
4527001220700	South Fork at S-111	USFS	3,418
4534461224442	Willamette River at SP&S Railroad Bridge	NA	3,253
	Water Temperature and pH		
4527001220900	Bull Run Reservoir at Headworks	USFS, EPA	24,273
4530001220300	Cougar Creek/ Deer Creek at S-10	USFS	6,081
4533491224317	Willamette S.I. Monitor	EPA	5,875
4527001220700	South Fork at S-111	USFS	4,875
4530001225400	Otter Creek/ Log Creek/ Blazed Alder Creek	USFS	4,699
	Dissolved Oxygen		
4527001220900	Bull Run Reservoir at Headworks	USFS, EPA	10,950
4533491224317	Willamette S.I. Monitor	EPA	5,694
4534411224451	Willamette River at SP&S Railroad Bridge	ODEQ	1,958
4534461224442	Willamette River at SP&S Railroad Bridge	NA	1,917
4456521230242	Willamette River at Salem Railroad Bridge	ODEQ	1,721
	Nutrients		
4526001220200	Fox Creek	USFS	2,993
14211720	Willamette River at Portland	USGS	935
452481225103	Tualatin River at Elsner Road Bridge	NA	864
14207500	Tualatin River at West Linn	USGS	784
14128910	Columbia River at Warrendale	USGS	774
	Trace Elements		
14128910	Columbia River at Warrendale	USGS	2,115
14211720	Willamette River at Portland	USGS	1,964
14207500	Tualatin River at West Linn	USGS	1,815
14247400	Columbia River at Bradwood	USGS	763
4524181225103	Tualatin River at Elsner Road Bridge	NA	587
	Organic Compounds		
14202000	Pudding River at Aurora	USGS	4,384
14201300	Zollner Creek near Mt. Angel	USGS	4,228
14206950	Fanno Creek at Durham	USGS	2,008
14211720	Willamette River at Portland	USGS	1,122
4431381231209	Muddy Creek near Peoria	USGS	800
	Suspended Sediment		
4526001220200	Fox Creek	USFS	2,868
4530001220200	North Fork Bull Run at RM 0.1 above S-10	USFS	2,022
4529001220100	Fir Creek at S-111	USFS	1,991
4527001220900	Bull Run Reservoir at Headworks	USFS, EPA	1,766
4530001220000	Bull Run Main stem/ Bear Creek West Fork	USFS	1,689
	Bacteria		
14138990	Bear Creek near Bull Run	USGS	329
14138900	North Fork Bull Run River near Multnomah Falls	USGS	322
14138960	Cougar Creek near Bull Run	USGS	322
14138950	Deer Creek near Bull Run	USGS	319
14138850	Bull Run River near Multnomah Falls	USGS	316
14139800	South Fork Bull Run River near Bull Run	USGS	316

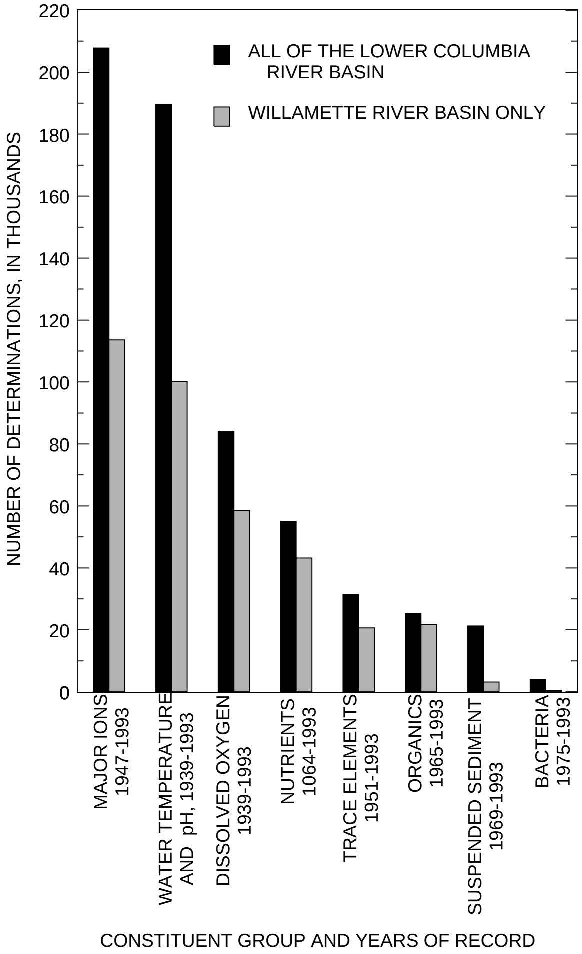


Figure 13. Number of historical surface-water-quality determinations by constituent group, lower Columbia River Basin, Oregon and Washington, 1939-93. (Sources of data: U.S. Environmental Protection Agency's STOrage and RETrieval System; U.S. Geological Survey's National Water Inventory System; Tetra Tech, Inc., 1993; and Tetra Tech, Inc., Redmond, Washington, unpub. data, 1994.)

The major ions, water temperature and pH, dissolved oxygen, and nutrient groups had the largest number of determinations, probably because these constituents (1) are the least costly to determine, (2) can provide a good preliminary indication of water-quality conditions, (3) are associated with other water-quality concerns, and (4) have methods of determination (with appropriate reporting limits) that have been available for the last couple of decades. In contrast, the potentially toxic constituent groups, including the trace elements and organic compounds, have fewer determinations, primarily due to the high costs of determination and shorter periods of record.

Current Data

The USGS, WDOE, and ODEQ collected data in the lower Columbia River Basin for the Bi-State ambient-monitoring program from January to December 1994 (table 7). All USGS data from this study are published in the U.S. Geological Survey Water Resources Data Report for Oregon for the 1994 water year (U.S Geological Survey, 1995). USGS data also are available in the NWIS database. All data for this study collected by the USGS, WDOE, and ODEQ will be stored in EPA's STORET database.

U.S. Geological Survey

Ten sites were sampled by the USGS in 1994 (fig. 14). The location of each site was determined by comparing landmarks in the field to 7–1/2 minute series topographic maps (scale 1:24,000). At every sampling, field measurements (dissolved oxygen, pH, water temperature, alkalinity, and specific conductance) were made and samples were collected for determination of major ions, nutrients, suspended sediment (concentration and percent finer than 63 µm [micrometers]), fecal-indicator bacteria, and chlorophyll. At each of the 10 sites, 4 samplings were made for trace elements and organic compounds. Analyses included measurements of trace elements in filtered water and in suspended sediment, organic compounds in filtered water[4], and organic carbon in filtered water and associated with suspended sediment. Sample collection dates were not based on hydrologic events, but were scheduled in advance, as is consistent with a basic monitoring program. Additional samplings for organic compounds were made at the Willamette River as part of the USGS Willamette NAWQA and Willamette State Study sampling program. Six of the 10 sites were sampled monthly by boat: the 4 Columbia River sites, the Willamette River at Portland, and Multnomah Channel near mouth. Tide tables were consulted at tidally affected sites to facilitate sampling during ebb tides and to insure that samples represented water-quality conditions upstream. The other four sites (the Sandy River,

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[4] The term "filtered water" is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-µm (0.70-µm for organic compounds) filter. The term "unfiltered water" refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix.

Table 7. Sampling sites and constituents analyzed, lower Columbia River Basin, Oregon and Washington, 1994

[USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; WDOE, Washington Department of Ecology; NA, not applicable; SS, suspended sediment; B, fecal-indicator bacteria; Ch, chlorophyll; TSS, total suspended solids; sites may be referred to by their abbreviated name in this report]

Agency site number	Site name (abbreviated site name)	Agency	River mile		Number of samples				Other constituents sampled
			Columbia	Tributary	Field values	Major ions	Nutrients	Trace elements and organic compounds	
14128910	Columbia River at Warrendale, Oregon (Warrendale)	USGS	141.0	NA	11	11	11	4	SS, B, Ch
453056 122213701	Sandy River near Troutdale, Oregon (Sandy River)	USGS	120.5	5.8	4	4	4	4	SS, B, Ch
402351	Sandy River at Troutdale, Oregon	ODEQ	120.5	3.1	13	0	13	0	B
14144710	Columbia River at river mile 102, downstream of Hayden Island, Oregon (Hayden Island)	USGS	102.0	NA	14	13	13	4	SS, B, Ch
14211720	Willamette River at Portland, Oregon (Willamette River)	USGS	101.5	12.8	14	14	14	6	SS, B, Ch
402288	Willamette River at Hawthorne Bridge, Oregon	ODEQ	101.5	13.2	14	14	14	0	B
455417 122441000	Lewis River at Woodland, Washington (Lewis River)	USGS	87.0	5.7	4	4	4	4	SS, B, Ch
27C070	Lewis River at Woodland, Washington	WDOE	87.0	5.7	12	0	12	0	TSS, B
14222850	Multnomah Channel near mouth, at St. Helens, Oregon (Multnomah Channel)	USGS	86.3	.9	12	12	12	4	SS, B, Ch
14222890	Columbia River near Columbia City, Oregon (Columbia City)	USGS	82.4	NA	12	12	12	4	SS, B, Ch
14223600	Kalama River above Spencer Creek, near Kalama, Washington (Kalama River)	USGS	73.1	2.8	4	4	4	4	SS, B, Ch
27B070	Kalama River near Kalama, Washington	WDOE	73.1	2.8	12	0	12	0	TSS, B
14244200	Cowlitz River at Kelso, Washington (Cowlitz River)	USGS	68.0	4.8	4	4	4	4	SS, B, Ch
26B070	Cowlitz River at Kelso, Washington	WDOE	68.0	4.8	12	0	12	0	TSS, B
14246900	Columbia River at Beaver Army Terminal near Quincy, Oregon (Beaver Army Terminal or Beaver)	USGS	53.8	NA	16	17	16	4	SS, B, Ch

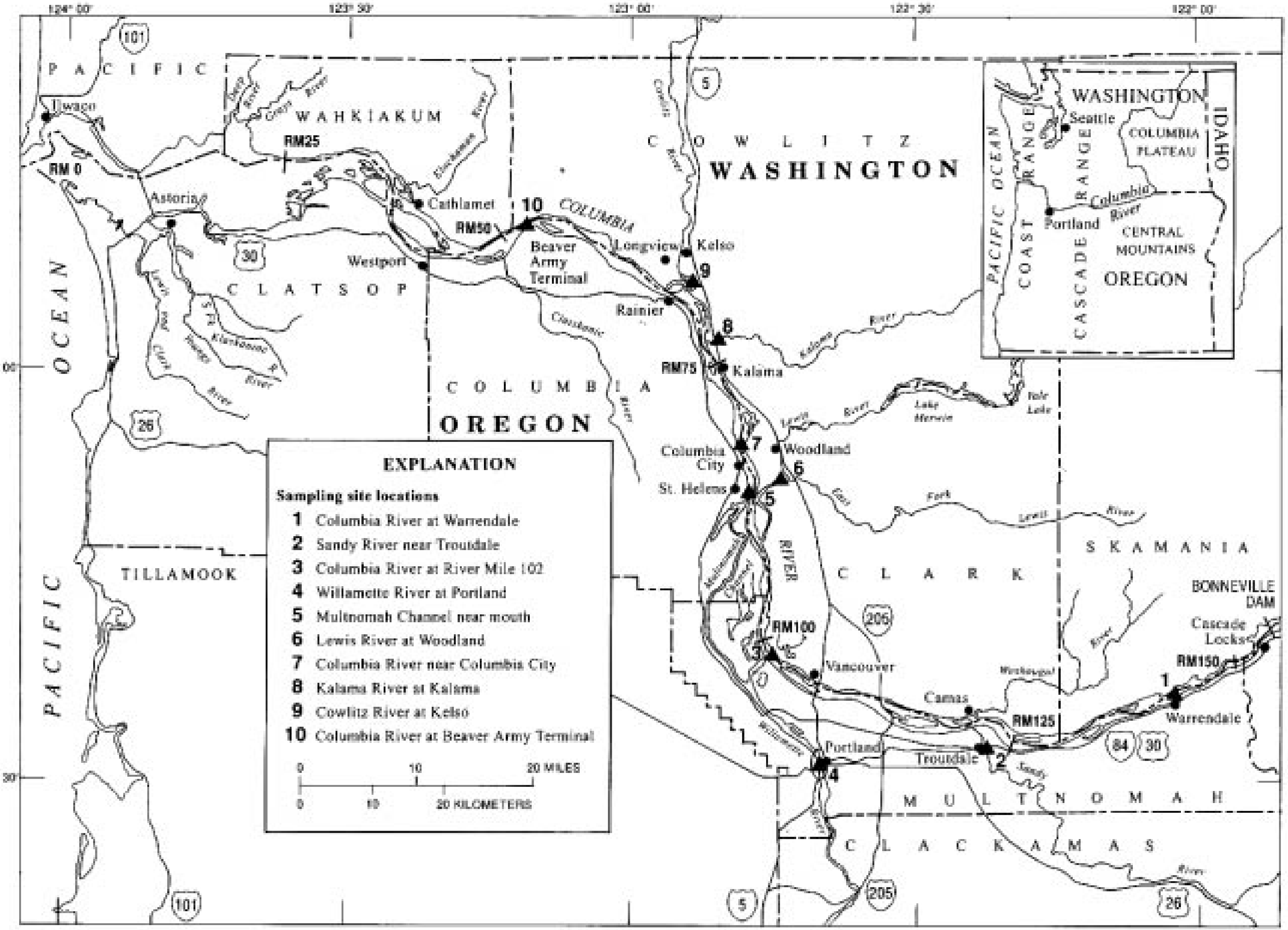


Figure 14. Map showing U.S. Geological Survey sampling locations, lower Columbia River Basin, Oregon and Washington, 1994.

Lewis River, Kalama River, and Cowlitz River) were sampled from bridges; each sites was sampled four times during 1994.

Sampling techniques described by Edwards and Glysson (1988) were used to insure that the sample was representative of the flow in the cross section. Samples were obtained either at equal spacing across the cross section (equal-width-increment method), or at the centroids of equal-discharge increments (equal-discharge-increment method). Samples were collected by using a weighted sampler designed to fill with water isokinetically (at the same rate as the flow velocity of the river). The sampler was lowered to the river bed (up to 80 feet deep) and raised by using a variable-speed power-operated winch. For the boat sites, an 8-liter (L) collapsible Teflon-bag sampler with Teflon cap and nozzle (C.F. Nordin, U.S. Geological Survey, written commun., 1981) was used following the procedures outlined by Meade and Stevens (1990) and Horowitz and others (1994). Alternatively, an epoxy-coated aluminum sampler (the D-77 depth-integrating sampler), which contained a 3-L Teflon bottle with Teflon cap and nozzle, was used at the bridge sites. Samples for bacterial analysis were collected from the midchannel section by using an autoclaved plastic bag in the sampler and a sterilized cap and nozzle. Field measurements were made by using a portable probe unit at a depth of 1 meter at 10 locations along the cross section. These measurements were recorded as the arithmetic mean of the 10 measurements. At the Columbia River sites, total dissolved gas was measured in June and July by using a Weiss saturometer.

The parts-per-billion protocol described by Horowitz and others (1994) was followed for the collection of samples for trace-element analysis of filtered water. This procedure involves acid rinsing or acid soaking the sampler and sample containers and the use of latex gloves by a person who touches only the sampler. Samples for trace elements, major ions, nutrients, suspended sediment, and chlorophyll were transferred from the sampler to a 14 L polyethylene churn splitter. Samples for organic compounds were transferred to a 10 L glass carboy, and samples for trace elements in suspended sediment were transferred to 10 L polycarbonate carboys. Bacteria samples were transferred to sterilized glass bottles. All samples were chilled immediately in the field, except for suspended trace-element samples for which the large volume (up to 120 L) made immediate chilling impractical. Large sample volumes were needed for suspended trace-elements, because the suspended sediment concentration in the Columbia River was often as low as 5 to 10 mg/L. On a monthly basis, quality assurance samples were included with routine water-quality samples to quantify accuracy, precision, presence of laboratory contamination, and analytical bias. The quality assurance program consisted of source solution blanks, field equipment blanks, split samples, standard reference samples, and for organic compounds only, field matrix spikes and surrogate spikes. Results of the quality assurance programs are included in the quality assurance section at the end of this report.

Equipment used for sampling and processing was washed with Liquinox, rinsed with hot tap water, once with 5-percent (by volume) hydrochloric acid, and three times with distilled/deionized water. The Teflon sample bottles and the filtration unit used for organic compounds also were rinsed with methanol and allowed to air dry. The organic-carbon filtration unit was instead rinsed with organic-free blank water. All sampling equipment was rinsed in ambient stream water prior to sample collection.

At the USGS laboratory in Portland, water samples were processed immediately and prepared for laboratory analysis. The churn splitter was used to resuspend the water/sediment mixture prior to subsampling for unfiltered-water determinations. Before filtered-water samples were processed, some of the water-suspended sediment mixture was withdrawn from the churn splitter into a graduated cylinder for organic-carbon analysis. The mixture was filtered through a 47-mm (millimeter) diameter, 0.45-μm pore-size silver filter. The filtrate for analysis of organic carbon in filtered water was collected in a 125-mL (milliliter) glass bottle with a Teflon lid-liner. The silver filter was removed from the filter assembly and placed in a petri dish for the analysis of organic carbon associated with suspended sediment. A portion of the water remaining in the churn splitter was filtered through a 0.45-μm pore-size capsule filter and dispensed into the corresponding sample bottles for filtered-water determinations. Filtered-water samples for trace elements were preserved with ultrapure nitric acid according to Horowitz and others (1994). Filtered-water samples for mercury were preserved with nitric acid/potassium dichromate. Nutrient samples were preserved with mercuric chloride. The samples for organic compounds were filtered through a 142-mm diameter, 0.7-µm pore-size glass-fiber filter that had been baked to remove the organic carbon. These filtered samples then were pumped through solid-phase extraction cartridges, which were submitted for analysis. All samples were shipped on ice to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado.

The samples for trace elements in suspended sediment were refrigerated at 4°C on arrival at the Portland laboratory. Within 1 week of collection, the samples were brought to room temperature and centrifuged to concentrate the suspended sediment. Centrifuge speed and spin times were adequate to remove 0.45-µm diameter or larger particles—assuming a particle density of 2.5 grams per cubic centimeter. Each sample was rinsed in approximately 250 mL of distilled/deionized water during the final centrifugation steps. Final sample concentrates were placed in the oven at room temperature until dry. The dried samples were shipped to the USGS Analytical Chemistry Services Group in Denver, Colorado, for analysis.

Bacteria samples were analyzed by membrane-filtration methods according to Britton and Greeson (1987) and the American Public Health Association and others (1989) at the USGS's Portland laboratory. Chlorophyll samples were analyzed using fluorometry (American Public Health Association and others, 1989) at the USGS's Portland laboratory. Samples for suspended-sediment concentration and size class were analyzed at the USGS laboratory in Vancouver, Washington, using the methods in Guy (1969).

Table 8 lists the major ions, nutrients, organic carbon, and trace elements determined at the USGS National Water Quality Laboratory. Water samples were analyzed for major ions according to methods of Fishman (1993) and Fishman and Friedman (1989). Nutrients were analyzed according to methods of Fishman (1993), Kim Pirkey, (USGS, written commun., 1995), and Patton and Truitt (1992). Organic carbon was analyzed according to the methods described in Brenton and Arnett (1993), and Wershaw and others (1987). Filtered-water samples for all trace elements except arsenic, selenium, and mercury were analyzed by inductively coupled plasma-mass spectrometry as described in Faires (1993). Arsenic and selenium were analyzed by hydride generation-atomic absorption spectrometry, and mercury was analyzed by cold vapor-atomic absorption spectrometry (Fishman and Friedman, 1989).

The method reporting limits (MRL's) shown in table 8 are based on reliable quantification, given various sample compositions. The purpose of using MRL's rather that method detection limits is to minimize the problems associated with field and laboratory contamination and to ensure a high degree of confidence in analytical results from a routine mode of operation. For trace elements in filtered water, the MRL's are approximately five times greater than the average-determined method detection limit (Faires, 1993).

Organic compounds in filtered water were analyzed at the NWQL by gas chromatography/mass spectrometry after eluting the analytes from the C-18 solid-phase extraction cartridge as described by Zaugg and others (1995). Table 9 lists the 47 organic compounds analyzed using this method (schedule 2010). The method detection limits (MDL) for schedule 2010 are listed in table 9. The MDL's represent the minimum analyte concentration present in a sample with a given composition containing the analyte that can be identified, measured, and reported with 99-percent confidence that the analyte concentration is greater that zero.

In addition to determinations of the 47 organic compounds listed above, a second group of 42 organic compounds was analyzed by using high-performance liquid-chromatography/ultraviolet spectrometry. Quality assurance for this new method (designated by the USGS as schedule 2051) is under review by the USGS's Methods Development Group. The USGS is reviewing analytical-method performance issues related to sample preservation/sample degradation, potential for saturation of the Carbopak solid-phase adsorbent cartridge and subsequent loss of analyte prior to analysis, lapsed time between sample extraction from the solid-phase cartridge and sample analysis, potential for coelution of analytes, and concerns regarding false negatives. All of these factors ultimately affect the quality of the reported organic-compound concentrations. Consequently, schedule 2051 data were unavailable for use in this study

Table 8. Method reporting limits for major ions, nutrients, organic carbon, and trace elements analyzed in filtered and unfiltered water, lower Columbia River Basin, Oregon and Washington, 1994

[Values are reported in milligrams per liter, except for trace elements which are reported in micrograms per liter; STORET, U.S. Environmental Protection Agency's STOrage and RETrieval system; method reference numbers correspond to:

a. Fishman, 1993,
b. Fishman and Friedman, 1989,
c. Kim Pirkey, U.S. Geological Survey National Water Quality Laboratory, written commun., 1995
d. Patton and Truitt, 1992,
e. Brenton and Arnett, 1993,
f. Wershaw and others, 1987, and
g. Faires, 1993]

STORET code	Constituent name	Method reference number	Method reporting limit
	Major ions in filtered water		
00915	Calcium	a. I-1472-87	0.02
00940	Chloride	b. I-2057-85	.1
00950	Fluoride	b. I-2057-85	.1
01046	Iron	a. I-1472-87	.003
00925	Magnesium	a. I-1472-87	.01
00935	Potassium	b. I-1630-85	.1
00955	Silica	a. I-1472-87	.01
00930	Sodium	a. I-1472-87	.2
00945	Sulfate	b. I-2057-85	.1
70300	Total dissolved solids	b. I-1750-85	1
	Nutrients in water		
00608	Ammonia as N, filtered water	a. I-2522-90	.01
00623	Ammonia plus organic nitrogen as N, filtered water	c. I-2515-91	.2
00625	Ammonia plus organic nitrogen as N, unfiltered water	c. I-4515-91	.2
00613	Nitrite as N, filtered water	a. I-2540-90	.01
00631	Nitrite plus nitrate as N, filtered water	a. I-2545-90	.05
00671	Orthophosphate as P, filtered water	a. I-2601-90	.001
00666	Phosphorus as P, filtered water	d. I-2610-91	.01
00665	Phosphorus as P, unfiltered water	d. I-4610-91	.01
	Organic carbon in water		
00681	Organic carbon, filtered water	e. O-1122-92	.1
00689	Organic carbon, associated with suspended sediment	f. O-7100-83	.1
	Trace elements in filtered water		
01106	Aluminum	g. I-2477-92	1
01095	Antimony	g. I-2477-92	1
01000	Arsenic	b. I-2062-85	1
01005	Barium	g. I-2477-92	1
01010	Beryllium	g. I-2477-92	1
01025	Cadmium	g. I-2477-92	1
01030	Chromium	g. I-2477-92	1
01035	Cobalt	g. I-2477-92	1
01040	Copper	g. I-2477-92	1
01049	Lead	g. I-2477-92	1
01056	Manganese	g. I-2477-92	1
71890	Mercury	b. I-2462-85	.1
01060	Molybdenum	g. I-2477-92	1
01065	Nickel	g. I-2477-92	1
01145	Selenium	b. I-2667-85	1
01075	Silver	g. I-2477-92	1
22703	Uranium	g. I-2477-92	1
01090	Zinc	g. I-2477-92	1

Table 9. Method detection limits for organic compounds analyzed in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; values are reported in micrograms per liter; STORET, U.S. Environmental Protection Agency’s STOrage and RETrieval system; DCPA, 3’,4’-dichloropropionanilide; DDE, dichlorodiphenyldichloroethylene; EPTC, S-ethyl dipropyl thiocarbamate; HCH, hexachlorocyclohexane; method discussed in Zaugg and others, 1995]

STORET code	Compound name	Chemical Abstracts Services registry number	Method detection limit
49260	Acetochlor	34256-82-1	0.009
46342	Alachlor	15972-60-8	.002
39632	Atrazine	1912-24-9	.001
82686	Azinphos-methyl	86-50-0	.001
82673	Benfluralin	1861-40-1	.002
04028	Butylate	2008-41-5	.002
82680	Carbaryl	63-25-2	.003
82674	Carbofuran	1563-66-2	.003
38933	Chlorpyrifos	2921-88-2	.004
04041	Cyanazine	21725-46-2	.004
82682	DCPA	1861-32-1	.002
34653	4,4’-DDE	72-55-9	.006
04040	Deethylatrazine	6190-65-4	.002
39572	Diazinon	333-41-5	.002
39381	Dieldrin	60-57-1	.001
82660	2,6-Diethylaniline	91-66-7	.003
82677	Disulfoton	298-04-4	.017
82668	EPTC	759-94-4	.002
82663	Ethalfluralin	55283-68-6	.004
82672	Ethoprop	13194-48-4	.003
04095	Fonofos	944-22-9	.003
34253	alpha-HCH	319-84-6	.002
39341	gamma-HCH (lindane)	58-89-9	.004
82666	Linuron	330-55-2	.002
39532	Malathion	121-75-5	.005
82667	Methyl parathion	298-00-0	.006
39415	Metolachlor	51218-45-2	.002
82630	Metribuzin	21087-64-9	.004
82671	Molinate	2212-67-1	.004
82684	Napropamide	15299-99-7	.003
39542	Parathion	56-38-2	.004
82669	Pebulate	1114-71-2	.004
82683	Pendimethalin	40487-42-1	.004
82687	cis-Permethrin	52645-53-1	.005
82664	Phorate	298-02-02	.002
04037	Prometon	1610-18-0	.003
82676	Pronamide	23950-58-5	.018
04024	Propachlor	1918-16-7	.007
82679	Propanil	709-98-8	.004
82685	Propargite	2312-35-8	.013
04035	Simazine	122-34-9	.005
82670	Tebuthiuron	34014-18-1	.010
82665	Terbacil	5902-51-2	.007
82675	Terbufos	13071-79-9	.007
82681	Thiobencarb	28249-77-6	.002
82678	Triallate	2303-17-5	.001
82661	Trifluralin	1582-09-8	.002

Suspended trace elements were analyzed at the USGS Analytical Chemistry Services Group in Denver for 44 trace elements (table 10).Most of the elements were analyzed by inductively coupled plasma-atomic emission spectrometry following multi-acid sample decomposition (Briggs, 1990). Alternatively, nine elements (antimony, arsenic, cadmium, lead, molybdenum, silver, thallium, thorium, and uranium) were analyzed by inductively coupled plasma-mass spectrometry following multi-acid sample decomposition (Briggs, 1990). Mercury was analyzed by continuous flow cold vapor-atomic absorption spectrometry following sample digestion with nitric acid and sodium dichromate (O'Leary and others, 1990). Selenium was analyzed by hydride generation-atomic absorption spectrometry following multi-acid digestion (Welsch and others, 1990; Crock and Lichte, 1982). About 0.5 grams of suspended sediment was necessary to perform all the analyses. On several occasions, especially in samples from the four smaller tributaries, there was not enough suspended sediment to perform the analyses for mercury and selenium.

Washington Department of Ecology

From February 1994 to December 1994, the WDOE sampled the following three sites from

Table 10. Method reporting limits for trace elements analyzed in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994

[Values are reported in micrograms per gram unless otherwise noted; STORET, U.S. Environmental Protection Agency's STOrage and RETrieval system; %, percent; --, no code available for thallium; methods discussed in Briggs, 1990, O'Leary and others, 1990, Welsch and others, 1990, and Crock and Lichte, 1982]

STORET code	Element name	Method reporting limit	STORET code	Element name	Method reporting limit
30221	Aluminum	0.005%	29841	Mercury	0.02
29816	Antimony	.1	29843	Molybde-num	.1
29818	Arsenic	.1	35037	Neodymium	9
29820	Barium	1	29845	Nickel	3
29822	Beryllium	1	35038	Niobium	4
35030	Bismuth	10	30292	Phosphorus	.005%
29826	Cadmium	.1	30294	Potassium	.01%
30240	Calcium	.005%	35039	Scandium	2
35051	Cerium	5	29847	Selenium	.2
29829	Chromium	2	29850	Silver	.1
35031	Cobalt	2	30304	Sodium	.006%
29832	Copper	2	35040	Strontium	2
35032	Europium	2	35042	Tantalum	40
35033	Gallium	4	--	Thallium	.1
82170	Gold	8	35043	Thorium	6
35035	Holmium	4	35044	Tin	5
30269	Iron	.02%	30317	Titanium	.005%
35036	Lanthanum	2	35046	Uranium	.07
29836	Lead	.25	29853	Vanadium	2
35050	Lithium	2	35048	Ytterbium	1
30277	Magnesium	.005%	35047	Yttrium	2
29839	Manganese	4	29855	Zinc	2

bridges about once a month: the Lewis River at Woodland, Kalama River near Kalama, and Cowlitz River at Kelso (table 7). Each site that the WDOE sampled was at exactly the same location as the corresponding USGS site. Temperature and specific conductance were measured by lowering a probe into the main channel, whereas measurements of pH and dissolved oxygen were made on a near-surface grab sample of water. Depth- and width-integrated water samples were collected by lowering a US DH-59 depth-integrating sampler at 10 equidistant points along a transect across the river (Edwards and Glysson, 1988). Each volume of water collected was composited into an acid-washed Nalgene container and agitated before individual subsamples were poured into containers prepared for each particular analysis. Water for nutrient analysis was filtered in the field through a 0.45-micrometer membrane filter (Bill Ehinger, WDOE, written commun., 1995). The samples were shipped to WDOE Environmental Laboratory in Manchester, Washington, where they were analyzed for nutrients, suspended solids, and fecal-indicator bacteria (table 11).

Oregon Department of Environmental Quality

From January 1994 to December 1994, the ODEQ sampled the Willamette River and the Sandy River each month. Even though the ODEQ Willamette River site was 0.4 miles upstream of the USGS site and the ODEQ Sandy River site was 2.7 miles downstream of the USGS site (table 7), data from the corresponding sites were grouped together with USGS data for analysis. The midpoint of each river was sampled from a bridge using a weighted stainless-steel grab sampler. Field measurements were made of dissolved oxygen, pH, water temperature, alkalinity, and specific conductance. Samples were collected and field measurements were made according to ODEQ protocols, and the laboratory analyses were performed in the ODEQ

Table 11. Laboratory analytical methods and reporting limits for Washington Department of Ecology, lower Columbia River Basin, 1994

[Values are reported in micrograms per liter for nutrients, milligrams per liter for solids, and colonies per 100 milliliters for bacteria; STORET, U.S. Environmental Protection Agency's STOrage and RETrieval system; --, not available; information obtained from Bill Ehinger, Washington Department of Ecology; method reference numbers correspond to:

a. U.S. Environmental Protection Agency, 1979,
b. American Public Health Association and others, 1992, and
c. Valderrama, 1981]

STORET code	Constituent name	Method of determination	Method reference number	Method reporting limit
		Nutrients in water		
00610	Ammonia as N, unfiltered water	Automated phenate	a. 350.1 b. 4500-NH3 D	10
00630	Nitrite plus nitrate as N, unfiltered water	Automated cadmium reduction	a. 353.2 b. 4500-NO3F	10
00600	Nitrogen, unfiltered water	Persulfate digestion, cadmium reduction	c.	25
00671	Orthophosphate as P, filtered water	Ascorbic acid	a. 365.3 b. 4500-PF	10
00665	Phosphorus as P, unfiltered water	Persulfate digestion, ascrobic acid	a. 365.3 b. 4500-PF	10
		Solids in water		
00500	Total dissolved solids, filtered water	--	a. 160.3 b. 2540B	1
00530	Suspended solids, unfiltered water	Gravimetric	a. 160.1	1
		Bacteria		
31616	Fecal coliform	Membrane filter	b. 9222D	1

laboratory in Portland, Oregon (Greg Pettit, ODEQ, written commun., 1995).

Samples were analyzed for major ions (Willamette River site only), nutrients, and fecal-indicator bacteria. Ammonia plus organic nitrogen in unfiltered water was analyzed by EPA Method 351.2, (U.S. Environmental Protection Agency, 1979), and phosphorus in unfiltered water and orthophosphate in filtered water were analyzed by Part 4500-P (American Public Health Association and others, 1989). Bacteria samples were analyzed by the Oregon Health Division, Office of Public Health Laboratories in Portland. Enterococci were analyzed by the membrane-filtration method, and fecal coliform were measured by the most probable number technique (American Public Health Association and others, 1989).

Data-Analysis Methods

Two methods of data analysis that require explanation and description are the estimation of loads and the determination of trends over time, which were calculated for several water-quality constituents.

Loads

In this report, monthly and annual mean daily loads were calculated using a regression model that assumes a linear relationship between the natural logarithm of concentration (log C) and the natural logarithm of streamflow (log Q). The model was created using the ESTIMATOR program, version 94.06 (Cohn and others, 1992). The ESTIMATOR program regresses log C against log Q and the sine and cosine of time (in decimal years, adjusted by 2π, for a yearly cycle) and generates equations for calculating monthly and annual mean daily load estimates. Monthly mean daily loads are the mean of the individual daily mean loads for each month, which the program computes, and annual mean daily loads are the mean of the individual daily mean loads for each year.

The ESTIMATOR program uses a minimum variance unbiased estimator (Cohn and others, 1989), which reduces the bias introduced when transforming load estimates from a log-regression equation (log space) back into arithmetic units (real space). The program also incorporates an adjusted maximum likelihood estimator (Cohn, Gilroy, and Baier, 1992) to deal with censored data values, which are values that are below a specified “detection limit.” The ESTIMATOR program is ideal for use in hydrologic studies, because water quality data generally show a log-log relation and commonly contain censored data. The ESTIMATOR program is widely used by the USGS, including the 35 current NAWQA studies. It is also used by the Maryland Department of the Environment on its Chesapeake Bay projects, and by the U.S. Army Corps of Engineers.

The ESTIMATOR program is recommended for use with at least 25 water-quality measurements per year for 2 years. The Columbia River at Warrendale and the Willamette River at Portland both had about 8 measurements per year for about 20 years, and the Columbia River at Beaver Army Terminal had 12 measurements per year for 4 years. Although these sites had fewer than recommended measurements per year, the periods of available data are longer than recommended. The Willamette and Warrendale sites had much more than the 50 total recommended measurements, and Beaver had nearly 50. No other sites in this study had data points in even close to these numbers. Loads were estimated for five constituents (suspended sediment, total dissolved solids, phosphorus in unfiltered water, nitrite plus nitrate in filtered water, and ammonia in filtered water) sampled at these three sites. Samples generally were collected at different seasons of the year, rather than clustered during short periods of time. See table 12 for the number of data values available for each constituent at each site.

The ESTIMATOR program uses daily mean streamflow data throughout the load computation period. Streamflow data for the Willamette and Beaver sites are available from the USGS streamflow gaging program. Because the Warrendale site is not gaged, data for daily mean outflow from Bonneville Dam, 5 miles upstream, were obtained from the U.S. Army Corps of Engineers and used as daily mean flow at Warrendale. Three water years (1974, 1975, and 1977) were chosen from the 20-year load estimation period to represent years of high-, median-, and low-streamflow, respectively, based on annual mean streamflows at the Columbia River at mouth streamflow-gaging station. These years are used to compare loads of the current year (1994) to low-, median-, and high-flow years in the past.

Table 12. Amount of water quality data available for load estimation program, and mean 95-percent confidence intervals for load estimates at three sites in the lower Columbia River Basin, Oregon and Washington

[The term "filtered water" is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term "unfiltered water" refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; see table 7 for full site names]

Site name	Years of data available	Total number of samples	Number of censored values	Mean 95-percent confidence interval for monthly estimates (percent of estimate)	Mean 95-percent confidence interval for annual estimates (percent of estimate)
Ammonia, filtered water					
Willamette	1979-94	111	0	31	16
Warrendale	1973-94	80	14	63	33
Beaver	1990-94	49	7	43	24
Nitrite plus nitrate, filtered water					
Willamette	1979-94	115	0	20	12
Warrendale	1979-94	86	22	29	16
Beaver	1990-94	49	8	51	36
Phosphorus, unfiltered water					
Willamette	1974-94	173	0	18	9
Warrendale	1973-94	172	3	30	14
Beaver	1990-94	48	3	38	20
Suspended sediment					
Willamette	1974-94	167	0	28	17
Warrendale	1973-94	164	0	44	21
Beaver	1990-94	49	0	24	12
Total dissolved solids, residue on evaporation at 180 degrees Celsius					
Willamette	1974-94	171	0	4	2
Warrendale	1973-94	155	0	5	2
Beaver	1990-94	49	0	7	4

Although the loads estimated by this regression model are believed to be the best estimates given the available data sets, their precision deserves some discussion. For each load estimate, the ESTIMATOR program calculates the standard error of prediction, from which a 95-percent confidence interval can be derived. As an example, if a load estimate of 200 tons per day has a 95-percent confidence interval of 20 percent, then there is a 95 percent chance that the true load was between 160 and 240 tons per day (200 ± 20 percent). Confidence intervals for annual mean daily load estimates tended to be about one-half as wide as intervals for monthly estimates. Table 12 shows the average 95-percent confidence intervals for monthly and annual load estimates from the ESTIMATOR program. The load estimates are most reliable for total dissolved solids and less reliable for other constituents (table 12). These differences are due to the differing degrees by which the constituent characteristics satisfy the assumptions of the regression model, particularly the linear relation between log C and log Q. The sampling strategy itself also affects the confidence intervals, because it was not designed to ensure sampling during peak flows. If more samples had been taken during higher flows, the confidence intervals would probably have been narrower.

Trends

A computer program called PT2 (Kenneth Lanfear, USGS, written commun., 1995) was used to determine monotonic-time trends in constituent concentrations in the lower Columbia River Basin. This program uses the seasonal Kendall test for water-quality trends (see Helsel and Hirsch [1992] for a description of the test). This distribution-free test (based on the 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 the probability level (ρ). For example, if $\rho = 0.05$, then there is a 5-percent chance of falsely rejecting the null hypothesis. For this study, trends with a ρ less than or equal to 0.05 were considered statistically significant.

There are two criteria for evaluating the suitability of water-quality data for trend testing. First, the data must have nearly spanned the time period selected for trend analysis. Second, for a given seasonal frequency (trends made on the basis of quarterly data, for instance), the beginning and ending parts of the record must have contained sufficient data such that most of the possible number of pairwise comparisons (as made in the seasonal Kendall test) were present for most of the seasons. Owing to a lack of continuous data for most sites, trend tests were performed only on data from the Columbia River at Warrendale and Willamette River at Portland sites (the two historical NASQAN sites).

Seasonal patterns that may affect results from trend analyses commonly are observed in water-quality data. 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 (for example, values from January 1993 are compared with those from January 1994). When there are not enough monthly data available, seasonal data can be used. 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 nonparametric test, censored data (values less than the reporting level) were included in the analysis and set equal to the reporting level.

Trends, unadjusted for streamflow, are important because they represent changes in constituent concentrations that may affect water quality and biota. Because monthly data were not available, trend analysis was made using quarterly (September-October-November, December-January-February, and so on) constituent concentrations for data collected from 1973 to 1995. For suspended-sediment data at the Willamette River at Portland, however, there were enough data to use a bimonthly season (September-October, November-December, and so on).

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 (or quarter) of different years between the data. For example, assume that the ammonia concentration at a site was 0.1 mg/L (milligrams per liter) in the first quarter of 1993 and 0.2 mg/L in the first quarter of 1994. The difference between the values divided by the number of years between the data is $(0.2-0.1)\div(1994-1993) = 0.1$ mg/L per year. After computing these differences for each quarter for all combinations of years, the slope (trend) is reported here as the median change in the constituent value per year. The slope (trend) also is reported in percent change per year and is calculated as follows: $(\text{slope} \div \text{median constituent value}) \times 100$.

Trends in water quality are associated not only with fluctuations in climate and streamflow but also with human-caused changes in basin processes, including land-use practices, point-source loading rates, and agricultural and forestry practices. Flow-adjustment procedures were used to determine trends that are associated with changes in basin processes. These procedures deduce a relation between concentration and streamflow and convert concentrations to residual values before performing a trend test on the residual values. This procedure removes the confounding effect of variations in streamflow. PT2 performs flow adjustment with a LOcally WEighted Scatterplot Smoothing (LOWESS) technique (discussed by Helsel and Hirsch [1992]). It is a robust technique that provides a reasonably good fit of concentration versus streamflow for a wide variety of situations. The slope estimator is then calculated from the flow-adjusted data to yield the trends.

Existing Water-Quality Guidelines

Water-quality constituent concentrations determined and physical measurements made in the lower Columbia River Basin in 1994 were screened to identify constituents and measurements that may require further study by State and local health agencies. These agencies are responsible for issuing advice or formal advisories to protect the public health. Major ion, nutrient, trace-element, and organic-compound concentrations in filtered-water samples are screened against EPA ambient water-quality criteria for the protection of aquatic life and human health (U.S. Environmental Protection Agency, 1995) and EPA primary drinking-water regulations and human health advisories (U.S. Environmental Protection Agency, 1994b). All EPA ambient water-quality criteria are nonenforceable guidelines that provide the basis for Oregon and Washington State standards and are designed to protect humans and aquatic organisms. The primary drinking-water regulations have been established for contaminants that are known to be present in public water systems and that may affect human health adversely (Nowell and Resek, 1994). Health advisories provide nonregulatory levels of contaminants in drinking water at which no known or anticipated health effects would result. For some constituents, the analytical detection limit is higher than the lowest water-quality guideline. Furthermore, guidelines are not available for evaluation of all potential adverse effects (specifically, acute and chronic toxicity to aquatic organisms, human health effects as a result of bioaccumulation in aquatic food organisms, and exposure through drinking water).

Bioavailability and toxicity vary with the form of a trace element (Jenne and Luoma, 1977). Aquatic organisms that feed on detritus are exposed to trace elements in solution and from the ingestion of sediment (Luoma, 1989). Trace elements associated with sediment generally are believed to be less bioavailable than trace elements dissolved in water (U.S. Environmental Protection Agency, 1992a). The toxicity to aquatic organisms from trace elements associated with sediment, however, is not necessarily zero. The concentrations of metals in sediment often are orders of magnitude higher than in water. Small geochemical changes in the chemistry of sediment can affect solution chemistry greatly and thus enhance bioavailability (Luoma, 1989). For example, trace elements associated with suspended sediment may dissolve in the chemical environment of the gill or the gut of an aquatic organism (U.S. Environmental Protection Agency, 1992a; Luoma, 1983).

Physical and microbiological measurements were compared to water-quality regulations of Oregon (State of Oregon, 1994) and Washington (Washington State Administrative Code, 1992). Washington 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, 1992). All of the Washington sites sampled in this study were at stream segments classified as class A (excellent), meaning that they must meet or exceed standards established for all, or substantially all, designated water uses.

Ambient Stream Water Quality

Aquatic Life

According to EPA's interim guidance on aquatic-life criteria for trace elements (U.S. Environmental Protection Agency, 1992a), the toxicity tests that form the basis for EPA ambient water-quality criteria for the protection of aquatic life were generally conducted in water "lower in metal-binding particulate matter and dissolved organic carbon than most ambient waters * * *. [Therefore], these toxicity tests may overstate the ambient toxicity of nonbiomagnified metals that interact with particulate matter or dissolved organic matter." In metal toxicity tests on which water-quality criteria were based, most of the metal was in the dissolved form. However, because the actual dissolved component was seldom measured in these tests, and because of the possible release of dissolved metal from particulate forms, EPA criteria are based on the total recoverable metal technique. This type of analysis for ambient stream water, with metal-binding phases, may extract trace elements from the particulate or carbon phases, and consequently, overstate ambient toxicity.

Although EPA's ambient water-quality criteria are based on analyses of unfiltered-water samples, the trace-element concentrations in filtered-water samples analyzed for this report were often high enough to equal or exceed the criteria. Consequently, EPA's ambient water-quality criteria are used as screening values for the protection of aquatic organisms. For many trace elements, including cadmium, chromium, lead, nickel, silver, and zinc, aquatic toxicity is related to the hardness of the water; toxicity increases (the screening value decreases) as hardness decreases. For example, as water hardness ranges from 200 to 50 mg/L (milligrams per liter) as calcium carbonate, lead toxicity to aquatic organisms ranges from 7.7 to 1.3 µg/L (micrograms per liter) (U.S. Environmental Protection Agency, 1986a). For trace elements with toxicity that varies with water hardness, the ambient water hardness at the time of sample collection was used to derive the appropriate screening value. Both acute (1-hour average concentrations) and chronic (4-day average concentrations) trace-element criteria for aquatic life were used to evaluate waters in the lower Columbia River Basin; however, single measurements, rather than multiple measurements were used to derive 1-hour or 4-day average trace-element concentrations.

Human Health

The ambient stream-water criteria for the protection of human health consist of ambient concentrations which, for noncarcinogens, prevent adverse health effects in humans and, for suspected or proven carcinogens, represent various levels of incremental cancer risk. The human-health criteria are designed to reflect human exposure to a contaminant from ingestion of both water and aquatic organisms or from ingestion of aquatic organisms only (U.S. Environmental Protection Agency, 1995). In the former, 100 percent of the exposure to humans is assumed to be from consumption of water containing a specified contaminant concentration and aquatic organisms that have biologically concentrated a contaminant from ambient stream water according to an assumed biological concentration factor (Nowell and Resek, 1994; U.S. Environmental Protection Agency, 1995). In the latter, 100 percent of the exposure to humans is assumed to be from consumption of aquatic organisms that have biologically concentrated a contaminant from water according to an assumed bioconcentration factor. Equations for deriving ambient contaminant concentrations for the protection of human health are given by Nowell and Resek (1994).

For carcinogens, the human-health criteria are derived from a two-part evaluation in which the element is assigned a weight-of-evidence classification and a slope factor. The weight-of-evidence classification is the likelihood that an element is a human carcinogen. Arsenic, which is measured in filtered-water samples, has a “Group A” weight-of-evidence classification—a human carcinogen (U.S. Environmental Protection Agency, 1989). The slope factor is generally a plausible upper-bound estimate (95-percent confidence limit) of a human developing cancer as a result of a lifetime (70 years) of exposure to a particular level of a potential carcinogen. Slope factors are derived from mathematical models that are used on available data sets. These models extrapolate from carcinogenic responses observed at high doses in experimental animals to responses expected in humans from lower exposure levels in the environment. If the extrapolation model selected is EPA's linearized-multistage model (as in the case of arsenic), then the resultant slope factor is known as q_1* (U.S. Environmental Protection Agency, 1989). For example, the slope factor or q_1* for arsenic is a 1.75 risk per milligram contaminant per kilogram body weight per day (U.S. Environmental Protection Agency, 1995).

The derivation of human-health criteria for ambient stream water is contingent on several additional assumptions, which include:

Risk Level (RL) = A unitless assigned level of maximum-acceptable individual-lifetime risk. Screening values for human health are based on a RL of 10^{-5}—a level of risk not to exceed one excess case of cancer per 100,000 individuals exposed over a 70-year lifetime (U.S. Environmental Protection Agency, 1993a).

Consumption Rate (CR) = Mean daily consumption rate, in kilograms per day (kg/d), of the species of interest by the general population or subpopulation of concern averaged over a 70-year lifetime. Screening values for human health are derived using a CR of 0.0065 kg/d—an estimate of the average fish and shellfish consumption by the general United States population (U.S. Environmental Protection Agency, 1993a). The value is equivalent to approximately one 6-ounce fillet of fish per month. In addition, screening concentrations that include a measure of chemical uptake from the consumption of water use a CR of 2 L of water per day (L/d)—an estimate of the average water consumption by the general United States population.

Body Weight (BW) = Mean body weight, in kg, of a standard adult within the general population or subpopulation of concern. Screening values for human health are derived using a BW of 70 kg (about 154 pounds), the average weight of the general United States population.

Biological Concentration Factor (BCF) = The ratio of the contaminant concentration in an aquatic organism, in milligrams per kilogram, to the contaminant concentration in the surrounding water, in mg/L, reported in units of liters per kg (L/kg). A weighted-average BCF, adjusted to the average percent lipids in fish and shellfish (3 percent), is used by EPA in deriving human-health guidelines (U.S. Environmental Protection Agency, 1995).

The screening value for arsenic is based on the inorganic form only (U.S. Environmental Protection Agency, 1992b). The arsenic determination in this study, however, is based on both the organic and inorganic forms of arsenic. As a conservative assumption for screening, arsenic is assumed to reside in ambient waters in the pentavalent and (or) trivalent forms—the former being most likely in surface water (Eisler, 1988, p. 8). Methylated forms of arsenic also reside in surface water; their exact proportions, however, are not known (Hem, 1989, p. 144). Methylated forms are significantly less toxic than inorganic forms of arsenic (U.S. Environmental Protection Agency, 1992b; U.S. Environmental Protection Agency, 1993b, p. III–56).

For noncarcinogens, the screening values are based on a Reference Dose (RfD), rather than an RL, which represents a daily exposure (with uncertainty spanning perhaps an order of magnitude or more) to the human population (including sensitive subpopulations) that is probably without appreciable risk of causing deleterious effects during a 70-year lifetime (U.S. Environmental Protection Agency, 1993a). Additionally, screening values for human health, which are derived from EPA ambient water-quality criteria for human health, are determined using the assumptions for BW, CR, and BCF listed above (U.S. Environmental Protection Agency, 1995). For the purpose of calculating screening values for mercury (a noncarcinogen), the EPA recommends that the RfD for methylmercury be lowered from 3.0×10^{-4} mg/kg/d to 6.0×10^{-5} mg/kg/d (U.S. Environmental Protection Agency, 1993a). The lowering of the RfD is based on evidence that the fetus, and possibly the pregnant woman, is at increased risk of adverse neurological effects from exposure to methylmercury.

Under the usual conditions of temperature and pressure, mercury in surface water exists in inorganic forms that include the liquid (Hg^0) and the ionic (Hg_2^+ and Hg^{2+}) states. In addition, inorganic forms in sediment and water can be methylated to highly soluble and toxic methylmercury (Moore, 1991). The analytical technique used in this study for measuring mercury in ambient stream water is defined as a total- (inorganic plus organic) mercury analysis. For screening purposes, total-mercury concentrations are compared to the screening values for human health. Using total-mercury concentrations for comparison to screening values is conservative, because 100 percent of the mercury that accumulates in fish tissue (based on a BCF of 5,500 L/kg) is assumed to be in the toxic methylmercury form. It is this methylated form of mercury that is highly toxic to humans (U.S. Environmental Protection Agency, 1993a).

Drinking-Water Quality

Element concentrations determined from filtered-water samples were screened by making comparisons with EPA drinking-water regulations (U.S. Environmental Protection Agency, 1994b) and EPA advisories for human health (U.S. Environmental Protection Agency, 1995). The water samples from the lower Columbia River Basin that are compared to drinking-water guidelines represent untreated water (ambient stream water rather than finished or treated water available for distribution to community water supplies). The City of Longview diverts its water supply directly upstream from the Cowlitz River sampling location, and the City of Kalama diverts just downstream from the sampling location on the Kalama River. Although nearly all sites sampled in this study were not sources for domestic-water supplies, water-quality exceedances are important because the Washington sites are all in stream segments classified as class A waters. It is important to note, however, that “although a surface water in Washington State may be designated as a potential domestic-water source” in Chapter 173–201 in the Washington State Administrative Code (1992), “approval for such use must first be obtained from the Washington State Department of Health following an evaluation of the water quality” (Harriet Ammann, Denise Laflamme, and Glen Patrick, Washington State Department of Health, written commun., 1993). Thus, the presence in filtered stream-water samples of elements in concentrations that exceed screening values (drinking-water regulations) does not indicate that human health is directly at risk.

Regulations

The types of primary and secondary drinking-water regulations set forth by the EPA include Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) (U.S. Environmental Protection Agency, 1991). The MCLs represent achievable levels of drinking-water quality that take into consideration health effects, treatment feasibility, and aesthetic considerations. The MCLGs are nonenforceable health goals that are not expected to cause any adverse human-health effects over a lifetime of exposure and include a margin of safety.

Health Advisories

Concentrations of constituents in filtered-water samples are screened for human-health effects by making comparisons to human-health advisories for drinking water (U.S. Environmental Protection Agency, 1994b). Unlike the ambient water-quality criteria, human-health advisories for drinking water are based only on the consumption of domestic water. In this study, however, ambient stream water is used to screen for health effects. Additionally, the aforementioned assumptions for BW (70 kg), CR (2 L/d of water), and RL (10^{-5}) are applicable to screening values for human-health advisories. For the carcinogen arsenic, the human-health advisory is a risk specific dose (RSD) associated with a specified RL and is calculated from the q_1* for arsenic (Nowell and Resek, 1994). For the noncarcinogen mercury, the human-health advisory is a lifetime-health advisory which is equal to 20 percent of the drinking-water equivalent level (DWEL). The DWEL is the highest lifetime-exposure level in drinking water, assuming 100 percent exposure from that medium, at which adverse noncarcinogenic health effects would not be expected to occur (Nowell and Resek, 1994).

ANALYSIS OF AVAILABLE SURFACE-WATER-QUALITY DATA

This section of the report is organized into topical water-quality sections, which include current (1994) and historical analyses (1939–93) of water temperature, dissolved oxygen and pH, total dissolved gas, suspended sediment, nutrients, major ions and related measures, trace elements, organic compounds, fecal-indicator bacteria, and radionuclides. Exceedances of water-quality guidelines by samples collected in the current (1994) study are discussed within the topical water-quality sections that follow. Specific information pertaining to the number of exceedances, sites with exceedances, and criteria and guidelines used to derive screening values are in tables 47, 48, and 49 (at back of report).

Water Temperature

The principal factors controlling riverine-water temperatures are energy-transfer processes. These processes include radiation inputs (air temperature, which varies with elevation and latitude), convection/advection (vertical and horizontal mixing, which varies with stream velocity, depth, and roughness of the stream channel), evaporation, and inflow of water of different temperature. Riverine-water temperature is important in a biological sense, because increased water temperatures are known to increase biological activity, which in turn increases the metabolic rate of cold-blooded aquatic organisms (MacDonald and others, 1991). High water temperature also can affect the survival of salmonid eggs and juvenile salmonids. The lethal-temperature limit for eggs of sockeye salmon is 13.5°C (MacDonald and others, 1991, p. 74). Spawning coho and steelhead may be intolerant of temperatures exceeding 10°C. Interspecies competition (for example warm-water versus cold-water fishes) is dependent upon water temperature (U.S. Environmental Protection Agency, 1986a). Unsuitable water temperatures can lead to disease outbreaks in migrating and spawning salmonids (Bjornn and Reiser, 1991).

The distribution of daily mean water temperatures was determined from continuous temperature recording stations at 14 sites in the lower Columbia River Basin. Periods of record at the various sites ranged from as few as 2 years (1968–69 WY) for the Columbia River at Prescott to as many as 17 years (1975–92 WY) for the Columbia River at Warrendale (table 13). The most recent continuous temperature measurements were made at the Columbia River at Beaver Army Terminal.

The distribution of daily mean water temperatures was generally uniform among sites in the lower Columbia River (fig. 15). These findings coincide with results from an earlier study by Moore (1968), who profiled water temperatures of the Columbia River from RM 928 to 53.5. Moore's temperature profiles show that the overall temperature gradient from the Canadian border to the mouth of the Columbia River was upward (July 1966 through September 1967), with increases ranging from 1 to 5°C per month from July through August. However, the principal temperature increases occurred well upstream of the lower Columbia River in an area between Coulee Dam (RM 596.6) and McNary Dam (RM 292). On the basis of monthly mean water temperatures for the period 1938–65, which includes effects of Brownlee Reservoir on the Snake River and stepped-up operations at Hanford (near RM 375), temperatures in the Columbia River at Bonneville Dam exceeding 20°C were measured as early as 1938. Additionally, the mean monthly water temperature for August (21.1°C) for the 1938–65 period also exceeded 20°C at Bonneville Dam.

Streamflow in the Willamette River did not significantly affect water temperature in the

Table 13. Water-quality sites that have continuous record of stream temperature, lower Columbia River Basin, Oregon and Washington, 1968-94

[Computer retrieval of chemical data by either the U.S. Geological Survey's (USGS) National Water Information System (NWIS) or U.S. Environmental Protection Agency's STOrage and RETrieval system (STORET) can be made using the USGS site number]

USGS site number	Site name	Period of record
14128910	Columbia River at Warrendale	1975-92
14144700	Columbia River at Vancouver	1968-70; 1973-79
14211720	Willamette River at Portland	1976-81
14211805	Willamette River above St. Johns Bridge	1972-75
14222880	Columbia River at Columbia City	1971
14222890	Columbia River near Columbia City	1969-72
14222910	Columbia River at Kalama	1969-79
14223780	Columbia River at Prescott	1968-69
14245295	Columbia River at Rainier	1972-79
14245300	Columbia River at Longview	1968-72
14246900	Columbia River at Beaver Army Terminal	1968-70; 1994-present
14247295	Columbia River at Wauna	1972-76
14247400	Columbia River at Bradwood	1977-81
14248600	Columbia River at Altoona	1972-79

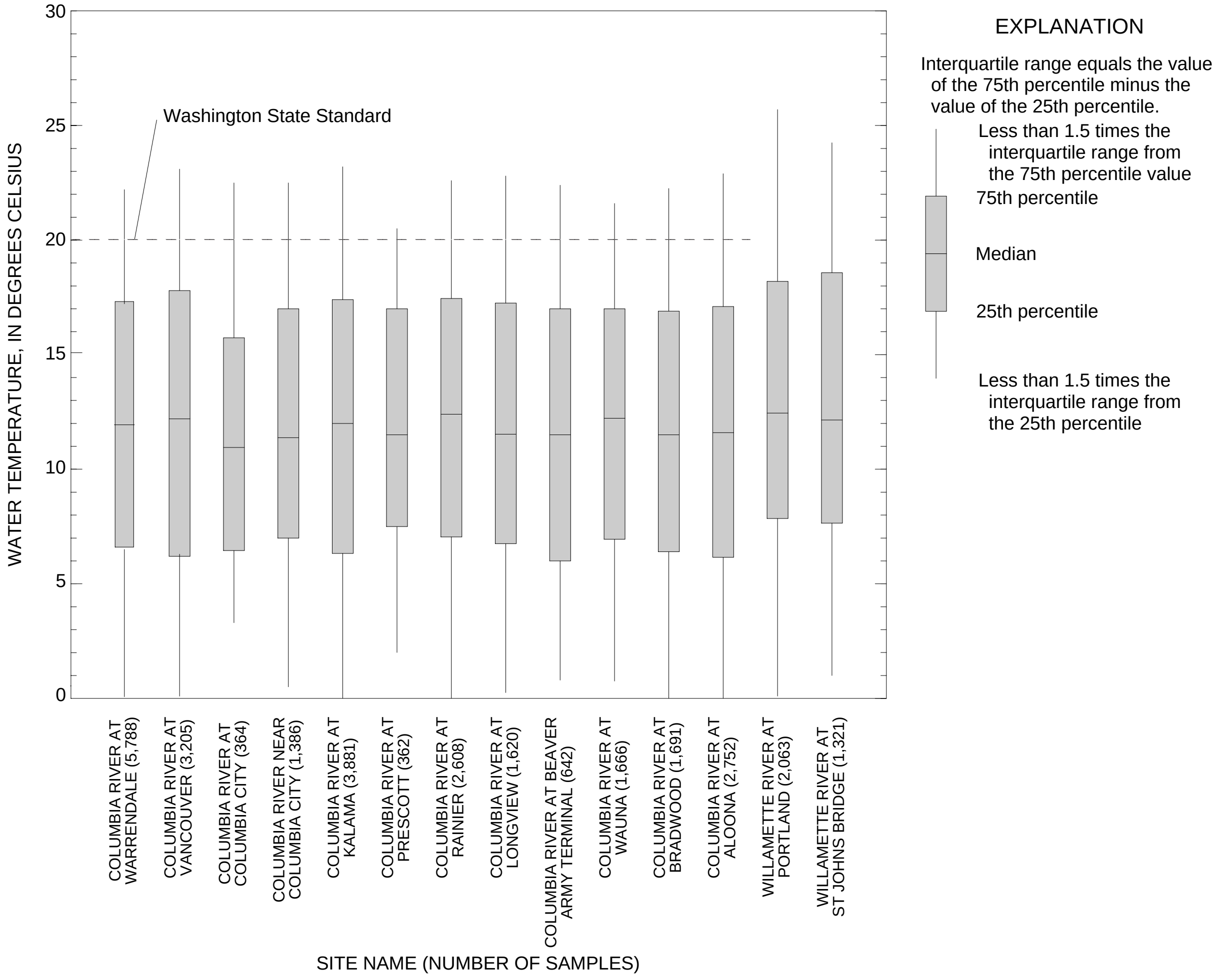


Figure 15. Distribution of daily mean water temperatures in the lower Columbia River Basin, Oregon and Washington, 1968-94 water years.

Columbia River during the period July 1966 to September 1967. On the basis of median (50th-percentile) daily mean water temperatures from historical data analyzed in this study, the Willamette River differed only slightly from the Columbia River. Specifically, the 75th-percentile values at the two Willamette River sites were slightly higher (by 0.4 to 0.8°C) than the 75th-percentile value (17.8°C) in the Columbia River at Vancouver (fig. 15). A temperature gradient between the Willamette River and the Columbia River during the summer months may be expected; however, a gradient is not noticeable due to the large difference in streamflow in the two river systems. During a median streamflow year (1967), the mean monthly streamflow in the Willamette River at Portland for the summer months (7,500 ft^3/s) was about 4 percent of the mean monthly streamflow in the Columbia River at Vancouver for the same time period. The absence of a temperature gradient may also result from tidal flow reversals and the associated mixing at the confluence of the two rivers.

The median daily mean water temperatures in the lower Columbia River (1968–92 WY) and in the Willamette River at Portland (1976–81 WY) were highest during August (fig. 16). In the Columbia River at Bradwood (RM 38.9), for example, 75 percent of the daily mean water temperatures (1977–81 WY) measured during August exceeded 20°C—only about 10 percent of the temperatures exceeded 20°C during the months of July and September (table 14).

Results of the seasonal Kendall trend test for water temperature indicate that significant ($\rho < 0.05$) upward trends exist in the Columbia River at Warrendale and Willamette River at Portland (table 50, at back of report). At Warrendale, the median water temperature was 11.9°C, and the seasonal

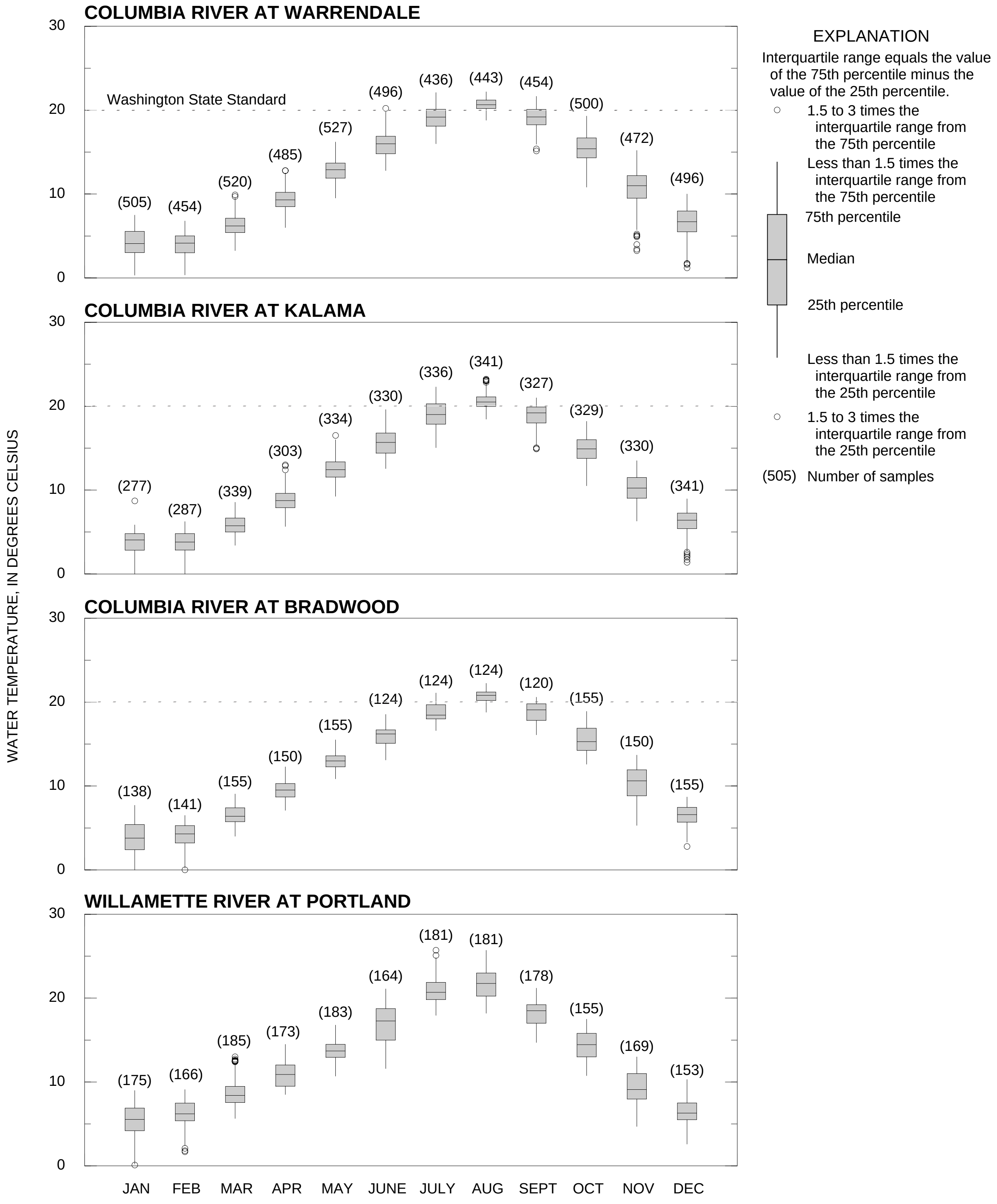


Figure 16. Distribution of daily mean water temperatures in the Columbia River at Warrendale, Kalama, and Bradwood and inthe Willamette River at Portland, lower Columbia River Basin, Oregon and Washington, 1975-92.

Table 14. Monthly distributions of daily mean water temperatures at selected sites, lower Columbia River Basin, Oregon and Washington, 1969-92

[Values are reported in degrees Celsius; shaded numbers represent water temperatures that exceed the Washington State standard of 20 degrees Celsius (Washington State Administrative Code, 1992)]

Month	Number of measurements	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Columbia River at Warrendale, Oregon, 1976-92								
January	505	0.0	2.2	3.0	4.1	5.6	6.3	7.5
February	454	.3	2.0	3.0	4.2	5.0	5.6	6.8
March	520	3.3	4.7	5.4	6.2	7.1	7.7	9.9
April	485	6.0	7.7	8.5	9.3	10.2	11.1	12.8
May	527	9.5	10.9	11.9	12.9	13.7	14.4	16.2
June	496	12.8	13.9	14.8	16.0	16.9	17.7	20.2
July	436	16.0	17.3	18.1	19.2	20.1	20.5	22.1
August	443	18.8	19.5	20.2	20.6	21.2	21.6	22.2
September	454	15.2	17.3	18.3	19.2	20.1	20.8	21.7
October	500	10.8	13.2	14.3	15.4	16.7	17.7	19.3
November	472	3.3	8.1	9.5	11.0	12.2	13.0	15.2
December	496	1.2	3.2	5.5	6.7	8.0	8.9	10.0
Columbia River at Kalama, Washington, 1969-79								
January	277	.0	1.9	2.8	4.0	4.8	5.2	8.7
February	287	.0	2.0	2.9	3.8	4.8	5.5	6.2
March	339	3.4	4.0	5.0	5.7	6.7	7.2	8.6
April	303	5.7	7.0	7.9	8.8	9.6	10.3	13.0
May	334	9.3	10.8	11.6	12.4	13.4	14.3	16.5
June	330	12.6	13.7	14.4	15.7	16.8	18.0	19.6
July	336	15.1	16.6	17.9	19.0	20.3	20.9	22.3
August	341	18.5	19.5	20.0	20.5	21.1	21.8	23.2
September	327	14.9	17.0	18.0	19.2	19.9	20.3	21.0
October	329	10.5	13.0	13.8	14.9	16.0	17.0	18.2
November	330	6.3	8.1	9.0	10.2	11.5	12.4	13.5
December	341	1.4	4.7	5.4	6.4	7.2	8.0	9.0
Columbia River at Bradwood, Washington, 1977-81								
January	138	.0	0.7	2.4	3.8	5.4	6.0	7.7
February	141	.0	2.0	3.2	4.3	5.3	6.1	6.5
March	155	4.0	5.5	5.7	6.4	7.4	7.9	9.1
April	150	7.1	7.9	8.7	9.5	10.3	10.9	12.3
May	155	10.9	11.9	12.3	13.0	13.6	14.5	15.5
June	124	13.1	14.3	15.1	16.2	16.7	17.6	18.5
July	124	16.6	17.4	18.0	18.5	19.7	20.6	21.1
August	124	18.8	19.6	20.2	20.8	21.2	21.6	22.3
September	120	16.1	16.9	17.8	19.1	19.8	20.2	20.6
October	155	12.6	13.6	14.3	15.3	16.9	17.6	18.9
November	150	5.3	7.1	8.8	10.6	11.9	12.7	13.7
December	155	2.8	4.8	5.7	6.6	7.5	7.9	8.7
Willamette River at Portland, Oregon, 1976-81								
January	175	0.1	2.5	4.2	5.6	6.9	7.6	9.0
February	166	1.7	4.4	5.4	6.2	7.5	8.6	9.1
March	185	5.7	6.8	7.5	8.4	9.5	10.2	13.0
April	173	8.5	9.0	9.5	10.9	12.0	12.8	14.5
May	183	10.7	12.2	13.0	13.7	14.5	15.5	16.8
June	164	11.6	13.6	15.0	17.3	18.8	19.7	21.1
July	181	18.0	18.9	19.8	20.7	21.9	23.2	25.7
August	181	18.2	18.9	20.3	21.8	23.0	24.9	25.7
September	178	14.7	15.9	17.0	18.5	19.2	19.8	21.2
October	155	10.8	12.2	13.0	14.5	15.8	16.9	17.5
November	169	4.7	6.3	8.0	9.1	11.0	11.7	13.0
December	153	2.6	5.1	5.5	6.3	7.5	8.5	10.3

Kendall slope estimator shows that water temperature has been increasing at a rate of 0.073°C per year, which represents a 0.6-percent change in the median water temperature per year. Data were unavailable for calculating a flow-adjusted trend at Warrendale. Both nonflow-adjusted and flow-adjusted trends, however, were found in the Willamette River. The median water temperature in the Willamette River was 12.5°C, and the seasonal Kendall slope estimator (nonflow-adjusted) shows that water temperature has been increasing by 0.14°C per year which represents a 1.1-percent change in the median water temperature per year. The flow-adjusted trend is smaller, however, representing only 0.9 percent of the median temperature per year.

The instantaneous water temperatures measured during July, August, and September, 1994, were generally similar at the main-stem sites (fig. 17). During July and August temperatures exceeded 20°C, and during September they were nearly 20°C. The Willamette River generally was the warmest tributary entering the main stem during the July to September period—instantaneous water temperatures were as high as 24.2°C. Conversely, the Lewis River and the Kalama River were the coldest tributaries entering the main stem during the July to September period—instantaneous water temperatures were as low as 14.3°C in the Lewis River and 15.8°C in the Kalama River.

In this study, instantaneous water temperature (for sites sampled in the lower Columbia River and Washington tributaries) were evaluated against water-quality standards for class A waters according to the Washington State Administrative Code (1992). The Code, which has special conditions for the lower Columbia River (main stem), states that freshwater-stream temperatures in the lower Columbia River "* * * shall not exceed 20.0°C due to human activities * * *"; all other freshwater-stream temperatures from Washington waters designated as class A (the Lewis, Kalama, and Cowlitz Rivers for this study) "* * * shall not exceed 18.0°C due to human activity* * *."

Temperature standards used by the State of Oregon are not directly applicable to instantaneous temperature measurements in ambient streamwater. Rather, they were designed to regulate temperature effects to rivers and streams from individual point sources. For example, for the lower Willamette

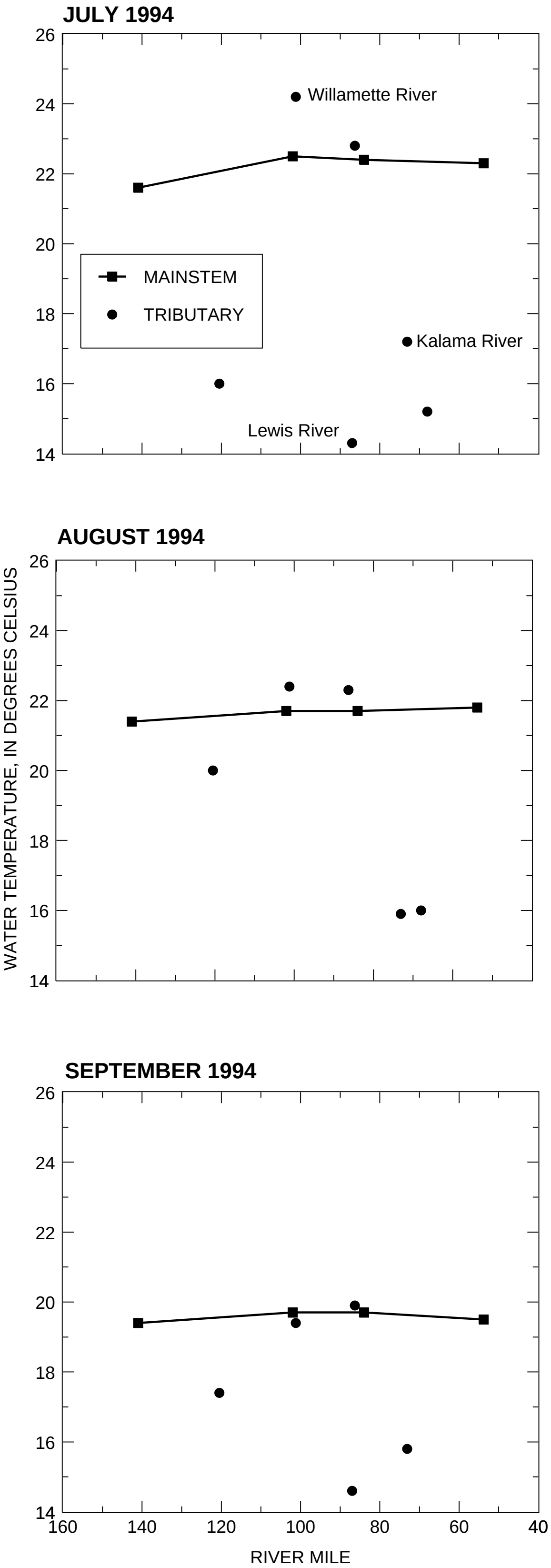


Figure 17. Instantaneous water temperatures in the main stem and tributaries of the lower Columbia River Basin, Oregon and Washington, July to September 1994. (See table 7 for full site names.)

River Basin (including Multnomah Channel), the State of Oregon (1994) states that “No measurable increases [in water temperature] shall be allowed outside of the assigned mixing zone, as measured relative to a control point immediately upstream from a discharge, when stream temperatures are 70°F [21°C] or greater ***.” Because individual measurements of point-source water temperatures were beyond the scope of this study, instantaneous water temperatures in Oregon tributaries were not evaluated relative to temperature standards.

The water temperatures in the main stem of the lower Columbia River exceeded the Washington water-quality standard (20°C) in 15 percent of the samples (table 47, at back of report), including consistent exceedances during July and August, 1994. This period coincides with seasonal high air temperatures and low streamflows, is consistent with historical water-temperature exceedances (table 14), and reflects water temperature concerns in the main stem of the lower Columbia River.

Dissolved Oxygen and pH

Most aquatic organisms require adequate dissolved-oxygen concentrations and a suitable pH range at all times. Anadromous cold-water fish are particularly sensitive to the dissolved-oxygen concentration and pH of fresh and marine waters. The Oregon freshwater regulatory standard states that dissolved oxygen should not be less than 90-percent saturation in the Columbia River and not less than 5 mg/L in the Willamette Harbor and Multnomah Channel (State of Oregon, 1994). The Washington standard states that dissolved-oxygen concentrations should not be less than 90-percent saturation in the Columbia River and should exceed 8 mg/L in Washington tributaries in the lower Columbia River drainage (Washington Administrative Code, 1992). Both agencies have standards requiring that pH not be less than 6.5 or greater than 8.5 for the lower Columbia River.

The solubility of oxygen in water is directly proportional to the partial pressure of oxygen above the water. The concentration of dissolved oxygen in water at saturation decreases as barometric pressure decreases (altitude increases) and (or) as water temperature increases. In addition, oxygen solubility decreases as the dissolved-solids content increases. The concentration of oxygen can also be changed by (1) aquatic plants producing oxygen as a product of photosynthesis, (2) aquatic organisms consuming oxygen as they respire, and (3) the physical process of spilling water at dams, which causes air bubbles to be entrained in the flow (Wilhelms and Gulliver, 1994). Aquatic plants will cause dissolved-oxygen concentrations to show diel (over the 24 hours in a day) variability, with maximum concentrations in the afternoon and minimum concentrations in the early morning.

Dissolved-oxygen concentrations in the lower Columbia River Basin during 1994 are summarized in figure 18. Concentrations at all Columbia River main-stem sites met the Oregon and Washington dissolved-oxygen standards. The Washington tributary sites had no dissolved-oxygen measurements that were below the Washington State standard. The Oregon tributary, Sandy River near Troutdale, had one dissolved-oxygen measurement below the Oregon State standard (table 47, at back of report). The Sandy River sample was measured during August when water temperatures were high and biological respiration was at a maximum.

Examples of seasonal variability of dissolved oxygen are shown in figures 19, 20, and 21. The box plots of data for the Columbia River at Warrendale in figure 19 indicate that there was minimal seasonal variability of dissolved oxygen (in percent saturation) for the 1974 to 1994 period. The 1994 data were typical of concentrations measured earlier. While there have been measurements of dissolved-oxygen concentrations that were below State standards, they generally were infrequent, occurring less than 25 percent of the time. During March through June and much of July, dissolved oxygen at Warrendale was usually supersaturated (above 100 percent of saturation). This pattern is the result of spilling water at the Bonneville Dam and other dams upstream on the Columbia River (U.S. Army Corps of Engineers, 1993).

Figure 20 shows dissolved-oxygen concentrations in the Willamette River at Portland. Figure 20a shows dissolved-oxygen concentrations measured from 1949 through 1958, when median concentrations during July, August, and September did not meet the State standard of 5 mg/L. Comparison of figures 20a and 20b (1972–94) indicates a significant increase in dissolved-oxygen concentrations, which is likely the result of U.S. Army Corps of Engineers dams releasing water

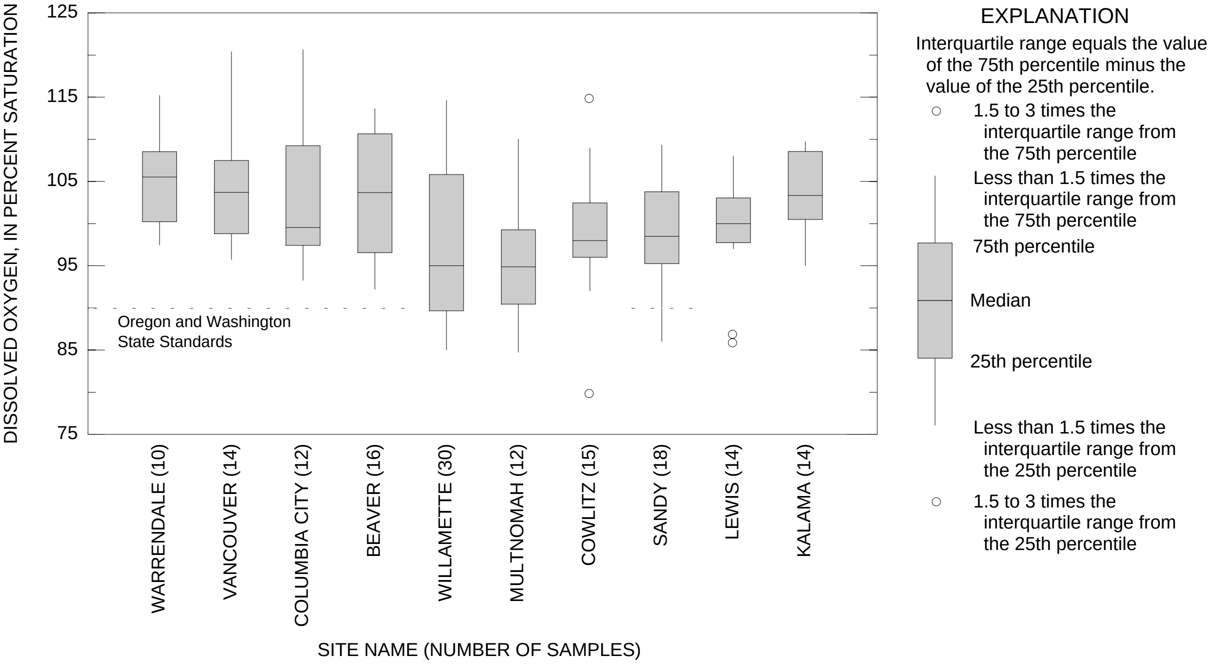


Figure 18. Distribution of dissolved-oxygen concentrations, lower Columbia River Basin, Oregon and Washington, 1994. (See table 7 for full site names; see State of Oregon [1994] and Washington State Administrative Code [1992] for standards.)

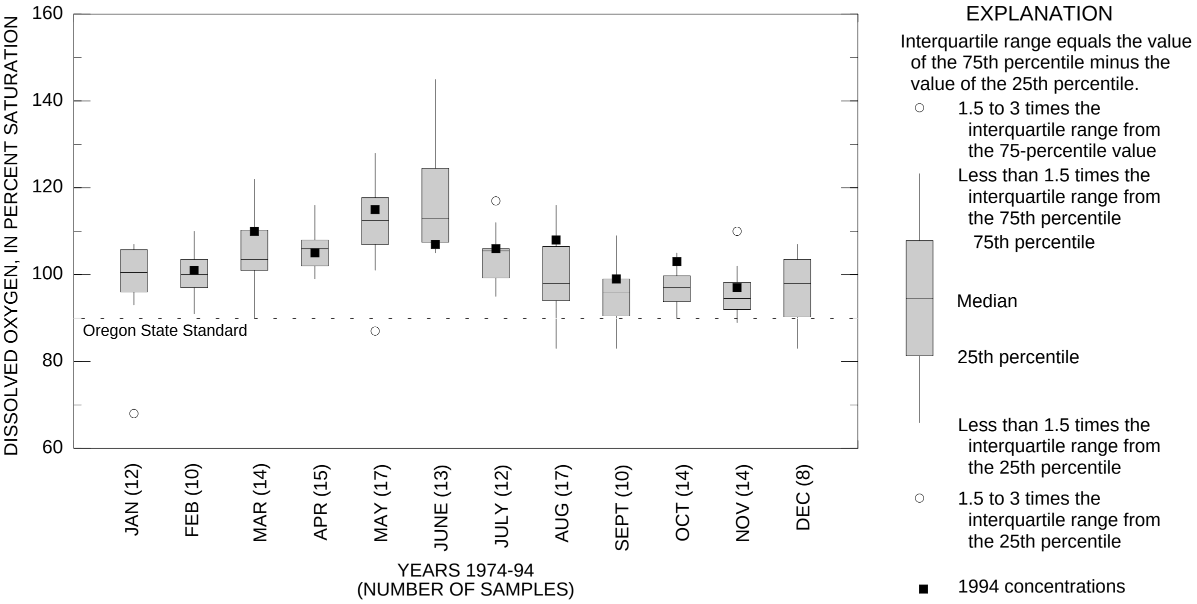


Figure 19. Distribution of 1974-94 and 1994 dissolved-oxygen concentrations measured in the Columbia River at Warrendale, lower Columbia River Basin, Oregon. (To avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per day was statistically summarized; see State of Oregon [1994] for standards.)

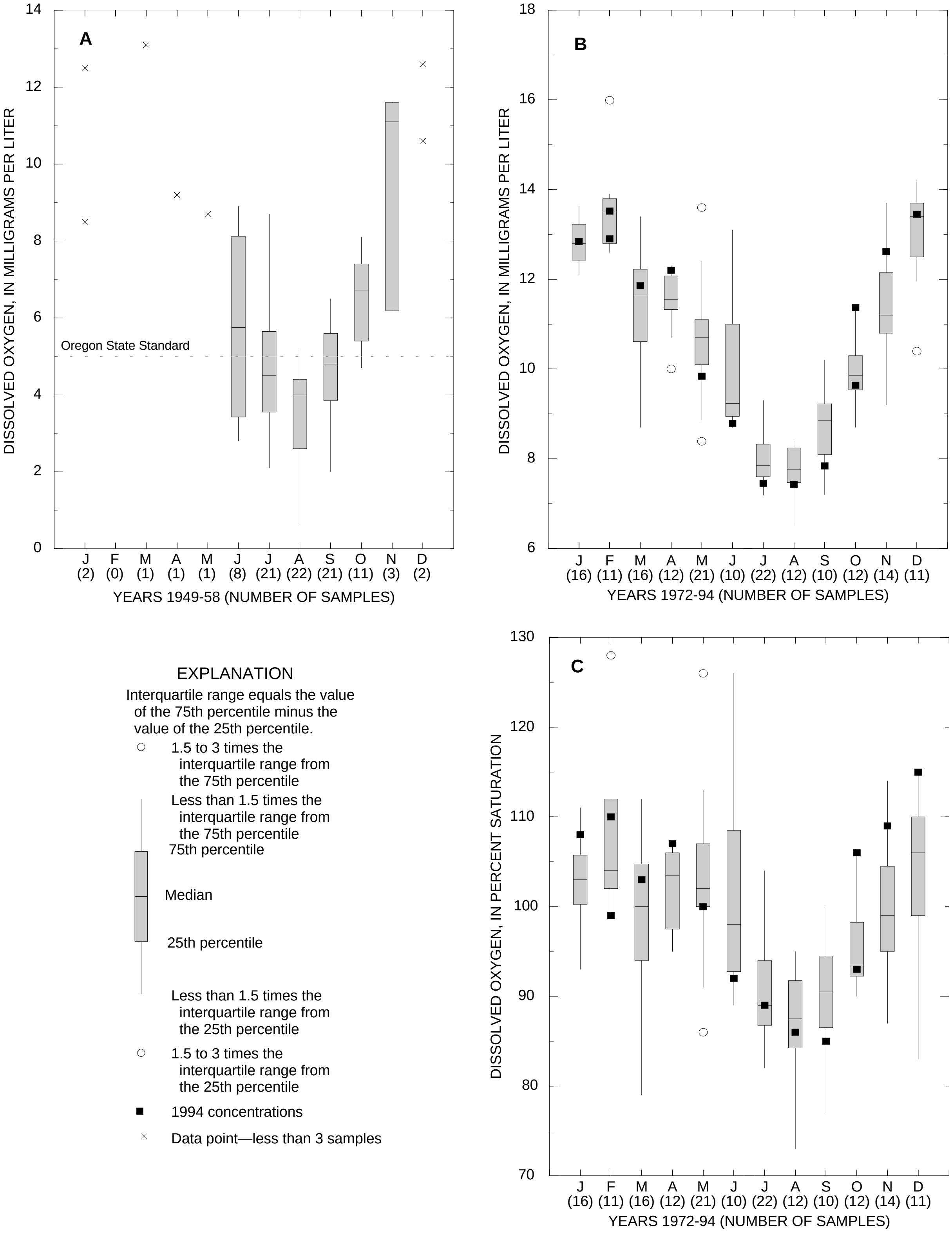


Figure 20. Distribution of (A) 1949–58, (B) 1972–94, and 1994 dissolved-oxygen concentrations measured in the Willamette River at Portland, lower Columbia River Basin, Oregon. (To avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per day was statistically summarized; see State of Oregon [1994] for standards.)

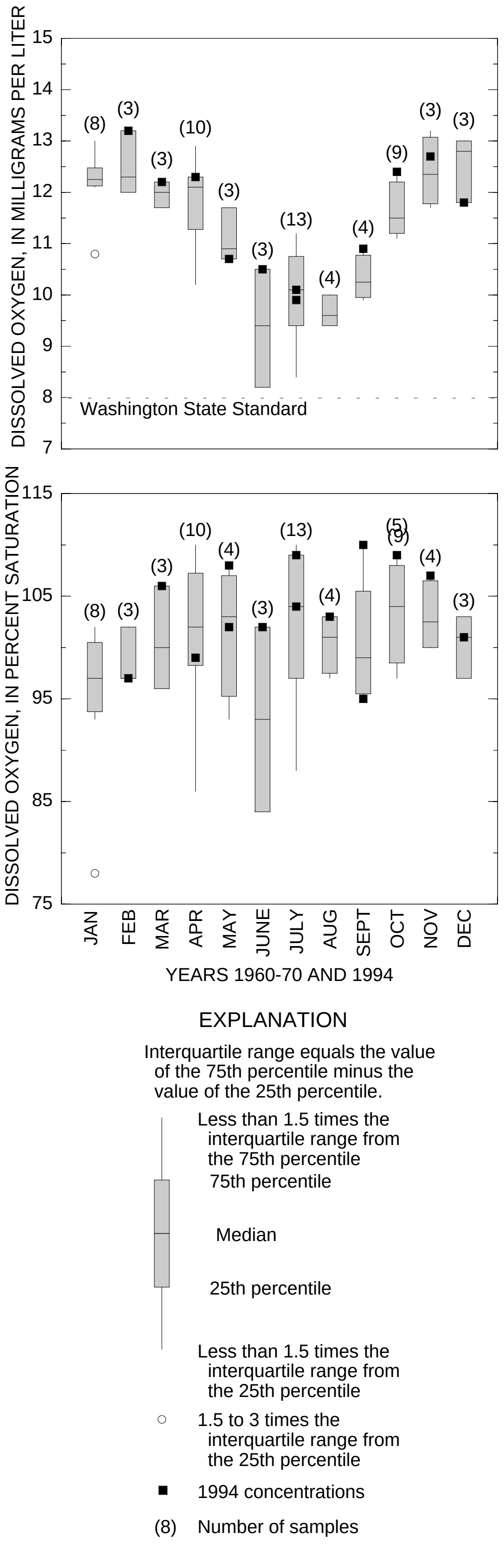


Figure 21. Distribution of 1960–74 and 1994 dissolved-oxygen concentrations measured in the Kalama River above Spencer Creek near Kalama, lower Columbia River Basin, Washington. (To avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per day was statistically summarized; see State of Oregon [1994] for standards.)

during the summer for navigation (Sherman, 1976) and the upgrading of wastewater discharges in the Willamette River Basin to secondary treatment levels by 1972 (Rickert and others, 1976). The major reason for the seasonal variability apparent in figures 20b and 20c can be attributed to temperature effects. Figure 20b can be viewed as an inverse of figure 16, which shows the monthly variability of temperature. Figure 20c shows that except for the months of July through September, the dissolved-oxygen concentrations were generally within 10 percent of saturation. During the low-flow summer period, the dissolved-oxygen concentrations were low probably because point and nonpoint sources were still placing a biochemical demand on the river and biological respiration is consuming oxygen at a maximum rate during this period of maximum temperatures. Most of the dissolved-oxygen concentrations during the months of December, January, February, April, and May were above 100-percent saturation, likely as a result of aeration caused by water spilling over Willamette Falls (RM 26.6).

Dissolved-oxygen concentrations in the Kalama River (fig. 21) are typical of a natural stream, with water temperature being the dominant factor on seasonal variability. As an example, very few of the percent-saturation data in figure 21fall outside the range of plus or minus 10 percent of saturation. Comparison of 1994 data to historical data suggests that dissolved-oxygen concentrations in 1994 were similar to those measured in 1960–74.

The pH of a water sample is a measure of its hydrogen-ion activity. Water is neutral at a pH of 7 and the pH can range from a minimum of 0 (highly acidic) to a maximum of 14 (highly alkaline). The pH of a stream can change because of an influx of acidic or alkaline wastes or because of photosynthesis and respiration (due to the daily cycles of release and uptake of carbon dioxide by aquatic plants). The toxicity to aquatic organisms of several chemical constituents is affected by pH, both directly and indirectly. Toxicity to freshwater aquatic life can occur when the pH falls outside the range of 6.5 to 8.5. A pH range of 5 to 9 is necessary for water to be suitable for domestic-water supplies (U.S. Environmental Protection Agency, 1986a). The dissociation of weak acids and bases is influenced by pH, which in turn, indirectly affects aquatic life. For example, as pH increases, the ammonium ion is dissociated to the toxic un-ionized ammonia form.

In 1994, three measurements in the lower Columbia River exceeded pH of 8.5 during April and May (fig. 22a, and table 48 at back of report). There were, however, no pH measurements near the lower limit of 6.5. The higher pH values were not associated with changes in alkalinity or specific conductance. The higher pH measurements in April and May in the Columbia River at RM 102 downstream from Hayden Island are associated with increased chlorophyll *a* concentrations (an indirect measure of algal productivity) in the water column (fig. 22b). The associated seasonal increase of pH and chlorophyll *a* suggests that phytoplankton may have been an important factor relative to pH levels in the lower Columbia River during April and May of 1994.

Total Dissolved Gas

Water is spilled at Columbia River dams when flows exceed the dams' capacity to store water or generate hydropower and to aid downstream migration of anadromous juvenile fish. Because of the Columbia River depths and the configuration of the dams spilling water into the next downstream pool, the spills usually cause atmospheric gasses to go into solution, resulting in supersaturation of gases in the river. When aquatic organisms are exposed to these supersaturated concentrations, they can develop Gas-Bubble Trauma (National Marine Fisheries Service, 1994). Some of the associated difficulties for outmigrating juvenile salmonids are identified in table 15.

Oregon and Washington both have State standards of 110 percent of saturation for total dissolved gas (TDG). TDG is equal to the sum of the partial pressures of nitrogen gas, oxygen gas, argon gas, and water vapor. State and Federal fishery agencies requested the States of Washington and Oregon to allow a variance to the TDG standard during the spring and summer of 1994 that would allow up to a 120 percent of saturation on a 24-hour average. The request was made to permit the release of water over spillways, thereby allowing migrating salmon smolt to avoid hydropower turbines. This request was granted by both states.

The U.S. Army Corps of Engineers has been monitoring total dissolved gas in the Columbia River since 1984. A complete record of the TDG-monitoring program for 1994 can be found in a

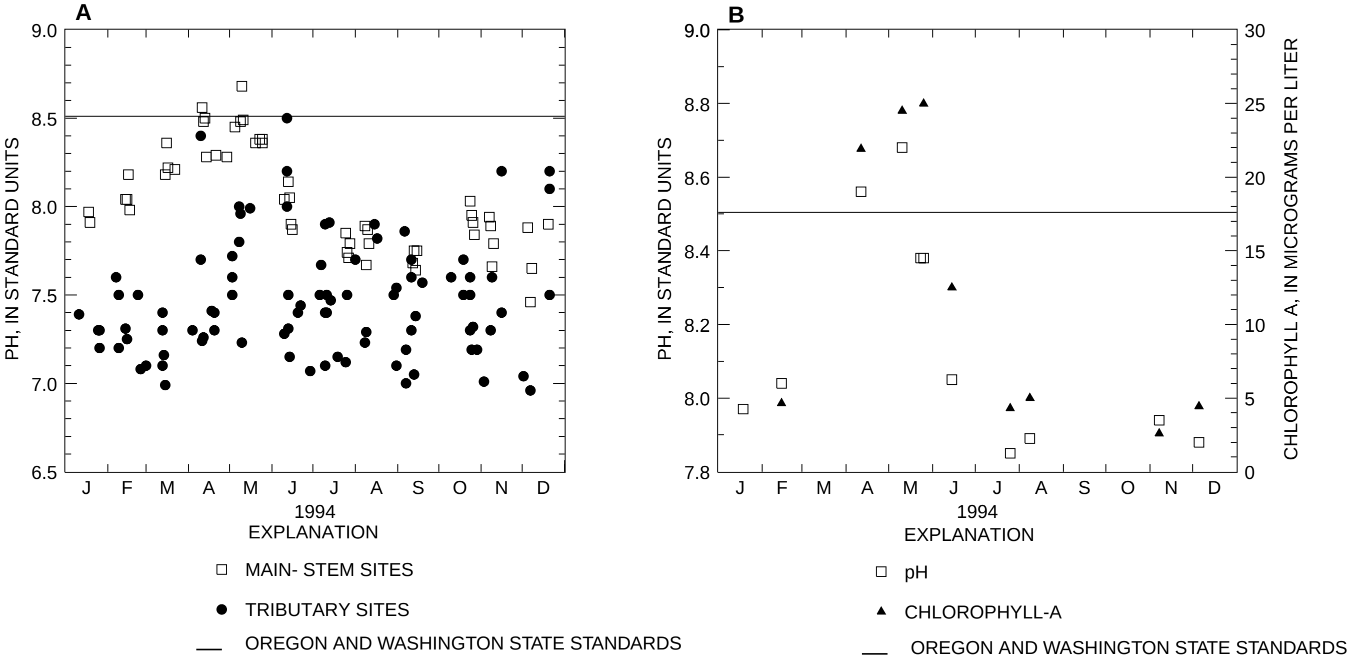


Figure 22. (A) pH in the main stem and tributaries of the lower Columbia River Basin and (B) chlorophyll-*a* concentrations in relation to pH in the Columbia River at river mile 102, downstream from Hayden Island, Oregon and Washington, 1994.

Table 15. Signs of gas-bubble trauma in salmonids
[Adapted from National Marine Fisheries Service, 1994; %, percent]

Signs and effects	Total dissolved gas threshold (sea level)	Age/class
Cardiovascular bubbles	acutely lethal at 115-118 %	Juveniles and adults
Subdermal emphysema including lining of mouth	about 110 %	Juveniles and adults
Bubbles in lateral line	about 110 %	Juveniles and adults
Rupture of swim bladder in small fish	about 110 %	Swim-up fry and juveniles
Over inflation of swim bladder in small fish	about 103 %	Swim-up fry and juveniles
Exophthalmia and ocular lesions	unknown, 102 % for ocular lesions	Juveniles and adults
Bubbles in intestinal tract	102 to 110 %	Juveniles and adults, larval (physoclistous)
Loss of swimming ability	about 106 %	Juveniles and adults
Reduced growth	102 to 105 % (Chinook, lake trout)	Juveniles
Immunosuppression (if present)	greater than 108 %	Juveniles and adults
Reduced ability to adapt to saltwater	variable	Juveniles

report by the U.S. Army Corps of Engineers (1994). In 1994, they operated continuous TDG monitors in the Columbia River at Warrendale (RM 140.5), Skamania (RM 140.6), Camas (RM 122), Kalama (RM 77), and Wauna Mill (RM 42). The TDG data from these sites included values between 100 and 120 percent of saturation during most of the spring and summer of 1994 decreasing in a downstream direction from Bonneville Dam to Wauna Mill. Figure 23 shows TDG concentrations at Warrendale during April through September of 1994 and 1984–93. The historic high values from April 15 through July 15 were generally caused by spills released at upstream dams because the Columbia River streamflow exceeded the capacity of the hydropower turbines. The higher-than-average values in 1994 that occurred from July 15 through August 20 were the result of requests for the U.S. Army Corps of Engineers to spill water at the dams during 12 hours each night to aid the outmigration of anadromous fish.

The few concentrations of TDG measured by the USGS were similar to the U.S. Army Corps of Engineers data. Generally, the TDG and the dissolved-oxygen concentrations (expressed as percent of saturation) were similar in magnitude. This is to be expected because oxygen makes up a relatively constant proportion of atmospheric gasses, which were the major source of dissolved gas in the lower Columbia River. (Photosynthesis and respiration by aquatic organisms were minimal).

Suspended Sediment

Suspended-sediment movement in streams is an important factor in the transport and fate of chemicals in the environment. Many contaminants, including nutrients, trace elements, organic compounds, and fecal-indicator bacteria are associated with suspended sediment. Sediment may be transported in the water column or may be deposited on the streambed for a period of time. During the process of transport and deposition, suspended particles often sort themselves such that coarse sand will dominate in one area and fine silt and clay particles in another area. Salinity causes the finest organic particles to coagulate and settle (Thurman, 1985), resulting in areas near the Columbia River mouth that are dominated by very fine sediment. Suspended-sediment concentrations

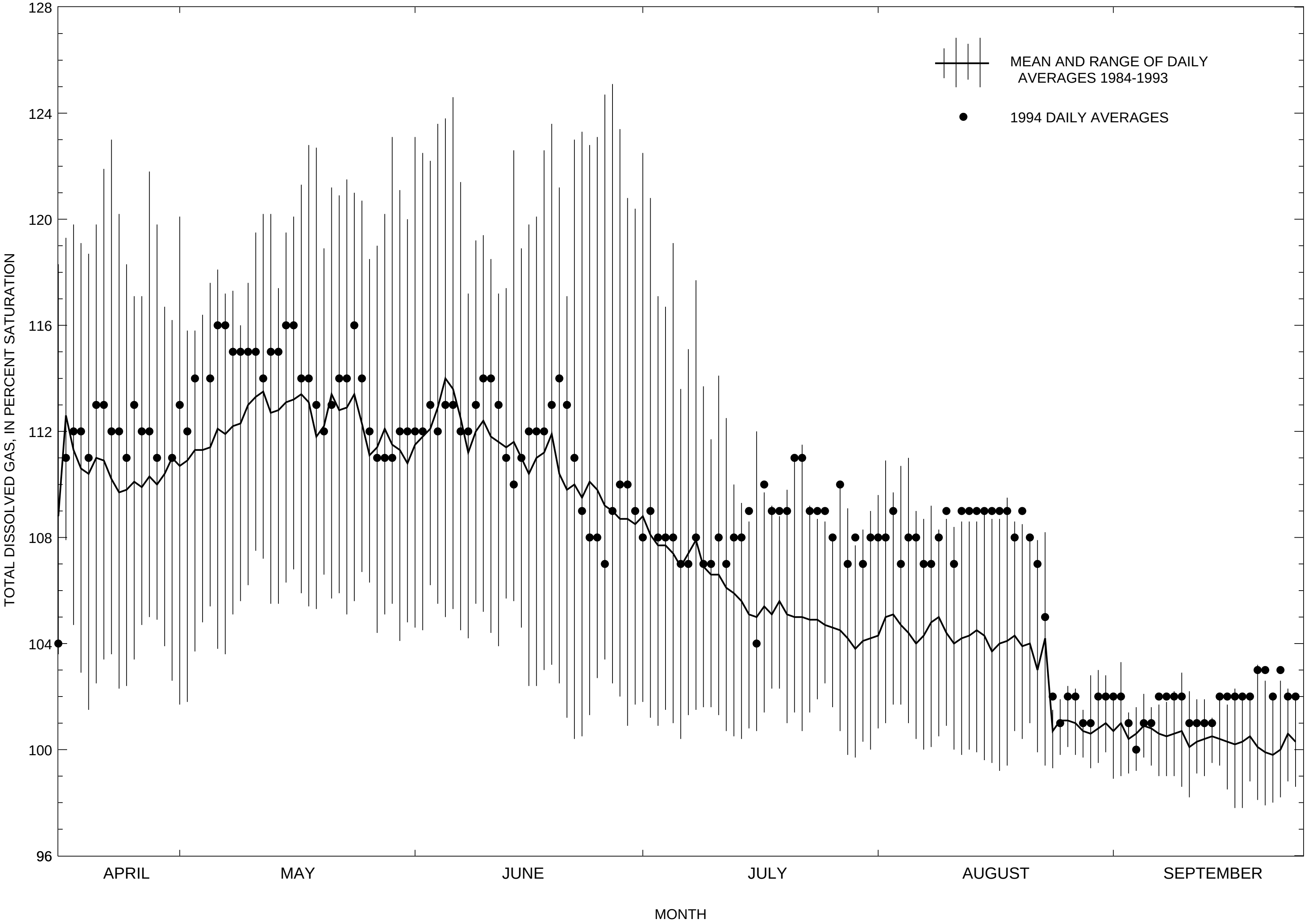


Figure 23. Total dissolved-gas concentrations in the Columbia River at Warrendale, lower Columbia River Basin, Oregon, 1984–93 and 1994. (Source of data: Fi
Passage Center, Portland, Oregon, unpub. data, 1995.)

and associated contaminants can potentially affect water used for domestic-water supplies, aquatic-life propagation, and recreation. High suspended-sediment concentrations often are associated with intense storms that increase streamflows, erosion, and resuspension of bed sediment.

Suspended-sediment concentrations analyzed by State agencies (ODEQ and WDOE) are gravimetric determinations of total suspended solids remaining after drying the sample at 105°C (STORET parameter code 00530; U.S. Environmental Protection Agency, 1979), and the USGS analyses are gravimetric determinations of suspended-sediment concentrations remaining after drying the sample at 105°C (STORET parameter code 80154; Guy, 1969). The ODEQ samples were generally grab samples from one point in the stream cross section, while the WDOE and USGS samples were depth- and width-integrated samples collected isokinetically relative to stream velocities. The nonfilterable-residue method of determination (total suspended solids) used by the State agencies requires that an aliquot of sample be withdrawn from a well-mixed sample bottle for analysis, whereas the suspended-sediment method of determination requires analysis of the entire contents of sediment and water in a sample container. As a result of differences in sampling and analytical methods among agencies, and on the basis of limited quality-assurance data (see Quality-Assurance section of this report), data generated from the two methods may not be comparable; consequently, USGS and State agency data are summarized separately (table 16).

Data from the four sites on the main stem Columbia River indicates that suspended sediment increases in a downstream direction (table 16). The median concentration of suspended sediment in the main stem ranged from 5 mg/L at Warrendale to 9 mg/L at Beaver Army Terminal. Maximum suspended-sediment concentrations generally coincided with peak streamflow for the Willamette River at Portland and the Columbia River at Warrendale (fig. 24). The Cowlitz and Willamette Rivers had the largest median suspended sediment concentrations (both were 21 mg/L, from USGS data) of the tributaries to the Columbia River. The Willamette and the Cowlitz Rivers had median suspended-sediment concentrations approximately 5 to 10 times those of the Sandy, Lewis, and Kalama Rivers. Results of the seasonal Kendall trend test for suspended-sediment concentration, both nonflow adjusted and flow adjusted, indicated no significant ($\rho < 0.05$) trends at the Columbia River at Warrendale or the Willamette River at Portland (table 49, at back of report).

Sites with adequate historical data to estimate monthly and annual mean daily loads for suspended sediment were the Columbia River at Warrendale, Columbia River at Beaver Army Terminal, and the Willamette River at Portland (tables 17 and 18). Both the Willamette and Warrendale sites had enough data to estimate loads for a period of about 20 years (1974–94). Three water years from that period were chosen (1977, 1975, 1974) to represent low-, median-, and high-flow years, respectively. These water years had flows similar to low-, median-, and high-flow water years shown for the period 1928–84 (see fig. 6). The estimated annual loads of suspended sediment for the current year (1994) are similar to the estimated loads for 1977, a low-flow year (table 18).

Load estimates for the lower Columbia River indicate seasonal variation in suspended sediment loads. During the period January through April of 1994, the suspended-sediment loads in the Willamette River plus the loads at Warrendale were greater than the loads at Beaver Army Terminal (table 17). The deficit of suspended sediment at Beaver Army Terminal may indicate deposition in the reach during this period. In contrast, from May to December of 1994, the Columbia River had downstream “net gains” in suspended sediment loads from Warrendale to Beaver Army Terminal, which cannot be accounted for by only inputs from the Willamette River. For example, in June, estimates of mean daily suspended-sediment load indicate that the Columbia River gained 2,300 tons per day between Warrendale and Beaver Army Terminal, while the Willamette River provided only 380 tons per day. The unaccounted-for load may be coming from the Cowlitz River and (or) resuspension in the main stem. Unfortunately, water-quality data were insufficient to calculate loads of suspended sediment on the Cowlitz River using the ESTIMATOR program. However, instantaneous suspended-sediment loads for the Cowlitz River show that the Cowlitz River can produce loads of similar magnitude to those of the Willamette River (101 to 812 tons/day). Therefore, the Cowlitz River may account for a portion of the additional suspended-sediment load at Beaver Army Terminal. Further, the

Table 16. Distribution of suspended-sediment and suspended-solids concentrations, lower Columbia River Basin, Oregon and Washington, 1994

[To avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per month was statistically summarized; see table 7 for full site names; concentrations are reported in milligrams per liter; -- indicates fewer than 5 samples collected, therefore percentile not calculated]

Site name	Agency	Number of samples	Minimum value	Value at indicated percentile			Maximum value
				25	50	75	
Columbia River at Warrendale	USGS	11	3	4	5	7	12
Columbia River at Hayden Island	USGS	12	1	5	7	8	15
Columbia River near Columbia City	USGS	12	5	5	9	15	18
Columbia River at Beaver Army Terminal	USGS	11	5	8	9	16	21
Sandy River	USGS	4	2	--	3	--	8
Sandy River	ODEQ	11	<1	2	4	6	10
Willamette River at Portland	USGS	12	5	10	21	70	146
Willamette River at Portland	ODEQ	11	2	4	5	6	24
Lewis River	USGS	4	1	--	2	--	3
Lewis River	WDOE	10	1	2	4	6	10
Multnomah Channel	USGS	11	7	9	11	17	25
Kalama River	USGS	4	2	--	4	--	8
Kalama River	WDOE	10	1	3	4	8	26
Cowlitz River	USGS	4	7	--	21	--	36
Cowlitz River	WDOE	10	2	6	7	28	391

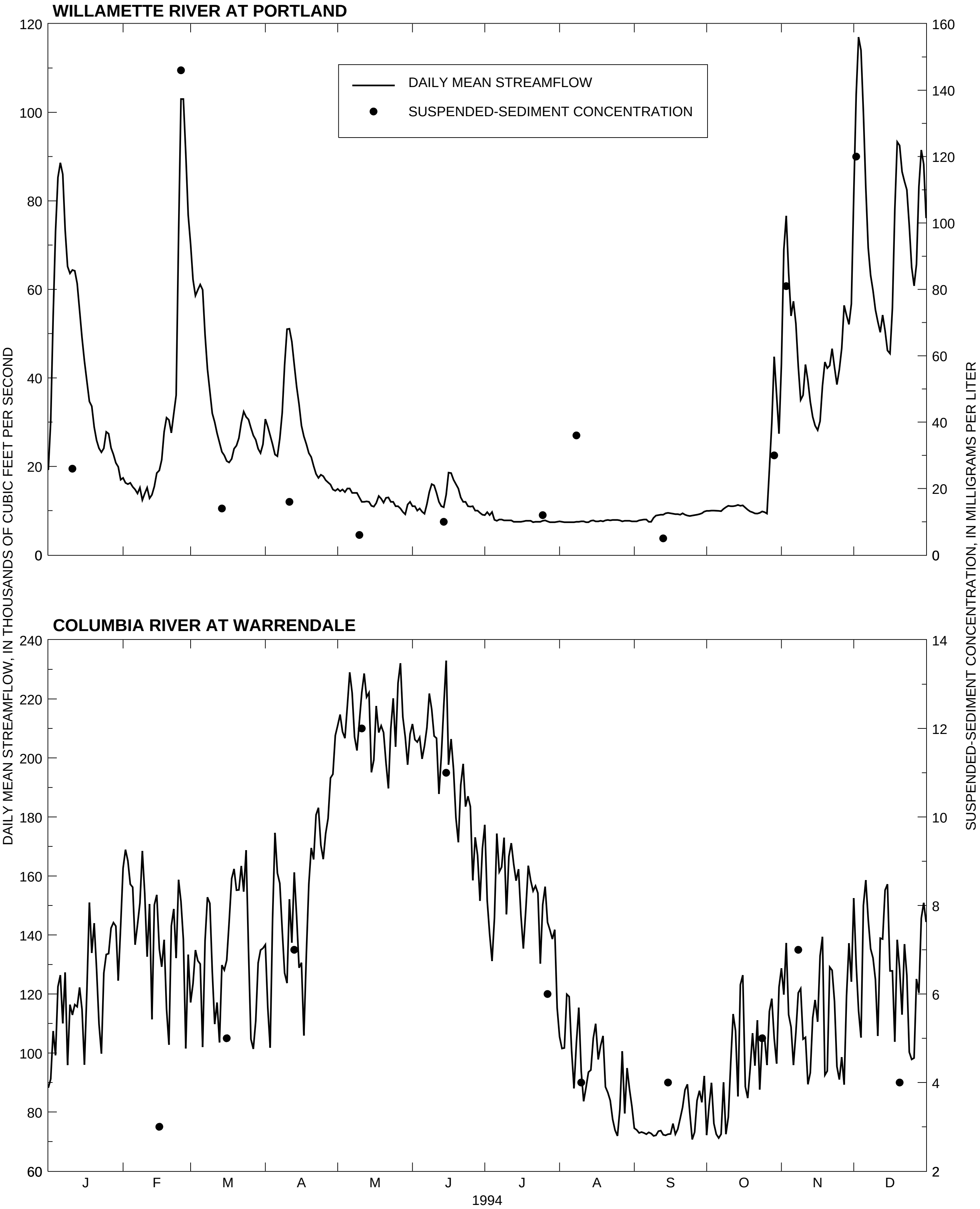


Figure 24. Relation between daily mean streamflow and suspended-sediment concentrations in the Willamette River at Portland and Columbia River at Warrendale, lower Columbia River Basin, Oregon, 1994.

Table 17. Calculated monthly and annual mean daily loads for suspended sediment at selected sites, lower Columbia River Basin, Oregon, 1994

[See table 7 for full site names; loads are reported in tons per day; -, minus; all mean daily loads were calculated using ESTIMATOR (Cohn and others, 1992)]

Month	Warrendale	Willamette	Beaver	Net gain (Beaver - Warrendale)	Unaccounted-for load (Net gain - Willamette)
January	3,900	2,800	5,000	1,100	-1,700
February	5,900	1,800	6,100	200	-1,600
March	5,900	1,600	6,500	600	-1,000
April	7,500	1,100	7,700	200	-900
May	11,000	330	12,000	1,000	670
June	8,700	380	11,000	2,300	1,900
July	4,900	200	6,700	1,800	1,600
August	2,000	200	2,700	700	500
September	1,200	260	1,700	500	240
October	1,800	590	2,700	900	310
November	2,400	3,500	6,700	4,300	800
December	3,600	6,900	13,000	9,400	2,500
Annual	4,900	1,600	6,800	1,900	300

higher flows in the Columbia River during May, June, and July (fig. 8) may provide the energy necessary to resuspend streambed sediment and supply the additional load at Beaver Army Terminal. Resuspension probably is greatest from May through July and in December.

Nutrients

Historical data show that nutrient concentrations are relatively low in the lower Columbia River Basin. Nutrient concentrations measured in 1994 were compared with historical data (1964–93) from the lower Columbia River Basin and data from 300 sites on rivers across the United States (table 19). The 1994 median concentration of phosphorus in unfiltered water is much smaller in the lower Columbia River Basin (0.03 mg/L) than the median for rivers across the United States (0.17 mg/L). Nitrite-plus-nitrate concentrations in filtered water have a similar pattern, with a 1994-median concentration of 0.17 mg/L in the lower Columbia River Basin compared to 0.71 mg/L for rivers across the United States. The historical concentrations of nutrients in the lower Columbia River Basin were generally twice as large as the current concentrations. Differences between the historical and current data likely are due to the predominance of data from the Willamette River Basin in the historical database, rather than a water-quality trend.

The Willamette River is affected by many municipal and agricultural sources, whereas much of the rest of the lower Columbia River Basin is chiefly forest lands (fig. 9). As a result, historical concentrations of nutrients are higher in the Willamette River Basin when compared with those in other areas of the lower Columbia River Basin. This pattern is apparent when the 90th-percentile concentrations for phosphorus in unfiltered water and nitrite plus nitrate and ammonia in filtered water are compared by geographical areas (fig. 25). By

Table 18. Calculated monthly and annual mean daily suspended-sediment loads for the current water year and low, median, and high streamflow water years in the Columbia River at Warrendale and Willamette River at Portland, lower Columbia River Basin, Oregon

[See table 7 for full site name; loads are reported in tons per day; all mean daily loads were calculated using ESTIMATOR (Cohn and others, 1992); see the "Streamflow Conditions" section for a description of flow-year designations]

Month	1977 Low streamflow year		1975 Median streamflow year		1974 High streamflow year		1994 Current year	
	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette
October	3,500	540	3,000	590	2,200	510	2,000	570
November	3,400	520	3,400	1,100	3,000	13,000	2,400	370
December	4,100	200	4,200	5,700	6,300	16,000	2,900	1,600
January	5,700	170	6,900	8,200	14,000	14,000	3,900	2,800
February	5,000	150	9,200	3,900	14,000	5,500	5,900	1,800
March	5,600	1,200	13,000	3,800	14,000	5,900	5,900	1,600
April	4,500	530	13,000	1,200	22,000	4,200	7,500	1,100
May	6,000	870	21,000	1,600	26,000	1,400	11,000	330
June	4,700	440	19,000	660	33,000	1,600	8,700	380
July	2,300	180	8,300	330	15,000	390	4,900	200
August	2,100	220	3,500	290	5,100	200	2,000	200
September	2,000	440	2,400	540	3,200	290	1,200	260
Annual	4,100	460	8,900	2,300	13,000	5,300	4,900	940

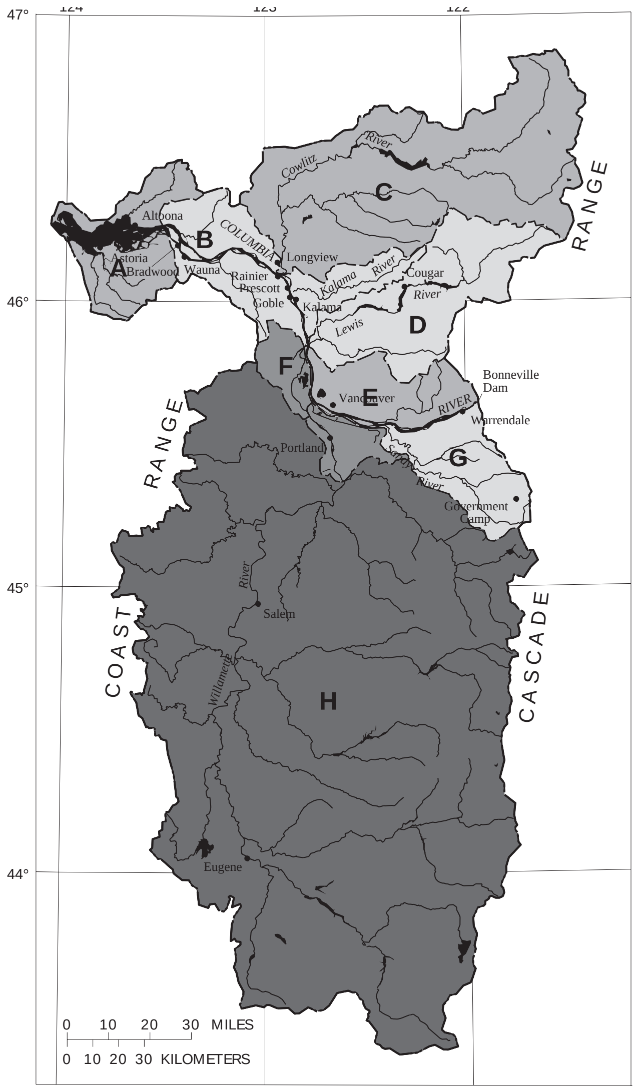
Table 19. Comparison of nutrient concentrations in water in the lower Columbia River Basin to surface waters of the United States

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one value per month per agency was statistically summarized; data for ammonia plus organic nitrogen in filtered water, nitrite in filtered water, and phosphorus in filtered water are not included in this table due to lack of historical comparative data; values are reported in milligrams per liter as nitrogen or phosphorus; NASQAN, National Stream Accounting Network based on data from 300 sites across the United States; --, no data; <, less than; USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; data for orthophosphate in filtered water from Washington Department of Ecology are not summarized because all data were below the method reporting limit of 0.01 milligrams per liter]

Constituent name	NASQAN 1974-81[a]			Lower Columbia River Basin (1964-93)[b]					Lower Columbia River Basin (1994)				
	Value at indicated percentile			Number of samples	Value at indicated percentile				Number of samples	Value at indicated percentile			
	25	50	75		25	50	75	90		25	50	75	90
Ammonia, filtered water	--	--	--	1,711	0.01	0.03	0.09	0.41	84	0.02	0.03	0.05	0.08
Ammonia plus organic nitrogen, unfiltered water	--	--	--	8,945	.2	.3	.6	1.1	94	<.2	<.2	.3	.4
Nitrite plus nitrate, filtered water	0.43	0.71	1.1	1,122	.10	.37	1.2	2.5	84	.06	.17	.34	.74
Phosphorus, unfiltered water	.11	.17	.27	10,927	.04	.07	.15	.30	114	.02	.03	.04	.08
Orthophosphate, filtered water (USGS data only)	--	--	--	9,051	.010	.027	.060	.152	84	.003	.012	.023	.040
Orthophosphate, filtered water (ODEQ data only)	--	--	--	9,051	.010	.027	.060	.152	21	.006	.036	.054	.068

[a] Richard Alexander, U.S. Geological Survey, written communication, 1994.

[b] U.S. Environmental Protection Agency’s STOrage and RETrieval system (STORET), U.S. Geological Survey’s National Water Information System (NWIS), and Tetra Tech, Inc., Redmond, Washington, unpub. data, 1994.



EXPLANATION

Total Phosphorus

░ Less than 0.1 milligrams per liter

▒ More than or equal to 0.1 and less than 0.2 milligrams per liter

▓ More than or equal to 0.2 and less than 0.3 milligrams per liter

█ More than or equal to 0.3 milligrams per liter

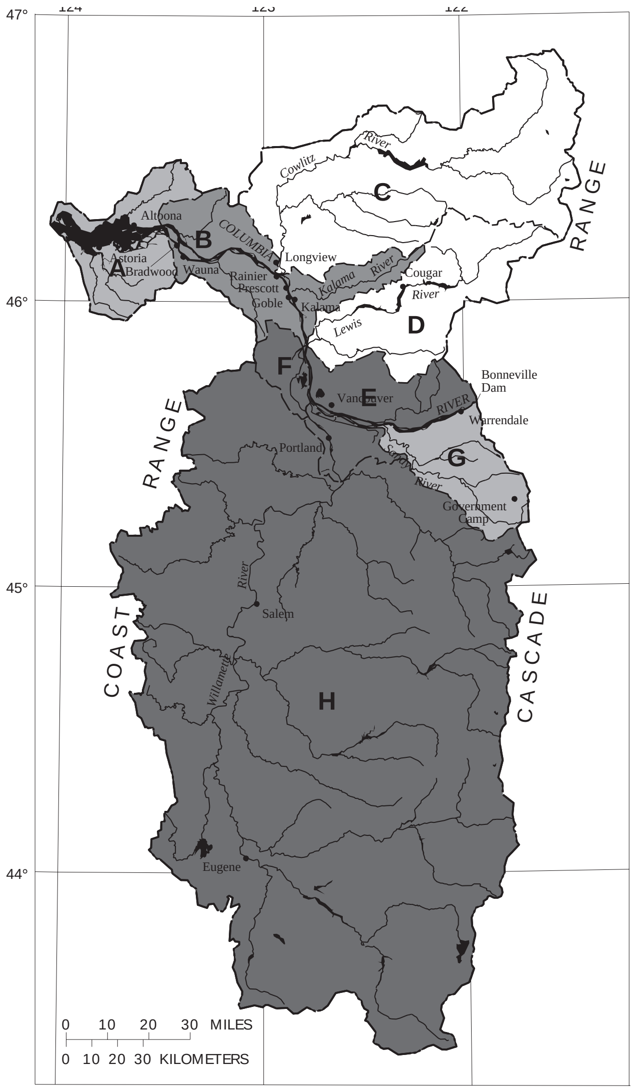
— – Subbasin or u nit border

—— Basin border

A Subbasin or unit name

1

Map Symbol	Subbasin or unit name	Number of samples
A	Lower Columbia (estuary) Unit	82
B	Lower Columiba-Clatskanie	553
C	Cowlitz River Subbasin	707
D	Lewis River Subbasin	248
E	Lower Columbia-Sandy, Washington	182
F	Lower Willamette Unit	1202
G	Lower Columbia-Sandy, Oregon	729
H	Willamette River Subbasin	7166



EXPLANATION

Nitrite plus nitrate

□ Insufficient data

░ Less than 0.5 milligrams per liter

▒ More than or equal to 0.5 and less than 1.0 milligrams per liter

█ More than or equal to 2.0 milligrams per liter

— – Subbasin or u nit border

—— Basin border

A Subbasin or unit name

Map Symbol	Subbasin or unit name	Number of samples
A	Lower Columbia (estuary) Unit	29
B	Lower Columiba-Clatskanie	55
C	Cowlitz River Subbasin	insufficient data
D	Lewis River Subbasin	insufficient data
E	Lower Columbia-Sandy, Washington	17
F	Lower Willamette Unit	176
G	Lower Columbia-Sandy, Oregon	107
H	Willamette River Subbasin	639

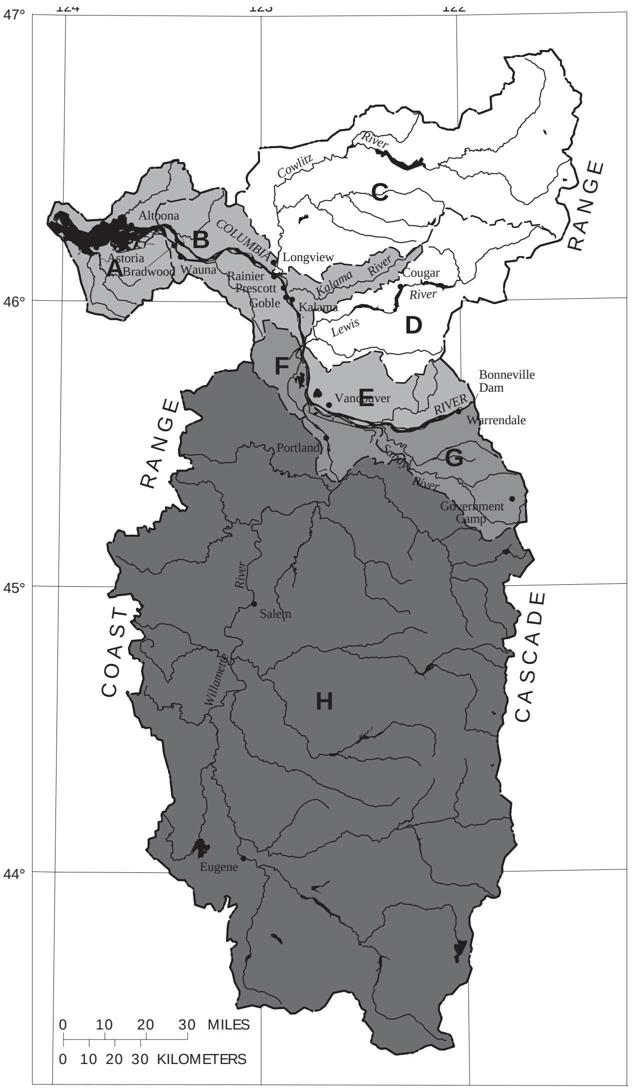


Figure 25. Spatial distribution of 90th-percentile values for phosphorus concentrations in unfiltered water and nitrite plus nitrate and ammonia in filtered water by subbasin or unit, lower Columbia River Basin, Oregon and Washington, 1964-93.

EXPLANATION

Ammonia

□ Insufficient Data

░ Less than 0.1 milligram per liter

▒ More than or equal to 0.1 and less than 0.2 milligram per liter

▓ More than or equal to 0.5 milligram per liter

— – Subbasin or unit border

— Basin border

A Subbasin or unit name

Map Symbol	Subbasin or unit name	Number of samples
A	Lower Columbia (estuary) Unit	8
B	Lower Columiba-Clatskanie	56
C	Cowlitz River Subbasin	insufficient data
D	Lewis River Subbasin	insufficient data
E	Lower Columbia-Sandy, Washington	13
F	Lower Willamette Unit	190
G	Lower Columbia-Sandy, Oregon	94
H	Willamette River Subbasin	967

showing the 90th percentiles of all historical data sampled in each subbasin or unit, figure 25 indicates which subbasins or units of the lower Columbia River Basin had comparatively low, medium, or high historical nutrient concentrations. The historical data were grouped into subbasins and units for statistical purposes only; these maps do not imply that the indicated nutrient concentration existed everywhere in a given unit. The maps do show in a general way the historical nutrient concentrations of different areas of the lower Columbia River Basin, as recorded by the sampling done. Detailed historical nutrient data are not presented, however, because the sampling methods and quality of data are unknown.

Current data for nutrient concentrations show that the Willamette River is a significant source of nutrients in the lower Columbia River Basin. In 1994, samples were collected and analyzed for phosphorus and ammonia plus organic nitrogen in unfiltered water and ammonia, nitrite plus nitrate, and orthophosphate in filtered water. The median concentration for each of the five species was largest at the Willamette River at Portland sampling site (table 20). When ranking the median concentrations from highest to lowest, the same general order of concentrations was followed at all sampling sites for all of the constituents analyzed:

Willamette River > Multnomah Channel > Columbia River sites downstream of the Willamette River > Columbia River sites upstream of the Willamette River > other tributaries.

Concentrations of ammonia and ammonia plus organic nitrogen were usually near the method reporting limit.

Seasonal variations in nutrient concentrations were apparent in 1994. Phosphorus concentrations in unfiltered water in the Willamette River at Portland were highest from November to February, during periods of winter-storm activity (fig. 26). In contrast, a large seasonal variation was not observed in phosphorus in the Columbia River at Hayden Island (RM 102) and Columbia River near Columbia City (RM 84). All three sites had variation, however, in concentrations of nitrite plus nitrate in filtered water. The highest concentrations in the Willamette River

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Table 20. Distribution of nutrient concentrations in water, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers tot he chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per month per agency was statistically summarized; values are reported in milligrams per liter as nitrogen or phosphorus; see table 7 for full site names; USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; WDOE, Washington Department of Ecology; <, less than; --, fewer than 5 samples collected, therefore percentile not calculated; for orthophosphate, different reporting limits were used by different agencies]

Site name	Agency	Number of samples	Minimum value	Value at indicated percentile			Maximum value
				25	50	75	
Ammonia, filtered water							
Columbia River at Warrendale	USGS	11	<0.01	0.01	0.02	0.03	0.06
Columbia River at Hayden Island	USGS	12	.01	.02	.03	.05	.09
Columbia River near Columbia City	USGS	12	.01	.02	.03	.04	.07
Columbia River at Beaver Army Terminal	USGS	11	.02	.02	.03	.04	.06
Willamette River at Portland	USGS	12	.04	.05	.06	.09	.12
Multnomah Channel near mouth	USGS	11	<.01	.02	.03	.07	.13
Sandy River near Troutdale	USGS	4	<.01	--	.01	--	.02
Lewis River at Woodland	USGS	4	.01	--	.01	--	.02
Kalama River near Kalama	USGS	4	.01	--	.02	--	.03
Cowlitz River at Kelso	USGS	3	<.01	--	<.01	--	.01
Ammonia plus organic nitrogen, unfiltered water							
Columbia River at Warrendale	USGS	11	<.2	<.2	<.2	<.2	.3
Columbia River at Hayden Island	USGS	12	<.2	<.2	<.2	.2	.3
Columbia River near Columbia City	USGS	12	<.2	<.2	<.2	.2	.5
Columbia River at Beaver Army Terminal	USGS	11	<.2	<.2	<.2	.3	.5
Willamette River at Portland	USGS	12	<.2	.2	.3	.5	.5
Willamette River at Portland	ODEQ	11	<.2	.3	.4	.4	.7
Multnomah Channel near mouth	USGS	11	<.2	<.2	.2	.3	.3
Sandy River near Troutdale	USGS	4	<.2	--	<.2	--	<.2
Sandy River near Troutdale	ODEQ	11	<.2	<.2	.2	.2	.4
Lewis River at Woodland	USGS	4	<.2	--	<.2	--	<.2
Kalama River near Kalama	USGS	4	<.2	--	<.2	--	<.2
Cowlitz River at Kelso	USGS	3	<.2	--	<.2	--	<.2
Nitrite plus nitrate, filtered water							
Columbia River at Warrendale	USGS	11	<.05	<.05	.16	.22	.42
Columbia River at Hayden Island	USGS	12	<.05	.05	.11	.32	.73
Columbia River near Columbia City	USGS	12	<.05	.07	.18	.37	.56
Columbia River at Beaver Army Terminal	USGS	11	<.05	.09	.17	.35	.47
Willamette River at Portland	USGS	12	.23	.30	.70	.97	1.4
Multnomah Channel near mouth	USGS	11	.05	.13	.24	.42	1.1
Sandy River near Troutdale	USGS	4	<.05	--	.04	--	.07
Lewis River at Woodland	USGS	4	<.05	--	<.05	--	.31
Kalama River near Kalama	USGS	4	0.06	--	0.07	--	0.12
Cowlitz River at Kelso	USGS	3	.06	--	.08	--	.15

Table 20. Distribution of nutrient concentrations in water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers tot he chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per month per agency was statistically summarized; values are reported in milligrams per liter as nitrogen or phosphorus; see table 7 for full site names; USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; WDOE, Washington Department of Ecology; <, less than; --, fewer than 5 samples collected, therefore percentile not calculated; for orthophosphate, different reporting limits were used by different agencies]

Site name	Agency	Number of samples	Minimum value	Value at indicated percentile 25	50	75	Maximum value
Orthophosphate, filtered water							
Columbia River at Warrendale	USGS	11	.001	0.002	.010	0.013	.017
Columbia River at Hayden Island	USGS	12	.002	.007	.012	.015	.042
Columbia River near Columbia City	USGS	12	.001	.003	.013	.018	.030
Columbia River at Beaver Army Terminal	USGS	11	.004	.005	.016	.020	.024
Willamette River at Portland	USGS	12	.010	.031	.040	.060	.070
Willamette River at Portland	ODEQ	11	.036	.041	.054	.065	.069
Multnomah Channel near mouth	USGS	11	.003	.011	.029	.041	.049
Sandy River near Troutdale	USGS	4	.002	--	.004	--	.007
Sandy River near Troutdale	ODEQ	10	<.005	<.005	.006	.007	.010
Lewis River at Woodland	USGS	4	<.001	--	.001	--	.002
Lewis River at Woodland	WDOE	10	<.01	<.01	<.01	<.01	<.01
Kalama River near Kalama	USGS	4	.006	--	.008	--	.008
Kalama River near Kalama	WDOE	10	<.01	<.01	<.01	<.01	<.01
Cowlitz River at Kelso	USGS	3	.001	--	.001	--	.002
Cowlitz River at Kelso	WDOE	10	<.01	<.01	<.01	<.01	<.01
Phosphorus, unfiltered water							
Columbia River at Warrendale	USGS	11	<.01	.02	.02	.04	.04
Columbia River at Hayden Island	USGS	12	.02	.03	.03	.04	.05
Columbia River near Columbia City	USGS	12	.02	.03	.04	.04	.05
Columbia River at Beaver Army Terminal	USGS	11	.02	.03	.04	.04	.06
Willamette River at Portland	USGS	12	.05	.07	.09	.14	.24
Willamette River at Portland	ODEQ	11	.06	.08	.09	.11	.16
Multnomah Channel near mouth	USGS	11	.02	.03	.06	.08	.09
Sandy River near Troutdale	USGS	4	<.01	--	<.01	--	.02
Sandy River near Troutdale	ODEQ	10	<.01	.01	.02	.02	.03
Lewis River at Woodland	USGS	4	<.01	--	<.01	--	.02
Lewis River at Woodland	WDOE	10	<.01	<.01	.01	.02	.02
Kalama River near Kalama	USGS	4	<.01	--	.01	--	.02
Kalama River near Kalama	WDOE	10	<.01	.01	.02	.02	.03
Cowlitz River at Kelso	USGS	3	<.01	--	.01	--	.02
Cowlitz River at Kelso	WDOE	10	<.01	<.01	.02	.04	.08

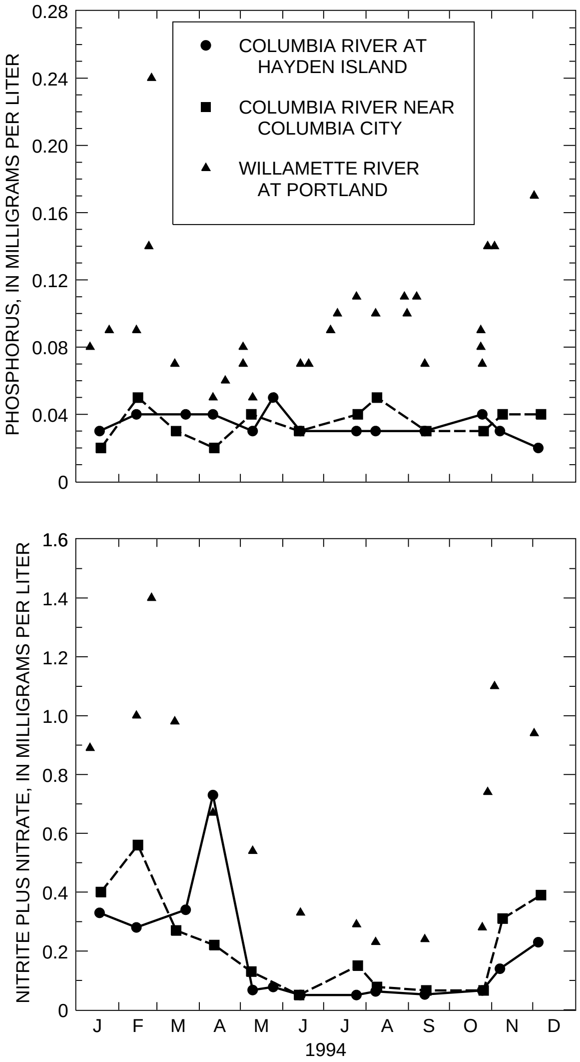


Figure 26. Concentrations of phosphorus in unfiltered water and nitrite plus nitrate in filtered water in the Columbia River at Hayden Island, Willamette River at Portland, and Columbia River near Columbia City, lower Columbia River Basin, Oregon and Washington, 1994.

and Columbia River near Columbia City occurred during the period of November to March, whereas the highest concentrations in the Columbia River at Hayden Island occurred in March and April. This difference in peaks on the Columbia River was probably due to the influence of the Willamette River. During these periods of colder temperatures and less light, nitrogen uptake by algae is decreased, therefore, the nitrogen concentration in the Columbia River is increased. As expected, the concentrations then decrease during the months of April through October when algal activity is increased.

The historical data were analyzed for trends in phosphorus, ammonia, nitrite plus nitrate, and orthophosphate. Seasonal Kendall trend tests showed a significant ($\rho < 0.05$) downward trend for phosphorus (unfiltered) in the Columbia River at Warrendale for the period 1973–94 (table 50, at back of report). Phosphorus concentrations decreased by 2.8 percent (nonflow adjusted) or 2.3 percent (flow adjusted) per year. This was the largest trend found in the lower Columbia River Basin. This trend may be a consequence of more conservative agricultural practices in the area upstream from Warrendale. A similar downward trend in phosphorus concentrations was observed in the Yakima River Basin, the most intensively irrigated basin in the United States, which drains to the Columbia River upstream from Warrendale (Rinella and others, 1992, p. 110). Because phosphorus is commonly associated with sediment particles (Hem, 1989), this downward trend also may have been influenced by the downward trend in suspended-sediment concentration. No significant trends for phosphorus were found in the Willamette River at Portland, the only other site with adequate data for trend testing. There were not adequate data to test for trends in ammonia, nitrite-plus-nitrate, and orthophosphate concentrations.

Adequate historical data were available for the Columbia River at Warrendale and the Willamette River at Portland to calculate monthly and annual mean daily loads for phosphorus in unfiltered water and ammonia and nitrite plus nitrate in filtered water for a period of about 20 years (1974–94). See the “Data-Analysis Methods” section for a discussion of the use of the ESTIMATOR program. The 1974, 1975, and 1977 water years represent conditions of high-, median-, and low-streamflow, respectively, and their estimated loads are shown in table 21. When the nutrient loads for the 1994 water year are compared with these historic loads, they are closest in magnitude to the low-flow water year of 1977 (table 21). This is consistent with the fact that 1994 was generally a year of lower precipitation and streamflow.

Load is a function of both concentration and streamflow. This relation explains how the annual mean daily loads for ammonia, nitrite plus nitrate, and phosphorus in 1994 at Warrendale could be larger by about twofold than those loads in the Willamette River (table 21), even though concentrations were higher in the Willamette River than at Warrendale (table 20).

Table 21. Calculated monthly and annual mean daily nutrient loads for the current water year and low, median, and high streamflow water years in the Columbia River at Warrendale and Willamette River at Portland, lower Columbia River Basin, Oregon

[See table 7 for full site name; loads are reported in tons per day; all mean-daily loads were calculated using ESTIMATOR (Cohn and others, 1992); see the "Streamflow Conditions" section for a description of flow-year designations]

Month	1977 Low streamflow year		1975 Median streamflow year		1974 High streamflow year		1994 Current year	
	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette
Ammonia, filtered water								
October	24	3	21	4	14	3	12	4
November	18	4	18	5	16	15	12	3
December	15	3	16	12	25	20	10	7
January	14	3	18	16	42	19	8	10
February	8	3	17	12	28	14	10	7
March	7	7	21	11	23	13	7	8
April	5	4	20	6	40	10	10	6
May	9	4	46	6	58	6	21	3
June	10	3	62	3	130	5	23	3
July	7	2	35	2	68	3	18	2
August	10	2	19	2	29	2	9	2
September	12	3	15	3	22	2	6	2
Annual	12	3	26	7	41	9	12	5
Nitrite plus nitrate, filtered water								
October	60	14	54	15	41	14	37	14
November	87	18	87	30	79	150	66	15
December	130	13	130	120	180	240	95	49
January	170	16	200	200	360	280	130	91
February	130	15	210	140	300	170	150	70
March	100	59	210	120	210	170	100	71

Table 21. Calculated monthly and annual mean daily nutrient loads for the current water year and low, median, and high streamflow water years in the Columbia River at Warrendale and Willamette River at Portland, lower Columbia River Basin, Oregon—Continued

[See table 7 for full site name; loads are reported in tons per day; all mean-daily loads were calculated using ESTIMATOR (Cohn and others, 1992); see the “Streamflow Conditions” section for a description of flow-year designations]

Month	1977 Low streamflow year		1975 Median streamflow year		1974 High streamflow year		1994 Current year	
	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette	Warrendale	Willamette
Nitrite plus nitrate, filtered water—Continued								
April	53	28	130	47	200	110	81	46
May	46	29	130	44	160	40	79	15
June	29	13	96	18	150	31	49	12
July	15	6	44	9	70	10	29	6
August	17	6	27	7	36	6	16	6
September	25	10	28	11	36	8	16	7
Annual	72	19	110	63	150	100	70	33
Phosphorus, unfiltered water								
October	17	4	15	4	10	4	9	4
November	16	4	16	6	14	23	12	3
December	18	2	19	15	29	28	12	7
January	21	2	26	19	57	25	14	10
February	15	2	28	12	44	15	17	7
March	13	6	35	11	37	15	14	7
April	9	4	29	6	53	11	16	5
May	13	4	49	6	62	6	25	3
June	11	3	51	4	94	6	21	3
July	6	2	24	2	45	3	14	2
August	7	2	12	2	18	2	6	2
September	8	3	10	4	14	2	5	2
Annual	13	3	26	8	40	12	14	4

Nutrient loads also had seasonal patterns. Phosphorus and ammonia had the same pattern of higher loads during periods of higher streamflow. This period corresponds to May through July for the Columbia River at Warrendale and November through March for the Willamette River (fig. 8). Since phosphorus is commonly associated with sediment particles (Hem, 1989) and higher suspended-sediment concentrations and loads correspond to seasonally higher streamflows (table 18), it is expected that phosphorus loads would be larger when flows are higher. Because of the relation between load and streamflow, ammonia loads also would be expected to increase during periods of higher runoff. In contrast to ammonia and phosphorus, nitrite-plus-nitrate loads are influenced more by season than by streamflow. Both the Warrendale and the Willamette sites had their highest loads during the winter months of December through March. During these periods of colder temperatures and less light, nitrogen uptake by algae is decreased, and, therefore, the nitrogen concentration in the river is increased.

Seasonal patterns for ammonia and phosphorus loads at Warrendale differed among low, median, and high streamflow years (table 21). In 1977, for example, the typically higher streamflows in the Columbia River from May through July were absent (fig. 5); consequently, June phosphorus loads in 1977 were nearly nine times smaller than in June 1974—a high streamflow year. Similar patterns and magnitude differences existed for ammonia loads among streamflow years.

Loads were also calculated (using the ESTIMATOR program) for the same three nutrient constituents at the Columbia River at Beaver Army Terminal for 1994, using data from 1990–94 to calculate the regression equation. Table 22 shows these load estimates for the calendar year 1994 at all three sites for comparison. Because the Willamette River is the major source of nutrients to the Columbia River main stem between the Warrendale and Beaver sites, from a simple mass balance standpoint, loads at the Beaver site would be expected to be approximately equal to the sum of the loads at the Warrendale and Willamette sites during the entire year. However, that was the case only for phosphorus (fig. 27); load sums for ammonia and nitrite plus nitrate differed from the load at Beaver during much of 1994. The explanation for the differences is tied to algal growth cycles.

The loads for ammonia generally fit the additive model from November through April. From May through October, however, the load at Beaver was much lower than expected from the sum. For example, in June, the load at Beaver (12 tons/day) was less than half of the sum of the loads at Warrendale and Willamette (26 tons/day). This time period corresponds to the growth period in the algae life cycle when nitrogen uptake is at its maximum. Consequently, some of the ammonia, the preferred nitrogen species for algae, probably is consumed by the algae before it reaches Beaver Army Terminal. The relation between the algae and ammonia can be seen in the ratio of the chlorophyll *a* concentration in milligrams per liter (an indirect measure of algal productivity) to the ammonia concentration in millgrams per liter. The ratio increased tenfold from February 17 (54) to June 10 (560), supporting the concept that increased algal activity in the summer results in decreased ammonia concentrations.

The algae have a similar effect on the nitrite-plus-nitrate loads from June through September at all three sites, but, in general, the additive model holds. From October to May, however, the load at Beaver is much higher than predicted by the sum of the Warrendale and Willamette loads. This pattern suggests that the input from the Willamette River does not fully account for the increase, and inputs from the other tributaries and point and nonpoint sources have a significant effect during this time period. Possible sources of nitrite plus nitrate include the 39 domestic facilities (most of which are sewage-treatment plants) that ultimately discharge into the Columbia River (fig. 10).

For all three constituents, the load at Beaver for December was much higher than for the rest of the year. This is especially apparent for the nitrite-plus-nitrate load, which had a mean daily value of 730 tons/day for December and a second-highest value of only 370 tons/day for February. These elevated December loads at Beaver were due to the increased streamflow at Beaver, not increased concentrations. For example, the nitrite-plus-nitrate concentration rose from 0.35 mg/L on November 10 at Beaver to only 0.37 mg/L on December 8, but the streamflow nearly doubled from 150,000 ft^3/s on October 27 to 296,000 ft^3/s on December 8. In contrast, the streamflow at Warrendale was kept

Table 22. Calculated monthly and annual mean daily loads for ammonia and nitrite plus nitrate in filtered water and phosphorus in unfiltered water at selected sites, lower Columbia River Basin, Oregon, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; loads are reported in tons per day; see table 7 for full site names; all mean daily loads calculated using ESTIMATOR (Cohn and others, 1992a)]

Month	Ammonia, filtered water				Nitrite plus nitrate, filtered water				Phosphorus, unfiltered water			
	Warrendale	Willamette	Beaver	Warrendale + Willamette	Warrendale	Willamette	Beaver	Warrendale + Willamette	Warrendale	Willamette	Beaver	Warrendale + Willamette
January	8	10	17	18	130	91	380	221	14	10	19	24
February	10	7	17	17	150	70	370	220	17	7	20	24
March	7	8	14	15	100	71	240	171	14	7	18	21
April	10	6	13	16	81	46	140	127	16	5	17	21
May	21	3	15	24	79	15	110	94	25	3	23	28
June	23	3	12	26	49	12	59	61	21	3	21	24
July	18	2	8	20	29	6	30	35	14	2	16	16
August	9	2	5	11	16	6	16	22	6	2	9	8
September	6	2	4	8	16	7	18	23	5	2	8	7
October	10	3	8	13	34	14	58	48	8	4	12	12
November	12	9	19	21	66	64	250	130	11	11	26	22
December	13	14	35	27	120	140	730	260	16	17	41	33
Annual	12	6	14	18	71	45	200	116	14	6	19	20

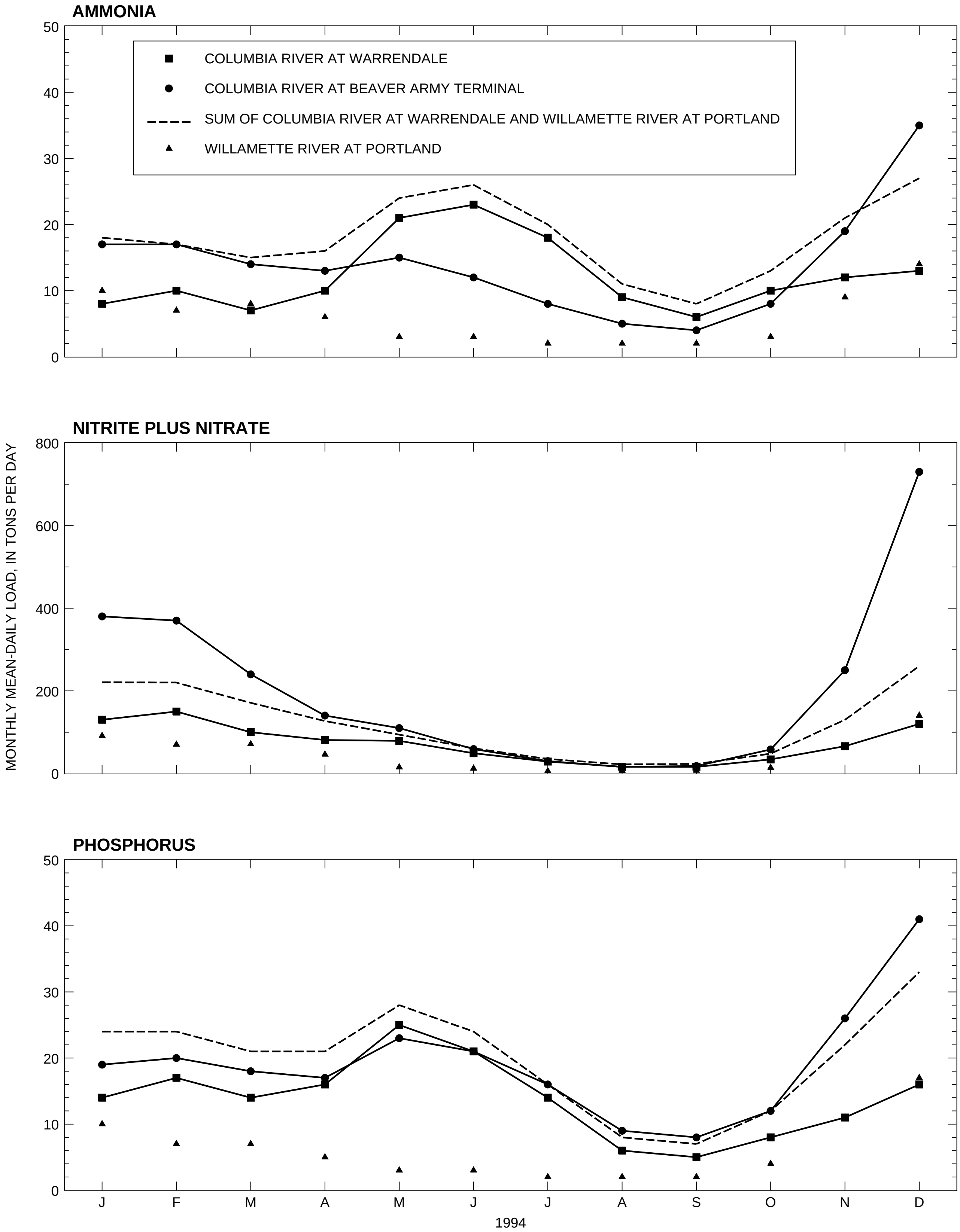


Figure 27. Monthly mean daily loads of ammonia and nitrite plus nitrate in filtered water and phosphorus in unfiltered water in the Columbia River at Warrendale, Willamette River at Portland, and Columbia River at Beaver Army Terminal, lower Columbia Rive Basin, Oregon and Washington, 1994.

within the range of about 90,000 ft^3/s to 140,000 ft^3/s by the operation of Bonneville Dam (fig. 8).

The transport dynamics of these three nutrients were studied by computing the instantaneous loads over three reaches of the main stem. The loads were calculated for both July and September of 1994. For each reach, the measured load at the downstream site (site-measured load) was compared with the calculated load for the reach (reach-calculated load), and the difference between the two was computed (tables 23 and 24). This type of analysis is called *mass balance*. The smaller the difference between the site-measured load and the reach-calculated load, the better the mass balance is for the reach. For comparison, mass-balance calculations also were made for streamflow, a conservative measure, and suspended sediment, a measure related to phosphorus loads. A positive difference between measured and calculated nutrient loads (calculated load greater than measured load) implies that unmeasured contributions to the site-measured load exist (from point sources, nonpoint sources, or resuspension and transport of streambed sediment); whereas a negative difference implies that unmeasured losses exist in the reach (from biological processes or suspended-sediment deposition). It should be noted that samples used in making intersite-load comparisons in this study were separated by days or weeks. Consequently, variability in daily mean streamflow and daily concentrations can contribute to differences that were observed between site-measured and reach-calculated loads.

In general, the mass balance for ammonia and nitrite-plus-nitrate loads was better in September than in July (table 23). Streamflow in the Columbia River was less variable during the September period than in July, when the streamflow was still decreasing (fig. 8). Another possible explanation for differences in mass balance between July and September is the effect of algal productivity. For example, chlorophyll *a* concentrations at Beaver decreased from 6.5 µg/L on July 28 to only 3.3 µg/L on September 12. This decrease indicates that algal productivity in July probably accounts for decreases in ammonia and nitrate loads. This removal by the algae may explain the losses in load reported at Beaver of 4.6 tons/day of ammonia and 20 tons/day of nitrite plus nitrate.

When examining the loads for phosphorus in unfiltered water, it is important also to examine the loads for suspended sediment (table 24). In July, the difference between site-measured and reach-calculated loads for suspended sediment and phosphorus can best be described by the effects of streamflow. For example, in the reach from Hayden Island (RM 102) to Columbia City (RM 84), the unaccounted-for gains in both phosphorus and suspended-sediment loads may be explained by the increased streamflow and resuspension of suspended sediment. In September, phosphorus loads, suspended-sediment loads, and streamflow were all smaller than they were in July. In table 24, there is very good balance for both phosphorus and suspended-sediment loads for the reach from Hayden Island to Columbia City, indicating little or no net deposition or resuspension. From Columbia City to Beaver (RM 53.8), however, there are unaccounted-for losses in both phosphorus and suspended sediment, indicating that deposition is occurring. This situation was expected due to the large input of suspended-sediment from the Cowlitz River and the low streamflow in the Columbia River main stem. The suspended-sediment load from the Cowlitz River (270 tons/day) represents 22 percent of the load measured at Beaver (1,200 tons/day).

Major Ions and Related Measures

Sources of major ions in water include mineral and organic assemblages in rocks and soils that contact surface and ground water and undergo natural weathering (solubilizing processes). Additional sources include point discharges (for example, effluents from sewage-treatment plants) and nonpoint discharges (for example, agricultural and urban runoff). Major cations include calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); major anions include bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3), and uncharged species such as silica $[Si(OH)_4]$. Collectively, the total concentration of dissolved material in water (inorganic salts and organic matter) is referred to as total dissolved solids (TDS) or “filterable residue”.

Median concentrations of Ca, Mg, Na, K, Cl, SO_4, and TDS (14, 4.0, 6.3, 1.1, 4.1, 9.6 and 78 mg/L, respectively) in the lower Columbia River Basin in 1994 (table 25) were similar to mean

Table 23. Mass balances for streamflow and ammonia and nitrite-plus-nitrate loads in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[Loads were determined from instantaneous measurements of ammonia and nitrite-plus-nitrate concentrations in filtered water and phosphorus concentrations in unfiltered water; the tern “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; ft^3/s, cubic feet per second; --, not applicable; cd, data is censored (below method reporting limit); see table 7 for full site names; see page 73 for a discussion of the mass-balance approach]

Site name	Sampling date	Columbia river mile	Streamflow (ft^3/s)				Ammonia load (tons/day)				Nitrite-plus-nitrate load (tons/day)			
			Main Stem				Main stem				Main stem			
			Site measured	Reach calculated	Site measured - Reach calculated	Tributary inflowing	Site measured	Reach calculated	Site measured - Reach calculated	Tributary Inflowing	Site measured	Reach calculated	Site measured - Reach calculated	Tributary Inflowing
July 1994														
Warrendale	07-27-1994	141	144,000	--	--	--	12	--	--	--	25	--	--	--
Sandy River	07-07-1994	120.5	--	--	--	725	--	--	--	0.020	--	--	--	cd
Hayden Island	07-25-1994	102	142,000	144,725	-2,725	--	15	12	+3	--	19	25	-6	--
Willamette River	07-25-1994	101.5	--	--	--	9,000	--	--	--	1.4	--	--	--	7.0
Lewis River	07-19-1994	87	--	--	--	1,260	--	--	--	.068	--	--	--	cd
Columbia City	07-26-1994	84	160,000	152,260	+7,740	--	13	16	-3	--	65	26	+39	--
Kalama River	07-13-1994	73.1	--	--	--	260	--	--	--	.014	--	--	--	.039
Cowlitz River	07-14-1994	68	--	--	--	4,390	--	--	--	cd	--	--	--	1.0
Beaver Army Terminal	07-28-1994	53.8	155,000	164,650	-9,650	--	8.4	13	-4.6	--	46	66	-20	--
September 1994														
Warrendale	09-15-1994	141	72,500	--	--	--	3.9	--	--	--	cd	--	--	--
Sandy River	09-19-1994	120.5	--	--	--	299	--	--	--	.016	--	--	--	cd
Hayden Island	09-13-1994	102	73,700	72,799	+901	--	4.0	3.9	+.1	--	10	cd	--	--
Willamette River	09-13-1994	101.5	--	--	--	9,100	--	--	--	2.2	--	--	--	5.9
Lewis River	09-07-1994	87	--	--	--	1,250	--	--	--	.034	--	--	--	cd
Columbia City	09-14-1994	84	97,200	84,050	+13,150	--	5.2	6.2	-1	--	17	16	+1	--
Kalama River	09-06-1994	73.1	--	--	--	189	--	--	--	.0051	--	--	--	.039
Cowlitz River	08-31-1994	68	--	--	--	3,230	--	--	--	cd	--	--	--	1.3
Beaver Army Terminal	09-12-1994	53.8	93,000	100,619	-7,619	--	5.0	5.2	-.2	--	22	18	+4	--

Table 24. Mass balances for streamflow, phosphorus loads in unfiltered water, and suspended-sediment loads, lower Columbia River Basin, Oregon and Washington, 1994

[Loads were determined from instantaneous measurements of ammonia and nitrite-plus-nitrate concentrations in filtered water and phosphorus concentrations in unfiltered water; the tern “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; ft^3/s, cubic feet per second; --, not applicable; cd, data is censored (below method reporting limit); see table 7 for full site names; see page 73 for a discussion of the mass-balance approach]

Site name	Sampling date	Columbia river mile	Streamflow (ft^3/s)				Phosphorus load (tons/day)				Suspended-sediment load (tons/day)			
			Main Stem			Tributary inflowing	Main stem			Tributary Inflowing	Main stem			Tributary Inflowing
			Site measured	Reach calculated	Site measured - Reach calculated		Site measured	Reach calculated	Site measured - Reach calculated		Site measured	Reach calculated	Site measured - Reach calculated	
July 1994														
Warrendale	07-27-1994	141	144,000	--	--	--	7.8	--	--	--	2,300	--	--	--
Sandy River	07-07-1994	120.5	--	--	--	725	--	--	--	cd	--	--	--	5.9
Hayden Island	07-25-1994	102	142,000	144,725	-2,725	--	12	7.8	+4.2	--	2,700	2,300	+400	--
Willamette River	07-25-1994	101.5	--	--	--	9,000	--	--	--	2.7	--	--	--	290
Lewis River	07-19-1994	87	--	--	--	1,260	--	--	--	0.068	--	--	--	10
Columbia City	07-26-1994	84	160,000	152,260	+7,740	--	17	15	+2	--	3,900	3,000	+900	--
Kalama River	07-13-1994	73.1	--	--	--	260	--	--	--	.021	--	--	--	3.5
Cowlitz River	07-14-1994	68	--	--	--	4,390	--	--	--	.12	--	--	--	130
Beaver Army Terminal	07-28-1994	53.8	155,000	164,650	-9,650	--	25	17	+8	--	3,300	4,000	-700	--
September 1994														
Warrendale	09-15-1994	141	72,500	--	--	--	3.9	--	--	--	780	--	--	--
Sandy River	09-19-1994	120.5	--	--	--	299	--	--	--	cd	--	--	--	2.4
Hayden Island	09-13-1994	102	73,700	72,799	+901	--	6.0	3.9	+2.1	--	1,200	780	+420	--
Willamette River	09-13-1994	101.5	--	--	--	9,100	--	--	--	1.7	--	--	--	120
Lewis River	09-07-1994	87	--	--	--	1,250	--	--	--	cd	--	--	--	3.4
Columbia City	09-14-1994	84	97,200	84,050	+13,150	--	7.9	7.7	+.2	--	1,300	1,300	0	--
Kalama River	09-06-1994	73.1	--	--	--	189	--	--	--	.0051	--	--	--	1.0
Cowlitz River	08-31-1994	68	--	--	--	3,230	--	--	--	cd	--	--	--	270
Beaver Army Terminal	09-12-1994	53.8	93,000	100,619	-7,619	--	5.0	7.9	-2.9	--	1,200	1,600	-400	--

Table 25. Distribution of major-ion concentrations in filtered and unfiltered water, lower Columbia River Basin, Oregon and Washington, 1994

[All measurements were performed on filtered-water samples, except specific conductance which was determined from an unfiltered-water sample; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in milligrams per liter, except where shown to be otherwise; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Alkalinity								
Warrendale	11	52.0	52.2	55.0	62.0	69.0	75.8	77.0
Hayden Island	12	53.0	53.3	55.2	59.0	66.0	71.0	71.0
Columbia City	12	48.0	48.3	51.2	54.5	61.5	66.4	67.0
Beaver	11	44.0	45.0	51.0	53.0	59.0	69.4	71.0
Willamette River	14	15.0	16.5	21.8	25.0	27.0	28.0	29.0
Multnomah Channel	11	23.0	23.2	31.0	36.0	46.0	48.6	49.0
Sandy River	11	12.0	12.0	13.0	15.0	22.0	24.4	25.0
Lewis River	4	16.0	--	--	17.0	--	--	20.0
Kalama River	4	20.0	--	--	23.5	--	--	24.0
Cowlitz River	4	25.0	--	--	26.5	--	--	27.0
All Sites	94	12.0	16.5	24.0	46.5	56.2	66.0	77.0
Calcium								
Warrendale	11	16.0	16.0	16.0	17.0	20.0	21.0	21.0
Hayden Island	12	15.0	15.3	16.0	17.0	19.3	20.7	21.0
Columbia City	12	14.0	14.0	14.3	15.5	17.8	20.7	21.0
Beaver	11	13.0	13.0	14.0	15.0	17.0	18.0	18.0
Willamette River	14	5.0	5.1	6.1	6.9	7.4	7.9	8.2
Multnomah Channel	11	5.4	5.6	6.8	9.7	13.0	14.8	15.0
Sandy River	1	6.0	--	--	6.0	--	--	6.0
Lewis River	4	4.0	--	--	4.2	--	--	4.3
Kalama River	4	4.6	--	--	5.7	--	--	6.2
Cowlitz River	4	7.7	--	--	8.9	--	--	9.3
All Sites	84	4.0	5.4	7.3	14.0	17.0	19.0	21.0
Chloride								
Warrendale	11	2.0	2.0	2.1	3.0	3.8	4.0	4.0
Hayden Island	12	1.9	2.0	2.7	3.5	4.3	5.0	5.0
Columbia City	12	2.8	2.9	3.9	4.2	4.5	4.6	4.6
Beaver	11	3.1	3.3	4.7	5.0	5.6	6.1	6.2
Willamette River	12	3.2	3.3	3.7	4.3	5.8	6.3	6.3
Multnomah Channel	11	4.3	4.4	4.9	6.4	9.1	13.1	14.0
Sandy River	4	1.6	--	--	2.0	--	--	2.5
Lewis River	4	1.6	--	--	1.8	--	--	1.9
Kalama River	4	2.5	--	--	3.7	--	--	4.9

Table 25. Distribution of major-ion concentrations in filtered and unfiltered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[All measurements were performed on filtered-water samples, except specific conductance which was determined from an unfiltered-water sample; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in milligrams per liter, except where shown to be otherwise; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Chloride								
Cowlitz River	4	4.1	--	--	5.5	--	--	5.9
All Sites	85	1.6	2.1	3.0	4.1	5.0	6.2	14.0
Fluoride								
Warrendale	11	.1	.1	.1	.1	.2	.2	.2
Hayden Island	12	.1	.1	.1	.1	.2	.2	.2
Columbia City	12	<.1	<.1	.1	.1	.2	.2	.2
Beaver	11	<.1	<.1	.1	.1	.2	.2	.2
Willamette River	12	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Multnomah Channel	11	.1	<.1	<.1	<.1	.1	.2	.2
Sandy River	4	<.1	--	--	<.1	--	--	<.1
Lewis River	4	<.1	--	--	<.1	--	--	.1
Kalama River	4	<.1	--	--	<.1	--	--	<.1
Cowlitz River	4	<.1	--	--	<.1	--	--	<.1
All Sites	85	<.1	<.1	<.1	.1	.1	.2	.2
Magnesium								
Warrendale	11	4.2	4.2	4.6	5.0	5.8	6.0	6.0
Hayden Island	12	4.0	4.1	4.5	4.8	5.3	6.0	6.0
Columbia City	12	3.7	3.9	4.2	4.4	5.2	6.0	6.1
Beaver	11	3.8	3.8	3.9	4.4	5.1	5.2	5.2
Willamette River	14	1.6	1.6	2.0	2.2	2.4	2.6	2.8
Multnomah Channel	11	1.8	1.9	2.3	3.1	3.8	4.3	4.4
Sandy River	1	2.3	--	--	2.3	--	--	2.3
Lewis River	4	1.0	--	--	1.1	--	--	1.1
Kalama River	4	1.2	--	--	1.5	--	--	1.5
Cowlitz River	4	1.7	--	--	1.9	--	--	2.0
All Sites	84	1.0	1.6	2.2	4.0	4.8	5.5	6.1
Potassium								
Warrendale	11	.9	.9	1.0	1.2	1.3	1.4	1.4
Hayden Island	12	.9	.9	1.1	1.2	1.3	1.4	1.4
Columbia City	12	0.7	0.8	1.0	1.1	1.3	1.3	1.3
Beaver	11	.9	.9	1.1	1.2	1.3	1.3	1.3
Willamette River	14	.5	.6	.7	.8	.9	1.1	1.1
Multnomah Channel	11	.7	.7	.8	1.1	1.2	1.2	1.2

Table 25. Distribution of major-ion concentrations in filtered and unfiltered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[All measurements were performed on filtered-water samples, except specific conductance which was determined from an unfiltered-water sample; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in milligrams per liter, except where shown to be otherwise; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Potassium—Continued								
Sandy River	1	.9	--	--	.9	--	--	.9
Lewis River	4	.4	--	--	.4	--	--	.4
Kalama River	4	.3	--	--	.5	--	--	.5
Cowlitz River	4	.7	--	--	.8	--	--	.8
All Sites	84	.3	.5	.8	1.1	1.2	1.3	1.4
Silica								
Warrendale	11	5.0	5.3	7.6	8.5	8.9	9.6	9.7
Hayden Island	12	5.4	5.9	7.4	8.7	9.7	10.0	10.0
Columbia City	12	6.3	6.6	7.4	9.4	10.0	11.0	11.0
Beaver	11	6.9	7.0	8.1	9.2	11.0	11.0	11.0
Willamette River	12	13.0	13.0	14.0	14.5	16.0	16.7	17.0
Multnomah Channel	11	8.2	8.5	10.0	13.0	15.0	16.8	17.0
Sandy River	4	17.0	--	--	18.0	--	--	21.0
Lewis River	9	6.5	6.5	6.7	6.8	6.9	7.0	7.0
Kalama River	10	5.0	5.1	6.6	7.7	8.7	19.8	21.0
Cowlitz River	10	5.3	5.4	6.4	6.7	7.1	13.3	14.0
All Sites	102	5.0	6.5	7.0	8.9	12.3	16.0	21.0
Sodium								
Warrendale	11	3.7	3.8	4.3	6.1	6.8	7.6	7.7
Hayden Island	12	4.1	4.2	5.0	6.2	7.1	7.9	8.0
Columbia City	12	4.0	4.3	6.0	6.4	6.9	7.6	7.8
Beaver	11	4.8	5.1	6.3	7.1	7.5	7.7	7.7
Willamette River	14	3.4	3.5	4.7	5.8	7.9	9.3	9.4
Multnomah Channel	11	3.9	4.1	5.6	7.1	9.7	11.6	12.0
Sandy River	1	5.2	--	--	5.2	--	--	5.2
Lewis River	4	3.0	--	--	3.1	--	--	3.1
Kalama River	4	3.1	--	--	4.3	--	--	4.9
Cowlitz River	4	6.6	--	--	8.2	--	--	8.8
All Sites	84	3.0	3.8	4.9	6.3	7.2	8.5	12.0
Specific conductance, in microsiemens per centimeter								
Warrendale	11	125.5	127.0	138.0	153.0	171.0	179.6	180.0
Hayden Island	12	125.2	128.3	140.5	150.3	168.7	187.1	191.0
Columbia City	11	126.1	126.5	133.3	145.9	152.2	172.0	175.0

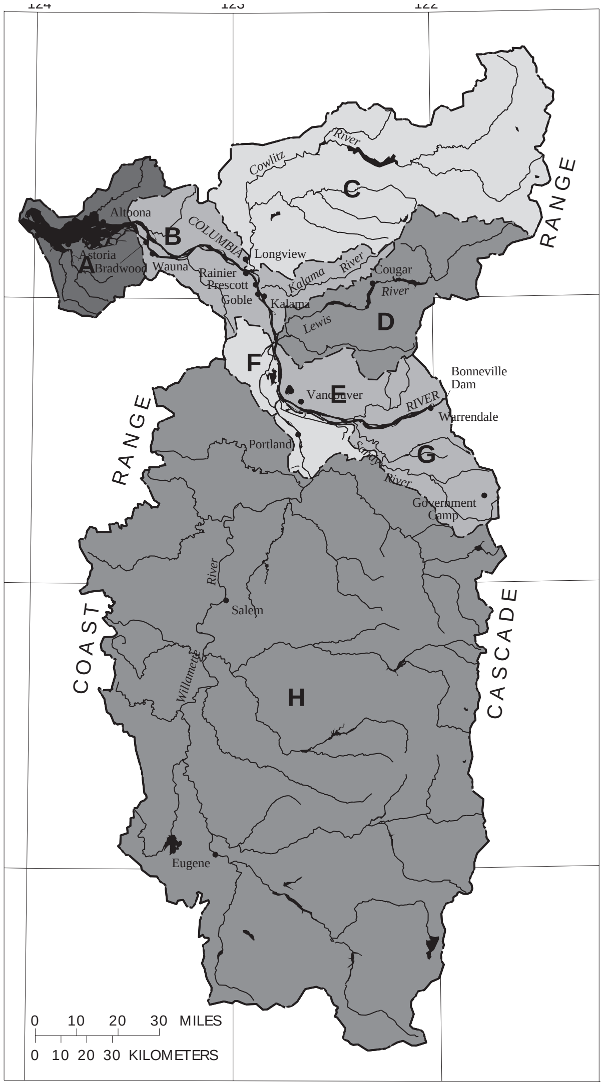
Table 25. Distribution of major-ion concentrations in filtered and unfiltered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[All measurements were performed on filtered-water samples, except specific conductance which was determined from an unfiltered-water sample; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in milligrams per liter, except where shown to be otherwise; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile 10	25	50	75	90	Maximum value
Specific conductance, in microsiemens per centimeter—Continued								
Beaver	11	121.9	122.5	129.8	149.0	156.0	169.4	171.0
Willamette River	14	56.8	57.8	77.5	86.0	93.0	130.5	158.0
Multnomah Channel	11	61.4	63.7	83.9	124.7	138.0	145.9	147.0
Sandy River	12	27.0	27.9	38.2	46.0	63.7	74.7	76.0
Lewis River	10	40.0	40.2	42.7	45.5	50.0	54.8	55.0
Kalama River	11	33.0	34.8	45.0	48.0	60.0	68.0	68.0
Cowlitz River	11	78.0	78.4	83.0	98.0	114.0	115.0	115.0
All Sites	114	27.0	43.5	58.4	106.5	147.0	161.5	191.0
Sulfate								
Warrendale	11	9.0	9.0	9.5	12.0	14.0	14.0	14.0
Hayden Island	12	8.8	8.9	10.2	11.0	12.8	14.7	15.0
Columbia City	12	9.0	9.2	9.6	10.5	12.0	13.7	14.0
Beaver	11	9.0	9.2	10.0	11.0	12.0	13.8	14.0
Willamette River	12	2.7	2.7	3.4	4.3	5.1	5.7	5.9
Multnomah Channel	11	3.1	3.3	4.2	6.8	8.5	9.9	10.0
Sandy River	4	2.6	--	--	5.0	--	--	6.4
Lewis River	4	1.9	--	--	2.1	--	--	2.1
Kalama River	4	1.1	--	--	1.5	--	--	1.5
Cowlitz River	4	12.0	--	--	15.0	--	--	15.0
All Sites	85	1.1	2.4	4.6	9.6	12.0	14.0	15.0
Total dissolved solids, residue on evaporation at 180 degrees Celsius								
Warrendale	11	77.0	77.2	85.0	89.0	100.0	108.6	109.0
Hayden Island	12	72.0	74.1	86.2	90.0	98.7	114.1	115.0
Columbia City	12	70.0	72.4	81.0	85.0	102.0	114.3	117.0
Beaver	11	80.0	80.2	83.0	88.0	96.0	104.4	105.0
Willamette River	14	34.0	41.5	54.7	64.5	77.0	87.5	89.0
Multnomah Channel	11	56.0	56.4	60.0	78.0	82.0	87.6	88.0
Sandy River	12	31.0	31.6	36.0	44.0	57.0	66.1	67.0
Lewis River	9	36.0	36.0	38.0	40.0	45.0	75.0	75.0
Kalama River	10	37.0	37.3	40.7	49.5	59.7	108.8	114.0
Cowlitz River	10	65.0	65.1	66.7	74.5	81.7	88.5	89.0
All Sites	112	31.0	40.0	57.0	78.0	88.0	100.0	117.0

concentrations observed in rivers throughout the world (14, 3.7, 5.7, 1.8, 6.8, 9.6, and 81 mg/L, respectively; Hem, 1989). On the basis of the historical data in the lower Columbia River Basin (STORET data retrieval, 1947–93 WY), the median concentrations of Ca, Mg, Na, K, Cl, SO_4, and TDS (6.3, 1.9, 4.0, 0.7, 3.7, 3.4, and 50 mg/L, respectively) historically were lower than measurements in this study. The higher concentrations in 1994 reflect the limited dilution capability of the tributaries during low-streamflow conditions. Figure 28 provides a spatial perspective of historical TDS data in the lower Columbia River Basin on the basis of their 90th-percentile values. The historical data were grouped into subbasins and units for statistical purposes only; these maps do not imply that the indicated TDS concentration existed everywhere in a given unit. The maps do show in a general way the historical TDS concentrations of different areas of the lower Columbia River Basin, as recorded by the sampling done. As expected, the highest TDS values (90th percentile: 270 mg/L) were in the estuary where seawater mixes with river water. The next highest subbasins were the Willamette River and the Lewis River subbasins (90th percentiles: 158 and 161 mg/L, respectively), while the Cowlitz River subbasin had the lowest TDS values (90th percentile: 76 mg/L).

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. In most waters, it can be related to the TDS concentration by multiplying by a factor in the range 0.55 to 0.75 (Hem, 1989, p. 67). In 1994, the median specific conductance in the Columbia River main stem ranged from 153 µS/cm (microsiemens per centimeter) in the Columbia River at Warrendale to 149 µS/cm in the Columbia River at Beaver Army Terminal (table 25). The median specific conductance during this study in the Willamette River at Portland was 86 µS/cm. The lower specific conductance in the Willamette River was primarily a result of lower Ca, Mg, and HCO_3 concentrations. The median Ca concentration in the Willamette River at Portland (6.9 mg/L), for example, was about one-half that in the Columbia River at Beaver Army Terminal.



EXPLANATION

Total dissolved solids

░ Less than 100 milligrams per liter

▒ More than or equal to 100 and less than 150 milligrams per liter

▓ More than or equal to 150 and less than 200 milligrams per liter

█ More than or equal to 200 milligrams per liter

— – Subbasin or unit border

— Basin border

A Subbasin or unit name

Map Symbol	Subbasin or unit name	Number of samples
A	Lower Columbia (estuary) Unit	30
B	Lower Columiba-Clatskanie	194
C	Cowlitz River Subbasin	26
D	Lewis River Subbasin	11
E	Lower Columbia-Sandy, Washington	29
F	Lower Willamette Unit	197
G	Lower Columbia-Sandy, Oregon	788
H	Willamette River Subbasin	424

Figure 28. Spatial distribution of 90th-percentile values for total dissolved solids by subbasin or unit, lower Columbia River Basin, Oregon and Washington, 1947-93..

The ionic composition of water in the lower Columbia River was relatively unchanged between Warrendale (RM 141) and Beaver Army Terminal (RM 53.8). In this reach, Ca and Mg were the dominant cations and HCO_3 was the dominant anion (fig. 29). As an example, Ca accounted for as much as 60 percent of the cation milliequivalents in the Columbia River at Beaver Army Terminal. Willamette River water, however, tends to have smaller proportions of Ca and HCO_3 and higher proportions of Na and Cl when compared to the Lower Columbia River. This may be a result of urban effects.

Although variations in median specific conductance along the main stem were small in 1994, some seasonal variations do exist. During the fall months, specific conductance decreased between the Columbia River at Warrendale and the Columbia River at Beaver Army Terminal. The specific-conductance gradient in November 1994, which was typical for October and December, showed that specific conductance decreased 37 μS/cm between Warrendale (RM 141) and Beaver Army Terminal (RM 53.8) (fig. 30); Ca concentrations between these sites also decreased by similar proportions. The decreasing conductivities in the fall coincide with an increase in the proportion of Willamette River water entering the main stem (RM 101.5) between Warrendale and Beaver Army Terminal. Ratios of mean daily streamflows (Willamette River at Portland: Columbia River at Warrendale) that coincide with water-quality measurements ranged from 0.68 to 0.84 in fall of 1994. These ratios underscore the diluting capability of the Willamette River's low-conductance waters. In contrast, during the summer months, the ratios of mean daily streamflows are less than 0.1, and the discharge of low-conductance water from the Willamette River has no measurable effect on

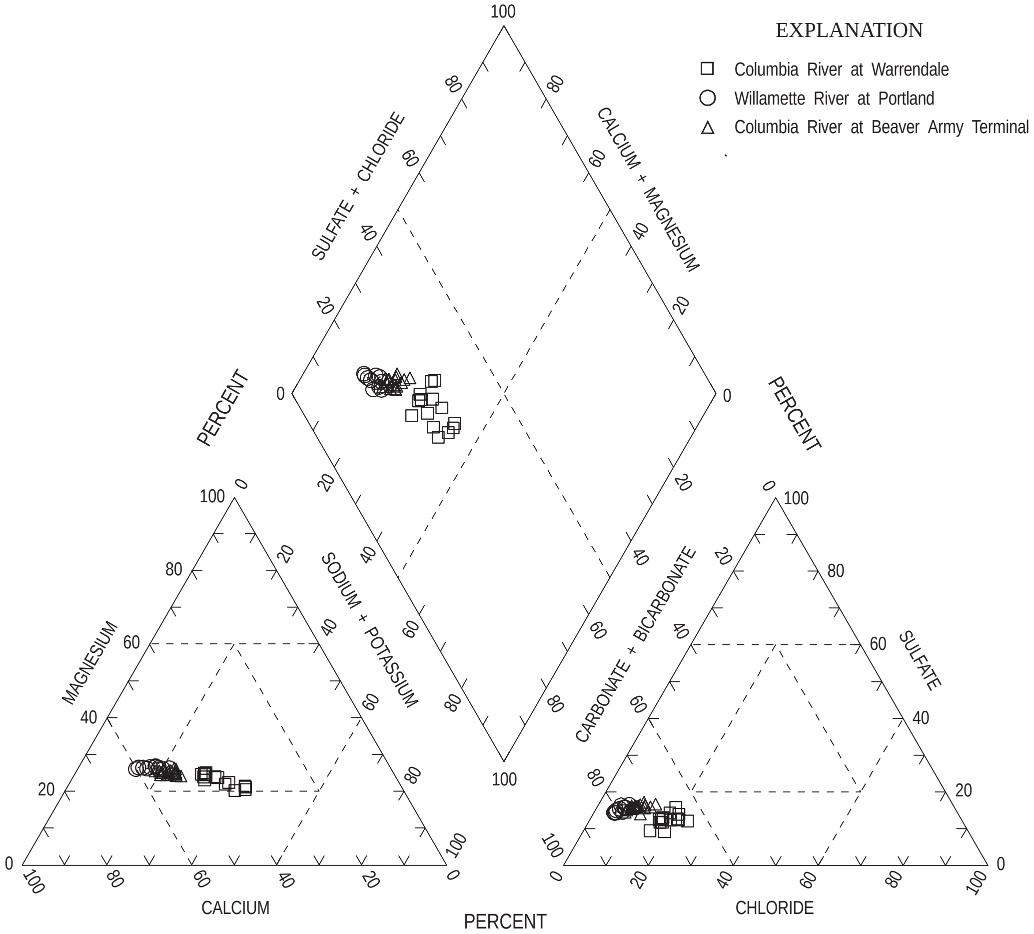


Figure 29. Major-ion composition in the Columbia River at Warrendale, Willamette River at Portland, and Columbia River at Beaver Army Terminal, lower Columbia River Basin, Oregon and Washington, 1994.

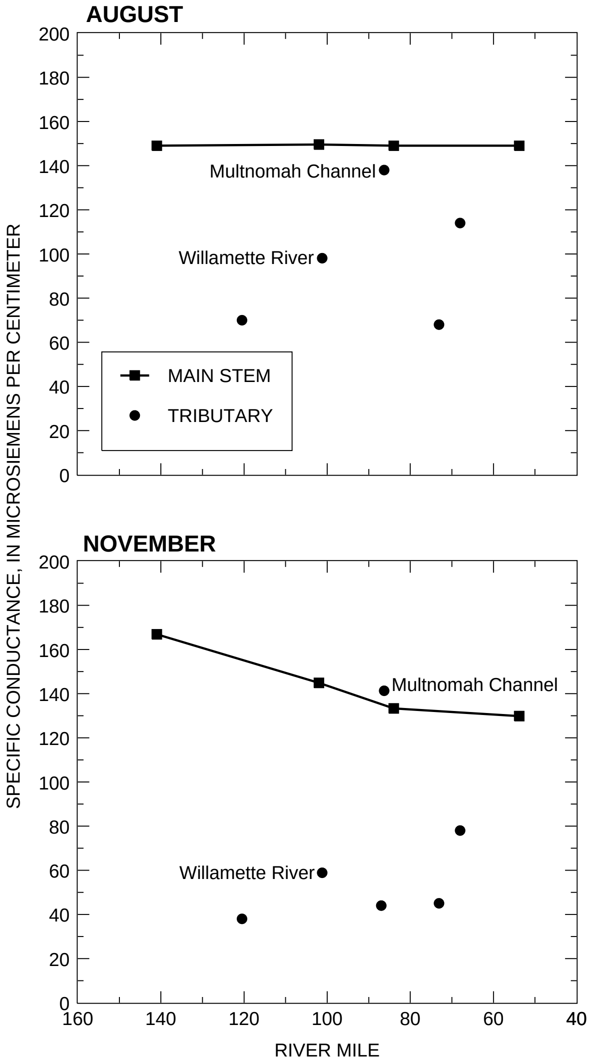


Figure 30. Specific conductance in the main stem and tributaries during August and November, lower Columbia River Basin, Oregon and Washington, 1994. (Willamette River = Willamette River at Portland, Oregon; Multnomah Channel = Multnomah Channel near mouth at St. Helens, Oregon)

specific conductance in the main stem. Consequently, from July to September of 1994, specific conductance varied little in the main stem. In August of 1994, for example, specific conductance along the main stem is nearly constant (fig. 30).

On the basis of the hydrologic connectivity between the Willamette River and Multnomah Channel, only small differences in specific conductance might be expected between the Willamette River and Multnomah Channel. Specific conductance, however, differs considerably between these sites and at times is related to the passage of Columbia River water through Multnomah Channel and at other times is related to local point and nonpoint sources. The major-ion composition throughout Multnomah Channel is generally the same as that in the Willamette River at Portland but differs from the Columbia River near Columbia City (RM 84) (fig. 31), which is located just downstream from the mouth of the Multnomah Channel (RM 86.3). The similarity in the composition of major ions between the Willamette River and Multnomah Channel suggests that the Willamette River is the dominant source of water throughout Multnomah Channel.

Concentration distributions of Ca, Mg, Na, K, Cl, SO_4, and TDS in Multnomah Channel exceed concentrations in the Willamette River (table 25), which may reflect the influence of local point and nonpoint sources. Local point sources affecting Multnomah Channel include effluents from the City of Scappoose’s sewage-treatment plant and effluents from Sauvie Island Moorage Company’s sewage-treatment plant (table 46, at back of report; fig. 10). Nonpoint sources include agricultural runoff from the southern portion of Sauvie Island and along the left bank of Multnomah Channel, as well as animal wastes associated with grazing within Sauvie Island’s northern wetlands area. Concentrations of Na and Cl in Multnomah Channel represent concentration maxima for the 10 sites sampled in 1994. Na and Cl are indices of human/animal wastes and commonly are associated with effluents from sewage-treatment plants (Fair and Geyer, 1954, p. 549). Concentrations of Na and Cl were highest in Multnomah Channel from May to October, a period when streamflow in the Willamette River is low and the potential effects from local point and nonpoint sources are high.

Although Columbia River water was at times present in Multnomah Channel, the Columbia River cannot account for the high major ion concentrations. From May to September, Columbia River waters may mix with waters in Multnomah Channel by flowing up the Willamette River (during high tide) and down Multnomah Channel (Rickert and others, 1976). Additionally, the lower silica concentrations, typical of Columbia River water, confirm the presence of Columbia River water in Multnomah Channel from May through September, 1994 (fig. 32). However, during the time when Columbia River water was resident in Multnomah Channel, major-ion concentrations in the Columbia

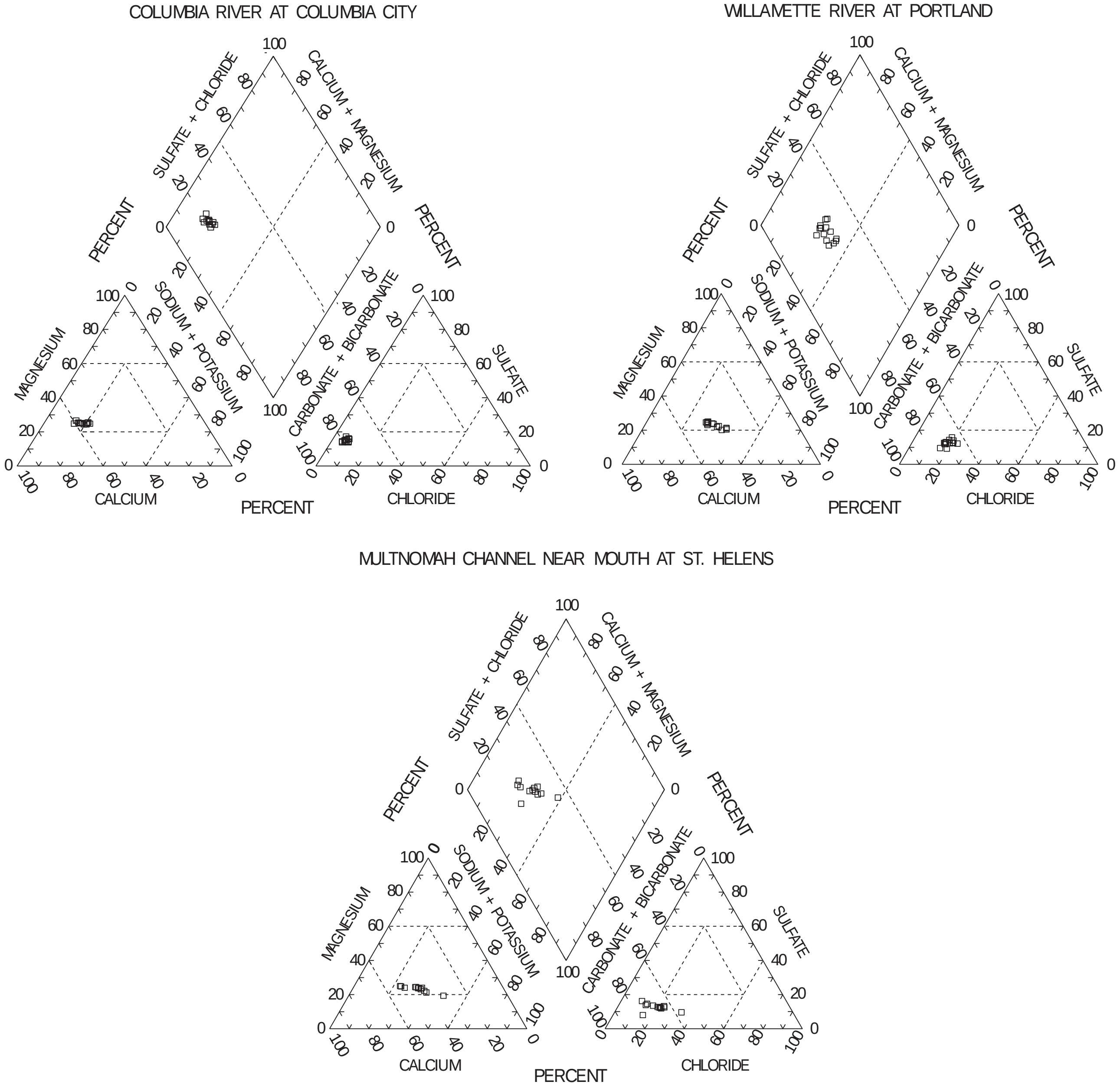


Figure 31. Major-ion composition in the Columbia River near Columbia City, Willamette River at Portland, and Multnomah Channel near mouth at St. Helens, lower Columbia River Basin, Oregon, 1994.

River at Warrendale and Columbia River at Hayden Island were small and cannot account for the high Na and Cl concentrations in Multnomah Channel. Additionally, the small Na and Cl concentrations in the Columbia River main stem in the vicinity of Portland’s sewage-treatment plant (RM 105.5) suggest that Na and Cl discharges from Portland’s plant are diluted, and hence, are not a source of ions to Multnomah Channel as a result of streamflow-reversal processes.

Specific conductance was selected as a major-ion surrogate for the purpose of examining trends in water quality; it is an overall measure of ionic composition. Results of the seasonal Kendall trend test for specific conductance for the period 1973–94 indicate that significant ($\rho < 0.05$) downward trends exist in the Columbia River at Warrendale (table 50, at back of report). Both nonflow- and flow-adjusted methods resulted in a 0.5-percent decrease per year in the median of 160 µS/cm. A decrease of this magnitude, for the nonflow adjusted trend, equates

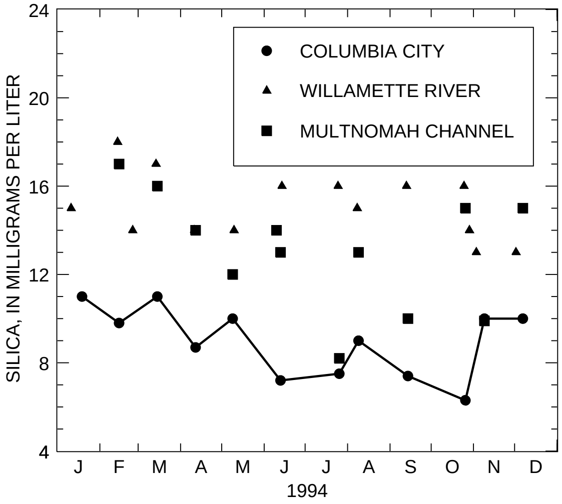


Figure 32. Concentrations of silica in the Willamette River at Portland, Multnomah Channel near mouth at St. Helens, and Columbia River near Columbia City, lower Columbia River Basin, Oregon, 1994. (Willamette River = Willamette River at Portland, Oregon; Multnomah Channel = Multnomah Channel near mouth at St. Helens, Oregon; Columbia River near Columbia City, Oregon)

to a decrease of about 1 µS/cm/year at Warrendale. No significant trends in specific conductance were found at the Willamette River at Portland for the period 1974–95. As expected, TDS, which is related proportionally to specific conductance, also had significant ($\rho < 0.05$) downward trends at Warrendale for both nonflow-adjusted and flow-adjusted methods. The median TDS concentration (96 mg/L) for the nonflow-adjusted trends, for example, decreased by 0.6 percent per year (-0.61 mg/L/year) at Warrendale for the period 1973–94.

Monthly and annual mean daily load estimates were calculated using the ESTIMATOR program for TDS in the Columbia River at Warrendale, Columbia River at Beaver Army Terminal, and Willamette River at Portland (table 26). In 1994, the annual TDS load increased between the Columbia River at Warrendale (RM 141) and the Columbia River at Beaver Army Terminal (RM 53.8). In this reach, the Willamette River alone accounted for 38 percent of the difference in annual loads between Warrendale and Beaver. Additionally, the monthly mean daily TDS loads at all three sites varied seasonally with streamflow; higher TDS loads were associated with higher streamflow conditions. In the Willamette River, for example, the high-streamflow months of fall and winter represented 76 percent of the annual streamflow and 74 percent of the annual TDS load. In contrast, the low-streamflow months of summer represented only 8 percent of the annual streamflow and 9 percent of the annual TDS load.

The Willamette River at Portland accounts for most of the difference in monthly mean daily TDS loads between the Columbia River at Warrendale and Columbia River near Beaver Army Terminal during the spring and summer months (April to September) (table 26). During these months, for example, the monthly mean daily loads in the Willamette River account for 57 to 100 percent of the difference. On average, the proportion of load contribution to the Columbia River between Warrendale and Beaver Army Terminal attributable to the Willamette River is 71 percent during the spring and summer months and 38 percent during the fall and winter months (October to March). The fall and winter month proportion is identical to that based on the annual mean daily load but is considerably different from the 71 percent during the spring and summer months. The higher proportion of load for the Willamette River during the spring and summer months probably reflects the large number of point and nonpoint sources affecting TDS in the Willamette River, in comparison to other tributaries in the lower Columbia River. The higher proportion of load contribution of the Willamette River to the Columbia River, especially in July and August (a period when streamflow on the Willamette is at its yearly low) implies that summer TDS loads were small in the other lower Columbia River tributaries. To underscore the minor effect of other lower Columbia River tributaries, the Kalama River on September 6, 1994, accounted for only 1 percent of the difference between the September mean daily loads for Warrendale and Beaver. The Cowlitz River was more significant, accounting for 34 percent of the difference in TDS load but is small in relation to the 75-percent contribution of the Willamette River.

Trace Elements

Median concentrations of most trace elements in filtered-water samples at the fixed sites sampled in 1994 were generally similar to background concentrations in North American streams, as well as concentrations found in inland waters throughout the world (table 27). Iron, however, is an exception. On the basis of historical data (1951–93), the interquartile range for iron concentrations in the lower Columbia River Basin was 20 to 130 µg/L and

Table 26. Calculated monthly and annual mean daily loads for total dissolved solids at selected sites, lower Columbia River Basin, Oregon, 1994

[Loads are reported in tons per day; see table 7 for full site names; all mean daily loads estimated using ESTIMATOR (Cohn and others, 1992)]

Month	Warrendale	Willamette	Beaver	$\frac{\text{Willamette}}{\text{Beaver} - \text{Warrendale}} \text{x100}$
January	39,000	6,200	53,000	44
February	45,000	4,700	56,000	43
March	41,000	5,100	53,000	42
April	43,000	4,000	50,000	57
May	52,000	2,000	54,000	100
June	43,000	1,900	46,000	63
July	32,000	1,300	34,000	65
August	21,000	1,300	23,000	65
September	18,000	1,500	20,000	75
October	24,000	2,100	29,000	42
November	31,000	6,200	51,000	31
December	39,000	9,700	77,000	26
Annual	36,000	3,800	46,000	38

far exceeded the interquartile range of 14 to 48 µg/L for sites sampled in 1994. The high iron concentrations, rather than being indicative of a trend over time, are the result of a disproportionately high number of sites sampled historically in the Willamette River Basin. The Willamette River, both historically and in 1994, was a source of high concentrations of filtered iron to the lower Columbia River. In 1994, for example, the interquartile range for filtered-water iron concentrations in the Willamette River at Portland was 49 to 182 µg/L, with a maximum concentration of 290 µg/L (table 28). In comparison, the interquartile range for filtered-water iron concentrations in the Columbia River at Warrendale for 1994 was only 7 to 18 µg/L. Additionally, the filtered-water iron concentration in the Willamette River collected by ODEQ on February 23, 1994, exceeded the water-quality criterion for the protection of human health (table 47, at back of report).

Arsenic was detected in several filtered-water samples in the lower Columbia River Basin. Its presence is important, because it is a known carcinogen to humans. Although median concentrations of arsenic were low (< 1 µg/L in 1994 and 1 µg/L from 1951 to 1993), a distinct pattern is present when main-stem data are separated from tributary data. In 1994, for example, arsenic was consistently detected at a concentration of 1 µg/L in 15 of 16 filtered-water determinations at all four main-stem sites. Additionally, the detections were present over a period of 1994 that spanned both high and low streamflow conditions. Based on all arsenic determinations (main stem and tributaries) in 1994, arsenic concentrations in 38 percent of the samples exceeded ambient water-quality criteria for the protection of human health and human-health advisories for drinking water (table 47, at back of report). Based on historical data, arsenic also was detected consistently in the Columbia River at Warrendale (1974–93) at RM 141 and Columbia River at Bradwood (1974–75) at RM 38.9 (U.S. Geological Survey NWIS retrieval). The absence of detectable arsenic in filtered-water samples from tributaries of the lower Columbia River Basin and the presence of arsenic in the main stem suggests that sources of arsenic exist above the lower basin. Data collected as part of the USGS’s NAWQA Program support the presence of outside sources. For example, the Yakima River (6,200 square miles of drainage), which flows into the Columbia River at RM 335.2, is an upstream source of arsenic. Monthly measurements of arsenic for the period 1987–90 at

Table 27. Comparison of selected major- and trace-element concentrations in filtered water in the lower Columbia River Basin to surface waters worldwide

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one value per month was statistically summarized; values are reported in micrograms per liter; NASQAN, National Stream Accounting Network based on data from 300 sites across the United States; <, less than; --, no data; *, percentile value below method reporting limit]

Element name	Background concentrations, inland waters[a]	North American streams [b] (median)	NASQAN 1974-81[c]			Lower Columbia River Basin (1951-93)[d]					Lower Columbia River Basin (1994)				
			Value at indicated percentile			Number of samples	Value at indicated percentile				Number of samples	Value at indicated percentile			
			25	50	75		25	50	75	90		25	50	75	90
Aluminum	< 30	--	--	--	--	511	*	13	100	300	49	7	12	22	93
Antimony	.1	--	--	--	--	15	*	*	*	*	41	<1	<1	<1	<1
Arsenic	2	<10	<1	1	3	607	*	1	1	2	41	<1	< 1	1	1
Beryllium	.01	<.3	--	--	--	350	*	*	*	*	41	<1	<1	<1	<1
Cadmium	.07	1	--	--	--	--	--	--	--	--	41	<1	<1	<1	<1
Chromium	.5	5.8	--	--	--	--	--	--	--	--	41	<1	<1	<1	1.0
Cobalt	.05	<1	--	--	--	493	*	*	*	*	48	<1	<1	<1	< 1
Copper	1.8	--	--	--	--	885	1	3	6	9	41	<1	1	2	2
Iron	< 30	--	36	63	157	758	20	60	130	250	81	14	25	48	120
Lead	.2	--	3	4	6	876	*	1	5	13.3	41	<1	<1	<1	<1
Manganese	<5	--	11	24	51	1,121	*	10	40	150	82	<1	2	5.2	11
Mercury	.01	([e])	--	--	--	--	--	--	--	--	41	< .1	< .1	< .1	< .1
Nickel	.3	10	--	--	--	527	*	*	*	5.5	48	<1	<1	<1	<1
Selenium	.1	.2	<1	<1	1	501	*	*	*	*	44	< 1	< 1	< 1	< 1
Silver	.3	.3	--	--	--	487	*	*	*	*	48	< 1	< 1	< 1	<1
Zinc	10	20	12	15	21	1,753	*	10	20	38	41	<1	1	2	4

[a] Based on a compendium of author contributions of inland-water chemistry worldwide (Forstner and Wittmann, 1979, p. 87).

[b] Hem, 1989

[c] Percentiles are calculated from site-mean concentrations (Smith and others, 1987).

[d] U.S. Environmental Protection Agency’s STOrage and RETrieval system (STORET), U.S. Geological Survey’s National Water Information System (NWIS), and Tetra Tech, Inc., Redmond, Washington, unpub. data, 1994

[e] Mercury concentrations rarely exceed a few tenths of a microgram per liter (Hem, 1989).

Table 28. Distribution of major- and trace-element concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in micrograms per liter; antimony, beryllium, cadmium, cobalt, lead, nickel, and selenium are not included in this table, because no samples had values greater than the method reporting limit; see table 8 for method reporting limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Aluminum								
Warrendale	4	5	--	--	8	--	--	17
Hayden Island	4	6	--	--	10	--	--	24
Columbia City	5	6	--	--	20	--	--	34
Beaver	8	5	5	9	16	40	50	50
Willamette River	8	5	5	8	56	148	170	170
Multnomah Channel	4	9	--	--	13	--	--	170
Sandy River	4	12	--	--	14	--	--	29
Lewis River	4	2	--	--	4	--	--	9
Kalama River	4	6	--	--	8	--	--	10
Cowlitz River	4	7	--	--	20	--	--	44
All Sites	49	2	5	7	12	22	93	174
Arsenic								
Warrendale	4	1	--	--	1	--	--	1
Hayden Island	4	1	--	--	1	--	--	1
Columbia City	4	1	--	--	1	--	--	1
Beaver	4	<1	--	--	1	--	--	1
Willamette River	5	<1	--	--	<1	--	--	<1
Multnomah Channel	4	<1	--	--	<1	--	--	1
Sandy River	4	<1	--	--	<1	--	--	<1
Lewis River	4	<1	--	--	<1	--	--	<1
Kalama River	4	<1	--	--	<1	--	--	<1
Cowlitz River	4	<1	--	--	<1	--	--	<1
All Sites	41	<1	<1	<1	<1	1	1	1
Barium								
Warrendale	4	22	--	--	24	--	--	28
Hayden Island	4	21	--	--	23	--	--	30
Columbia City	4	20	--	--	21	--	--	23
Beaver	8	17	17	18	20	21	21	21
Willamette River	8	5	5	6	7	7	8	8
Multnomah Channel	4	6	--	--	8	--	--	11
Sandy River	4	1	--	--	2	--	--	2
Lewis River	4	1	--	--	1	--	--	1

Table 28. Distribution of major- and trace-element concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in micrograms per liter; antimony, beryllium, cadmium, cobalt, lead, nickel, and selenium are not included in this table, because no samples had values greater than the method reporting limit; see table 8 for method reporting limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile 10	25	50	75	90	Maximum value
Barium—Continued								
Kalama River	4	1	--	--	1	--	--	2
Cowlitz River	4	2	--	--	2	--	--	3
All Sites	48	1	1	2	7	21	24	30
Chromium								
Warrendale	4	<1	--	--	<1	--	--	1
Hayden Island	4	<1	--	--	1	--	--	2
Columbia City	4	<1	--	--	<1	--	--	1
Beaver	4	<1	--	--	<1	--	--	1
Willamette River	5	<1	--	--	<1	--	--	<1
Multnomah Channel	4	<1	--	--	<1	--	--	1
Sandy River	4	<1	--	--	<1	--	--	<1
Lewis River	4	<1	--	--	<1	--	--	<1
Kalama River	4	<1	--	--	<1	--	--	1
Cowlitz River	4	<1	--	--	<1	--	--	<1
All Sites	41	<1	<1	<1	<1	<1	1	2
Copper								
Warrendale	4	1	--	--	1	--	--	3
Hayden Island	4	<1	--	--	<1	--	--	2
Columbia City	4	1	--	--	2	--	--	2
Beaver	4	<1	--	--	1	--	--	2
Willamette River	5	<1	--	--	<1	--	--	2
Multnomah Channel	4	1	--	--	2	--	--	3
Sandy River	4	<1	--	--	<1	--	--	1
Lewis River	4	<1	--	--	<1	--	--	<1
Kalama River	4	<1	--	--	1	--	--	2
Cowlitz River	4	<1	--	--	1	--	--	2
All Sites	41	<1	<1	<1	1	2	2	3
Iron								
Warrendale	11	2	3	7	9	18	24	25
Hayden Island	12	5	5	8	10	17	33	39
Columbia City	12	10	11	14	18	30	45	49
Beaver	9	10	10	14	20	44	53	53
Willamette River	10	33	34	49	104	182	280	290

Table 28. Distribution of major- and trace-element concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in micrograms per liter; antimony, beryllium, cadmium, cobalt, lead, nickel, and selenium are not included in this table, because no samples had values greater than the method reporting limit; see table 8 for method reporting limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile 10	25	50	75	90	Maximum value
Iron—Continued								
Multnomah Channel	11	14	14	27	43	120	154	160
Sandy River	4	38	--	--	53	--	--	66
Lewis River	4	25	--	--	38	--	--	48
Kalama River	4	17	--	--	19	--	--	20
Cowlitz River	4	44	--	--	61	--	--	73
All Sites	81	1	8	14	25	48	120	290
Manganese								
Warrendale	11	<1	<1	<1	<1	<1	2	2
Hayden Island	12	<1	<1	1	1	2	3	3
Columbia City	12	<1	<1	<1	2	3	4	4
Beaver	9	<1	<1	<1	1	3	3	3
Willamette River	11	<1	1	6	8	11	16	16
Multnomah Channel	11	<1	<1	2	4	11	20	20
Sandy River	4	3	--	--	4	--	--	4
Lewis River	4	3	--	--	12	--	--	12
Kalama River	4	<1	--	--	2	--	--	4
Cowlitz River	4	5	--	--	6	--	--	7
All Sites	82	<1	<1	<1	2	5	11	20
Mercury								
Warrendale	4	<.1	--	--	<.1	--	--	<.1
Hayden Island	4	<.1	--	--	<.1	--	--	<.1
Columbia City	4	<.1	--	--	<.1	--	--	<.1
Beaver	4	<.1	--	--	<.1	--	--	3.6
Willamette River	5	<.1	--	--	<.1	--	--	.6
Multnomah Channel	4	<.1	--	--	<.1	--	--	.1
Sandy River	4	<.1	--	--	<.1	--	--	<.1
Lewis River	4	<.1	--	--	<.1	--	--	<.1
Kalama River	4	<.1	--	--	<.1	--	--	<.1
Cowlitz River	4	<.1	--	--	<.1	--	--	<.1
All Sites	41	<.1	<.1	<.1	<.1	<.1	<0.1	3.6
Molybdenum								
Warrendale	4	<1	--	--	<1	--	--	1
Hayden Island	4	<1	--	--	<1	--	--	1

Table 28. Distribution of major- and trace-element concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; values are reported in micrograms per liter; antimony, beryllium, cadmium, cobalt, lead, nickel, and selenium are not included in this table, because no samples had values greater than the method reporting limit; see table 8 for method reporting limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Molybdenum—Continued								
Columbia City	4	<1	--	--	<1	--	--	1
Beaver	8	<1	<1	<1	3	5	5	5
Willamette River	8	<1	<1	<1	3	5	10	10
Multnomah Channel	4	<1	--	--	<1	--	--	<1
Sandy River	4	<1	--	--	<1	--	--	<1
Lewis River	4	<1	--	--	<1	--	--	<1
Kalama River	4	<1	--	--	<1	--	--	<1
Cowlitz River	4	<1	--	--	<1	--	--	<1
All Sites	48	<1	<1	<1	<1	<1	5	10
Uranium								
Warrendale	4	<1	--	--	<1	--	--	<1
Hayden Island	4	<1	--	--	<1	--	--	1
Columbia City	4	<1	--	--	<1	--	--	<1
Beaver	4	<1	--	--	<1	--	--	<1
Willamette River	6	<1	<1	<1	<1	<1	<1	<1
Multnomah Channel	4	<1	--	--	<1	--	--	<1
Sandy River	4	<1	--	--	<1	--	--	<1
Lewis River	4	<1	--	--	<1	--	--	<1
Kalama River	4	<1	--	--	<1	--	--	<1
Cowlitz River	4	<1	--	--	<1	--	--	<1
All Sites	42	<1	<1	<1	<1	<1	<1	1
Zinc								
Warrendale	4	<1	--	--	<1	--	--	8
Hayden Island	4	<1	--	--	2	--	--	4
Columbia City	4	<1	--	--	1	--	--	2
Beaver	4	<1	--	--	3	--	--	14
Willamette River	5	1	--	--	2	--	--	2
Multnomah Channel	4	1	--	--	2	--	--	5
Sandy River	4	1	--	--	2	--	--	2
Lewis River	4	<1	--	--	<1	--	--	3
Kalama River	4	<1	--	--	2	--	--	2
Cowlitz River	4	<1	--	--	<1	--	--	1
All Sites	41	<1	<1	<1	1	2	4	14

the terminus of the Yakima River Basin had a median filtered-water arsenic concentration of 1µg/L. Additionally, 25 percent of the time, the arsenic concentration at the terminus of the basin was 2 µg/L, and waters draining agricultural fields in the Yakima River Basin had arsenic concen-trations as high as 9 µg/L (Fuhrer and others, in press).

In 1994, chromium was detected in 8 of 16 filtered-water samples at the 4 main-stem sites (table 29). In contrast, chromium was detected at only 2 of 6 tributary sites and in only 2 of 25 determinations. Chromium was detected most frequently in the Columbia River at Hayden Island, where three of four filtered-water samples had detectable concentrations ranging from 1 to 2 µg/L. Several possible point sources of chromium exist along the main stem of the Columbia River. These sources include some chemical industries (Kalama Chemical [RM 74] and Wacker Siltronic Corporation [Willamette RM 6.6]), wood–treating and wood-product industries (Allweather Wood Treaters [RM 123.3] and Boise Cascade St. Helens Veneer Mill [RM 86]), aluminum industries (ALCOA [RM 103] and Reynolds Metal in Troutdale [RM 120]), and miscellaneous facilities (Pendleton Woolen Mills [RM 122.8] and the Gould Superfund site [Willamette RM 7.0]). Table 47 (at back of report) provides a more complete listing of possible point-source contributions. Chromium was detected only once in Multnomah Channel (August 8, 1994), and its detection coincided with a time period in which surface water in the Columbia River flows up the Willamette River and down Multnomah Channel. The detection of chromium also coincides with lower silica concentrations which are indicative of the presence of Columbia River water in Multnomah Channel (see the “Major Ions and Related Measures Section” section for discussion). None of the chromium detections, however, exceeded ambient water-quality criteria or drinking-water guidelines (table 49, at back of report).

Mercury was detected in filtered-water samples in 3 of 41 determinations (table 29). It was detected at the Multnomah Channel (0.1 µg/L), Willamette River at Portland (0.6 µg/L), and Columbia at Beaver Army Terminal (3.6 µg/L). Mercury was detected in the Willamette River in June and Beaver Army Terminal and Multnomah Channel in August, with all detections occurring during low-streamflow conditions. Detections during low streamflows for most trace elements are to be expected, because trace elements discharged from point sources are diluted to a lesser extent during periods of extended low streamflow. Detections of mercury are problematic given its ubiquitous nature as a common field and laboratory contaminant (Zief and Mitchell, 1976, p. 9). The concentrations of mercury detected in this study were well above the 0.01 µg/L reported by Forstner and Wittmann (1979) as a background concentration for inland waters. Also, suspended-sediment samples, which were concurrently collected with filtered-water samples, lacked anomalies that would support the presence of high concentrations of filtered mercury. Despite these questions, filtered-water mercury concentrations exceeded ambient water-quality criteria and drinking-water criteria (table 47, at back of report); however, caution should be exercised in using these data given mercury’s affinity to contaminate samples between the time of collection and processing and in the laboratory, prior to analysis.

In 1994 and historically, higher concentrations of filtered-water iron in the Willamette River at Portland were often associated with high streamflows which usually started in October. On November 3, 1994, for example, the filtered-water iron concentration in the Willamette River (290 µg/L) was 6 times that measured on September 13, 1994, during the low-streamflow period. The corresponding filtered-water iron load (120,000 lbs/d [pounds per day]) on November 3, 1994, was about 50 times that measured on September 13, 1994 (2,400 lbs/d), during the low-flow period (table 30). The filtered-water iron load during winter-high flows in the Willamette River also represents a large proportion of the filtered-water iron load in the Columbia River. For the November 3, 1994 sampling, the filtered-water iron load in the Willamette River is nearly 17 times that measured on November 8, 1994, in the Columbia River at Warrendale (7,100 lbs/d). The large instantaneous load and concentration of filtered-water iron in November in the Willamette River underscores the significance of the Willamette River as a source of iron during winter high streamflows. Similar concentration patterns and trends in load also exist for aluminum and, to a lesser extent, for manganese.

Table 29. Frequency of detection of selected major and trace elements in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[Method reporting limits (MRL) are reported in micrograms per liter; see table 7 for full site names; n, number of samples analyzed; --, not detected]

Element name	MRL	Main stem				Tributaries					
		Warrendale	Hayden Island	Columbia City	Beaver	Sandy River	Willamette River	Lewis River	Multnomah Channel	Kalama River	Cowlitz River
		n = 4	n = 4	n = 4	n = 4	n = 4	n = 5	n = 4	n = 4	n = 4	n = 4
Aluminum	1	4	4	4	4	4	5	3	4	4	4
Antimony	1	--	--	--	--	--	--	--	--	--	--
Arsenic	1	4	4	4	3	--	--	--	1	--	--
Beryllium	1	--	--	--	--	--	--	--	--	--	--
Cadmium	1	--	--	--	--	--	--	--	--	--	--
Chromium	1	2	3	2	1	--	--	--	1	1	--
Cobalt	1	--	--	--	--	--	--	--	--	--	--
Copper	1	4	2	4	3	1	3	--	--	2	3
Iron	3	4	4	4	4	4	5	4	4	4	4
Lead	1	--	--	--	--	--	--	--	--	--	--
Manganese	1	--	3	1	2	4	4	3	3	3	4
Mercury	.1	--	--	--	1	--	1	--	1	--	--
Nickel	1	--	--	--	--	--	--	--	--	--	--
Selenium	1	--	--	--	--	--	--	--	--	--	--
Silver	1	--	--	--	--	--	--	--	--	--	--
Zinc	1	2	3	2	3	4	5	1	4	3	2

Table 30. Instantaneous loads for major and trace elements for selected low and high streamflow conditions in the Columbia River at Warrendale, Willamette River at Portland, and Columbia River at Beaver Army Terminal, lower Columbia River Basin, Oregon, 1994

[Loads are reported in pounds per day; ft^3/s, cubic feet per second; Filt., filtered load; Sus., suspended load; F/S, filtered-water load divided by suspended load; the term “filtered” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; --, value could not be calculated because at least one concentration was below the method reporting limit]

Element name	Columbia River at Warrendale						Columbia River at Beaver Army Terminal						Willamette River at Portland					
	High streamflow ($233,000 ft^3/s$) June 15, 1994			Low streamflow ($93,800 ft^3/s$) August 8, 1994			High streamflow ($234,000 ft^3/s$) April 14, 1994			Low streamflow ($90,800 ft^3/s$) August 11, 1994			High streamflow ($76,600 ft^3/s$) November 3, 1994			Low streamflow ($9,100 ft^3/s$) September 13, 1994		
	Filt.	Sus.	F/S	Filt.	Sus.	F/S	Filt.	Sus.	F/S	Filt.	Sus.	F/S	Filt.	Sus.	F/S	Filt.	Sus.	F/S
Al	6,000	920,000	0.01	4,000	130,000	0.03	59,000	1,100,000	0.05	4,400	270,000	0.02	66,000	2,900,000	0.02	1,000	18,000	0.06
Sb	--	20	--	--	4	--	--	30	--	--	4	--	--	40	--	--	.2	--
As	1,000	100	10	500	20	25	--	100	--	500	30	17	--	300	--	--	2	--
Ba	28,000	8,000	3.5	12,000	1,200	10	25,000	13,000	1.9	10,000	2,200	4.5	2,000	17,000	.12	200	150	1.3
Be	1,000	--	--	--	--	--	--	--	--	--	--	--	--	100	--	--	--	--
Cd	--	--	--	--	4	--	--	10	--	--	--	--	--	10	--	--	.1	--
Cr	--	700	--	500	100	5	--	800	--	500	200	2.5	--	2,400	--	--	20	--
Co	--	200	--	--	40	--	--	300	--	--	70	--	--	900	--	--	7	--
Cu	1,000	600	1.7	500	100	5	--	600	--	500	200	2.5	800	2,100	.38	50	10	5
Fe	11,000	570,000	.02	4,600	87,000	.05	60,000	620,000	.10	7,300	160,000	.05	120,000	2,000,000	.06	2,400	13,000	.18
Pb	--	400	--	--	70	--	--	300	--	--	100	--	--	1,200	--	--	7	--
Mn	--	18,000	--	--	3,400	--	800	14,000	.06	--	5,900	--	4,100	64,000	.06	300	1,000	.30
Hg	100	2	50	--	--	--	--	8	--	--	.7	--	--	4	--	--	.04	--
Mo	--	8	--	--	1	--	--	20	--	--	2	--	--	30	--	--	.4	--
Ni	--	400	--	--	60	--	--	400	--	--	100	--	--	1,300	--	--	8	--
Se	--	8	--	--	--	--	--	6	--	--	2	--	--	10	--	--	--	--
Ag	--	4	--	--	.8	--	--	9	--	--	1	--	--	10	--	--	.5	--
Ur	--	40	--	--	7	--	--	40	--	--	10	--	--	70	--	1	.8	1.2
Zn	--	3,200	--	500	600	.83	18,000	2,400	7.5	1,000	700	1.4	800	4,000	.20	100	40	2.5

The suspended-iron concentration (iron concentration associated with the suspended-sediment fraction) on November 3, 1994, in the Willamette River (6.1 percent) was about 45 percent larger than that measured on November 8, 1994 in Columbia River at Warrendale (4.2 percent). Overall, suspended-iron concentrations in the Willamette River were the highest for the 10 sites sampled in the lower Columbia River Basin in 1994 (table 31). Unlike filtered-water iron concentrations, suspended-iron concentrations were similar during the winter high flows and the summer low flows. However, suspended-sediment loads and, consequently, suspended-iron loads were much greater during periods of high flow than during periods of low flow. The respective high- and low-streamflow concentrations of suspended iron (6.1 and 5.2 percent) on November 3 and September 13 differed by only 0.9 percent, yet the respective suspended-iron load during the high-flow sampling in November (2,000,000 lbs/d) was more than 150 times that measured in September (13,000 lbs/d) (table 30). The large difference in suspended-iron load between seasons is the result of the large differences in November and September suspended-sediment concentrations (81 mg/L and 5 mg/L, respectively) and streamflows (76,000 ft^3/s and 9,100 ft^3/s, respectively).

The suspended form of iron is the dominant transport phase in the lower Columbia River. During high streamflows in the Columbia River at Warrendale, the suspended-iron load exceeded the filtered-water load by a factor of 50; during low streamflows, the suspended load was still dominant, exceeding the filtered-water load by a factor of 20. Patterns similar to those for iron at Warrendale also existed at other sites sampled in 1994. Additionally, the suspended form is the major transport phase for aluminum and manganese.

The significance of tributary loads of suspended trace elements to the main stem of the Columbia River was determined by comparing instantaneous loads at tributary sites to instantaneous loads in the Columbia River at Warrendale. The summer low-streamflow months were selected as the time period for comparing loads, because they approximate steady-state streamflow conditions to a greater extent (based on present-study data) than the winter high-streamflow months. Ideally, a winter high-streamflow period would be best for comparing instantaneous loads because of the relation between suspended-sediment transport and rain-induced high streamflows; however, samples collected for use in making intersite-load comparisons in this study were sometimes separated by days and weeks. Also, during winter months, intrasite variations in both streamflow and suspended-sediment concentration can be large over periods as long as days or weeks. During the low-streamflow period, the Willamette River and the Cowlitz River were the largest contributors of suspended trace elements. For example, the suspended-silver load during the low-flow period in the Willamette River (0.5 lbs/d) was 60 percent of the suspended load at Warrendale (0.8 lbs/day), even though the streamflow in the Willamette River was only 10 percent of the streamflow in the Columbia River at Warrendale[5]. The Cowlitz River had suspended loads of nickel (25 lbs/d), aluminum (23 tons/day), and antimony (1.2 lb/d) during low-flow conditions (3,230 ft^3/s), which were respectively, 42 percent, 35 percent, and 30 percent of the corresponding loads at Warrendale, yet the streamflow was only 3 percent of the streamflow at Warrendale (table 30). Conversely, the Willamette River and the Cowlitz River were relatively small contributors of suspended zinc and arsenic. The suspended zinc and arsenic loads during the low-flow period in the Willamette River were 8 and 6 percent, respectively, of the suspended loads at the Columbia River at Warrendale. Percentages for suspended zinc and arsenic were similarly low in the Cowlitz River. On the basis of tributary loads during summer low-flow months, sources of suspended silver, nickel, aluminum, and antimony exist in the lower Columbia Basin and the sources of suspended zinc and arsenic exist outside of the lower basin.

Comparing transport phases (filtered-water versus suspended) for several constituents, including Sb, Be, Cd, Co, Pb, Hg, Se, and Ag, is problematic because of the large amount of censored data for filtered-water determinations. In most cases where trace elements in filtered-water samples were detected and quantified, however, the filtered-water fraction was the dominant transport phase.

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[5] A potential point source of silver in the lower Willamette River is the EPA Gould Superfund site (a former battery manufacturing and recycling plant) managed by Canonie Environmental Services Corporation which is allowed to discharge up to 4.1 µg/L silver under the NPDES program (table 46, at back of report).

Table 31. Distribution of major- and trace-element concentrations in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994

[Values are reported in micrograms per gram, except aluminum and iron which are in percent; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore percentile not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Aluminum, in percent								
Warrendale	4	6.4	--	--	6.4	--	--	6.9
Hayden Island	4	6.5	--	--	7.2	--	--	8.6
Columbia City	4	6.4	--	--	6.7	--	--	8.3
Beaver	4	6.8	--	--	7.1	--	--	7.5
Willamette River	4	7.4	--	--	8.1	--	--	8.8
Multnomah Channel	4	7.7	--	--	8.0	--	--	9.3
Sandy River	4	5.9	--	--	6.7	--	--	7.1
Lewis River	3	4.3	--	--	4.7	--	--	7.4
Kalama River	4	4.9	--	--	5.2	--	--	6.5
Cowlitz River	4	8.0	--	--	8.2	--	--	8.7
All Sites	40	4.3	4.9	6.4	6.9	8.0	8.6	9.3
Iron, in percent								
Warrendale	4	4.0	--	--	4.1	--	--	4.3
Hayden Island	4	4.1	--	--	4.7	--	--	6.1
Columbia City	4	4.1	--	--	4.3	--	--	5.2
Beaver	4	4.1	--	--	4.2	--	--	5.4
Willamette River	4	5.2	--	--	5.9	--	--	6.1
Multnomah Channel	4	5.0	--	--	5.3	--	--	6.4
Sandy River	4	3.0	--	--	4.0	--	--	4.8
Lewis River	3	3.8	--	--	3.9	--	--	4.2
Kalama River	4	3.3	--	--	3.5	--	--	4.4
Cowlitz River	4	3.7	--	--	3.9	--	--	4.3
All Sites	40	3.0	3.7	4.0	4.2	5.1	6.0	6.4
Antimony								
Warrendale	4	1.4	--	--	1.6	--	--	1.9
Hayden Island	4	1.1	--	--	1.1	--	--	1.6
Columbia City	4	.9	--	--	1.3	--	--	2.0
Beaver	4	.9	--	--	1.4	--	--	2.1
Willamette River	4	.4	--	--	.7	--	--	1.1
Multnomah Channel	4	.7	--	--	1.0	--	--	1.6
Sandy River	4	.4	--	--	.6	--	--	4.1
Lewis River	3	.3	--	--	1.8	--	--	2.0
Kalama River	4	.4	--	--	.6	--	--	7.2
Cowlitz River	4	.2	--	--	.6	--	--	2.3
All Sites	40	.2	.4	.6	1.2	1.6	2.1	7.2

Table 31. Distribution of major- and trace-element concentrations in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Values are reported in micrograms per gram, except aluminum and iron which are in percent; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore percentile not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile 10	25	50	75	90	Maximum value
Arsenic								
Warrendale	4	8.0	--	--	9.0	--	--	11.0
Hayden Island	4	6.0	--	--	7.1	--	--	8.4
Columbia City	4	6.0	--	--	8.4	--	--	8.9
Beaver	4	6.4	--	--	8.6	--	--	11.0
Willamette River	4	2.6	--	--	7.0	--	--	8.0
Multnomah Channel	4	6.0	--	--	6.9	--	--	10.0
Sandy River	4	2.2	--	--	3.6	--	--	12.0
Lewis River	3	7.6	--	--	9.4	--	--	15.0
Kalama River	4	3.5	--	--	4.7	--	--	5.0
Cowlitz River	4	1.7	--	--	3.2	--	--	4.2
All Sites	40	1.7	2.7	4.7	7.0	8.8	11.0	15.0
Beryllium								
Warrendale	4	1	--	--	1	--	--	1
Hayden Island	4	1	--	--	2	--	--	2
Columbia City	4	1	--	--	1	--	--	2
Beaver	4	1	--	--	1	--	--	2
Willamette River	4	1	--	--	2	--	--	4
Multnomah Channel	4	1	--	--	2	--	--	3
Sandy River	4	1	--	--	1	--	--	2
Lewis River	3	1	--	--	1	--	--	2
Kalama River	4	1	--	--	1	--	--	1
Cowlitz River	4	1	--	--	1	--	--	5
All Sites	40	1	1	1	1	2	3	5
Cadmium								
Warrendale	4	1.0	--	--	2.0	--	--	2.3
Hayden Island	4	1.0	--	--	1.7	--	--	5.1
Columbia City	4	.8	--	--	1.7	--	--	7.8
Beaver	4	.8	--	--	1.3	--	--	3.1
Willamette River	4	.3	--	--	.4	--	--	1.0
Multnomah Channel	4	.3	--	--	1.0	--	--	1.0
Sandy River	4	.4	--	--	1.0	--	--	1.2
Lewis River	3	.5	--	--	.6	--	--	1.0
Kalama River	4	.5	--	--	.9	--	--	1.0
Cowlitz River	4	.2	--	--	1.0	--	--	1.0
All Sites	40	.2	.3	.8	1.0	1.3	2.3	7.8

Table 31. Distribution of major- and trace-element concentrations in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Values are reported in micrograms per gram, except aluminum and iron which are in percent; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore percentile not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Chromium								
Warrendale	4	48	--	--	55	--	--	58
Hayden Island	4	53	--	--	58	--	--	79
Columbia City	4	56	--	--	62	--	--	72
Beaver	4	54	--	--	56	--	--	67
Willamette River	4	71	--	--	76	--	--	82
Multnomah Channel	4	75	--	--	76	--	--	78
Sandy River	4	20	--	--	33	--	--	48
Lewis River	3	23	--	--	23	--	--	35
Kalama River	4	49	--	--	52	--	--	62
Cowlitz River	4	20	--	--	25	--	--	31
All Sites	40	20	23	34	56	70	78	82
Copper								
Warrendale	4	30	--	--	41	--	--	59
Hayden Island	4	37	--	--	63	--	--	86
Columbia City	4	40	--	--	69	--	--	83
Beaver	4	42	--	--	45	--	--	260
Willamette River	4	51	--	--	64	--	--	110
Multnomah Channel	4	48	--	--	56	--	--	70
Sandy River	4	41	--	--	74	--	--	110
Lewis River	3	45	--	--	50	--	--	91
Kalama River	4	71	--	--	80	--	--	100
Cowlitz River	4	41	--	--	58	--	--	66
All Sites	40	30	40	46	60	78	99	260
Lead								
Warrendale	4	26.9	--	--	32.0	--	--	49.0
Hayden Island	4	23.7	--	--	27.0	--	--	41.0
Columbia City	4	26.2	--	--	30.0	--	--	36.0
Beaver	4	20.1	--	--	23.9	--	--	50.0
Willamette River	4	7.9	--	--	22.5	--	--	33.0
Multnomah Channel	4	24.0	--	--	31.0	--	--	49.0
Sandy River	4	12.0	--	--	19.0	--	--	37.2
Lewis River	3	12.0	--	--	21.0	--	--	21.0
Kalama River	4	15.0	--	--	16.8	--	--	26.0
Cowlitz River	4	2.2	--	--	10.2	--	--	15.0
All Sites	40	2.2	12.0	15.4	24.5	30.0	40.6	50.0

Table 31. Distribution of major- and trace-element concentrations in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Values are reported in micrograms per gram, except aluminum and iron which are in percent; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore percentile not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
				Manganese				
Warrendale	4	1,200	--	--	1,500	--	--	2,000
Hayden Island	4	1,200	--	--	1,450	--	--	2,100
Columbia City	4	1,200	--	--	1,450	--	--	1,800
Beaver	4	1,100	--	--	1,400	--	--	2,000
Willamette River	4	1,500	--	--	2,950	--	--	4,000
Multnomah Channel	4	1,900	--	--	2,150	--	--	2,600
Sandy River	4	900	--	--	1,500	--	--	1,700
Lewis River	3	2,100	--	--	3,100	--	--	5,000
Kalama River	4	1,100	--	--	1,400	--	--	1,800
Cowlitz River	4	1,100	--	--	1,550	--	--	2,300
All Sites	40	900	1,110	1,300	1,650	2,100	3,910	5,700
				Mercury				
Warrendale	3	.08	--	--	.17	--	--	.18
Hayden Island	3	.10	--	--	.17	--	--	3.20
Columbia City	4	.11	--	--	.14	--	--	.22
Beaver	4	.10	--	--	.16	--	--	.54
Willamette River	4	.11	--	--	.18	--	--	1.50
Multnomah Channel	4	.11	--	--	.12	--	--	.72
Sandy River	2	.09	--	--	.12	--	--	.14
Kalama River	2	.10	--	--	.18	--	--	.27
Cowlitz River	4	<.02	--	--	.09	--	--	.31
All Sites	30	.01	.08	.11	.15	.19	.70	3.20
				Nickel				
Warrendale	4	26	--	--	28	--	--	31
Hayden Island	4	28	--	--	30	--	--	36
Columbia City	4	29	--	--	30	--	--	34
Beaver	4	26	--	--	28	--	--	38
Willamette River	4	34	--	--	37	--	--	38
Multnomah Channel	4	33	--	--	34	--	--	41
Sandy River	4	25	--	--	26	--	--	76
Lewis River	3	19	--	--	23	--	--	120
Kalama River	4	29	--	--	32	--	--	96
Cowlitz River	4	10	--	--	18	--	--	47
All Sites	40	10	18	26	30	36	46	120

Table 31. Distribution of major- and trace-element concentrations in suspended sediment, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Values are reported in micrograms per gram, except aluminum and iron which are in percent; see table 7 for full site names; -- indicates fewer than 6 samples collected, therefore percentile not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Selenium								
Warrendale	2	0.6	--	--	0.6	--	--	0.6
Hayden Island	2	.5	--	--	.6	--	--	.6
Columbia City	3	.5	--	--	.6	--	--	.6
Beaver	3	.4	--	--	.6	--	--	.6
Willamette River	3	.3	--	--	.4	--	--	.6
Multnomah Channel	3	.4	--	--	.4	--	--	.4
Sandy River	1	.3	--	--	.3	--	--	.3
Cowlitz River	4	<.2	--	--	.4	--	--	.4
All Sites	21	<.2	.3	.4	.4	.6	.6	.6
Silver								
Warrendale	4	.3	--	--	.3	--	--	.6
Hayden Island	4	.2	--	--	.5	--	--	.6
Columbia City	4	.3	--	--	.4	--	--	1.1
Beaver	4	.3	--	--	.5	--	--	.7
Willamette River	4	.3	--	--	.6	--	--	2.0
Multnomah Channel	4	.3	--	--	.5	--	--	.6
Sandy River	4	.1	--	--	.3	--	--	.3
Lewis River	3	.1	--	--	.3	--	--	1.0
Kalama River	4	.2	--	--	.3	--	--	.4
Cowlitz River	4	<.1	--	--	.1	--	--	.3
All Sites	40	<.1	.1	0.2	.3	.5	.7	2.0
Zinc								
Warrendale	4	220	--	--	230	--	--	300
Hayden Island	4	190	--	--	205	--	--	230
Columbia City	4	170	--	--	240	--	--	260
Beaver	4	160	--	--	200	--	--	270
Willamette River	4	120	--	--	145	--	--	180
Multnomah Channel	4	140	--	--	175	--	--	180
Sandy River	4	81	--	--	108	--	--	220
Lewis River	3	69	--	--	81	--	--	95
Kalama River	4	83	--	--	106	--	--	320
Cowlitz River	4	67	--	--	79	--	--	86
All Sites	40	67	76	88	170	220	259	320

Trace elements transported predominantly in the filtered-water phase in the lower Columbia River include arsenic, barium, chromium, and copper (table 30). Although the filtered-water:suspended ratios for loads always exceeded one for these elements, they varied with streamflow. Consider arsenic, which had higher filtered-water:suspended ratios during summer low streamflows in the lower Columbia River and lower ratios during spring high streamflows. In the Columbia River at Warrendale, for example, the filtered-water:suspended ratios for arsenic for high and low streamflows, respectively, were 13 and 25. This same pattern of higher filtered-water loads during low streamflows in the main stem was repeated at all main-stem sites and resulted from low suspended-sediment concentrations, which are typical of low-streamflow conditions in the main stem. When suspended-sediment concentrations are low, the related transport of suspended arsenic is low and hence the filtered-water:suspended load is also low.

The dominant transport phase for some elements alternated from filtered-water to suspended depending on streamflow conditions. For example, during winter high flows in the Willamette River at Portland, the filtered-water zinc phase is one-fifth the suspended phase. During summer low streamflows, however, loads shift, and the filtered-water phase is 2.5 times the suspended phase (table 30). These shifts are not attributable to seasonal variations in concentrations of filtered-water or suspended zinc; rather, they result from seasonal variations in suspended-sediment concentration. In the case of the Willamette River, the suspended-sediment concentration during the November 3, 1994, high-flow sampling was 81 mg/L, whereas it was only 5 mg/L during the September 13, 1994, low-flow sampling. These shifts in suspended-sediment concentration have a paramount effect on suspended-zinc loads. These same effects were not prominent in the main stem, however. The lack of shifts in the main stem was probably a result of less dynamic suspended-sediment concentrations—a characteristic of the numerous reservoirs in the main stem which minimize peak streamflow and result in less resuspension/scouring, and which provide conditions for settling of particulates in forebays and their regulating effect on peak streamflow. Similar transport-phase shifts also were measured for barium and copper.

The transport dynamics of suspended aluminum and zinc were studied by computing suspended loads over three reaches of the main stem. The suspended loads were determined based on data collected during a low-streamflow period from August through September 1994. Aluminum was selected because of its natural abundance, and zinc was selected because it is a trace contaminant often associated with human activities. For each reach, the measured load at the downstream site (site-measured load) was compared to the calculated load for the reach (reach-calculated load), and the difference between the two was computed (table 32). This type of analysis is termed *mass balance*. The smaller the difference between the site-measured load and the reach-calculated load, the better the mass balance is for the reach. For comparison, mass-balance calculations also were made for streamflow, a relatively conservative measure. A positive difference between measured and calculated suspended-zinc loads or streamflows implies that unmeasured contributions (from point or nonpoint sources and [or] resuspension and transport of zinc-affected streambed sediment, for example) to the site-measured load exist, whereas a negative difference implies that unaccountable losses (from suspended-sediment deposition, for example) exist in the reach. As mentioned earlier, samples that were collected during the low-streamflow months and used in making intersite-load comparisons were sometimes separated by days or weeks. Consequently, variability in daily mean streamflow and daily concentrations can contribute to differences that were observed between site-measured and reach-calculated loads.

Between the Columbia River at Warrendale (RM 141) and the Columbia River near Columbia City (RM 84), the site-measured zinc load differed from the reach-calculated load by +25 lbs/d. This difference in load is small (about 3 percent of the site-measured load at Columbia City) and indicates a good mass balance over the Warrendale to Columbia City reach. The major contributing tributary over this reach is the Willamette River. It has a suspended-zinc load (39 lbs/d) that is small in comparison to the 610 lbs/d of suspended-zinc entering the lower Columbia River at Warrendale. Between Columbia City and the Columbia River at Beaver Army Terminal, the difference between the site-measured load and reach-calculated load is small (+13 lbs/d), and again, is indicative of a good

Table 32. Mass balances for streamflow, suspended zinc loads, and suspended aluminum loads, lower Columbia River Basin, Oregon and Washington, August through September, 1994

[Loads were determined from instantaneous measurements of suspended aluminum and zinc concentrations made during a low-streamflow period and daily mean streamflow for the day the suspended-trace element sample was collected; ft^3/s, cubic feet per second; lb/d, pounds per day; --, not applicable; nd, no data; see table 7 for full site names; see page 95 for a discussion of the mass-balance approach]

Site name	Sampling date	Columbia river mile	Streamflow (ft^3/s)				Suspended zinc load (lb/d)				Suspended aluminum load (tons/d)			
			Main Stem			Tributary inflowing	Main stem			Tributary Inflowing	Main stem			Tributary Inflowing
			Site measured	Reach calculated	Site measured - Reach calculated		Site measured	Reach calculated	Site measured - Reach calculated		Site measured	Reach calculated	Site measured - Reach calculated	
Warrendale	08-10-1994	141	93,800	--	--	--	610	--	--	--	65	--	--	--
Sandy River	08-15-1994	120.5	--	--	--	570	--	--	--	5.4	--	--	--	0.9
Hayden Island	nd	102	nd	nd	nd	--	nd	nd	nd	--	nd	nd	nd	--
Willamette River	09-13-1994	101.5	--	--	--	9,000	--	--	--	39	--	--	--	9.1
Lewis River	09-07-1994	87	--	--	--	1,250	--	--	--	.6	--	--	--	.1
Columbia City	09-14-1994	84	97,000	104,620	-7,620	--	680	655	+25	--	89	75.1	+13.9	--
Kalama River	08-17-1994	73.1	--	--	--	200	--	--	--	1.0	--	--	--	.05
Cowlitz River	08-31-1994	68	--	--	--	3,230	--	--	--	46.4	--	--	--	23
Beaver Army Terminal	08-11-1994	53.8	90,800	100,430	-9,630	--	740	727	+13	--	130	112	+18	--

mass balance for suspended zinc. The major contributing tributary over this reach is the Cowlitz River, which has a suspended-zinc load (46 lbs/d) that is slightly larger than that of the Willamette River but small in comparison to the load at Warrendale. The difference in load between the Willamette River and the Cowlitz River results from a higher concentration of suspended sediment in the Cowlitz River, rather than a higher concentration of suspended zinc. The general agreement between site measured and reach calculated loads (good mass balance) is indicative of a sampling network that spatially is adequate to account for major sources of trace elements in the lower Columbia River Basin. The good mass balance, however, is limited to low-streamflow periods in late summer. The degree of mass balance during high streamflow periods is unknown. Depending on the magnitude of the high streamflows, mass balance may be affected by resuspension and transport between reaches and by load contributions from episodic point sources.

Organic Compounds

Water samples in the lower Columbia River Basin were analyzed for organic compounds beginning in 1965. This limited period of record and the high cost of analysis explain why the number of determinations for organic compounds is much smaller than those for other constituents addressed in this report. Of the 82 organic compounds analyzed historically, 32 were not detected and 56 had fewer than 10 detections (table 33).

Organic compounds were detected at 7 of the 10 sites in 1994; data for sites with detections are listed in table 34. The organic compounds analyzed, including common name, application, and pesticide class are shown in table 35. Of the 47 organic compounds analyzed, 20 were detected in this study. Organic compounds were detected at all four main-stem sites and at three of the six tributary sites. The Willamette River at Portland had the largest number of detections, and, of the 20 organic compounds detected in the lower Columbia River Basin, all were detected at one time or another in the Willamette River. Sites without any detections of organic compounds were the Sandy River near Troutdale, Kalama River above Spencer Creek near Kalama, and Cowlitz River at Kelso.

In addition to determinations of the 47 organic compounds listed above, a second suite of 41 organic compounds was analyzed using a high performance liquid chromatography (HPLC) method which is presently under development by the USGS. Quality assurance for this new method is under review by the USGS's Methods Development Group. The USGS is reviewing analytical-method performance, issues related to sample preservation and sample degradation, potential for saturation of the solid-phase adsorbent cartridge and subsequent loss of analyte prior to analysis, lapsed time between sample extraction from the solid-phase cartridge and sample analysis, potential for coelution of analytes, and other factors that ultimately affect the quality of the reported organic-compound data. Consequently, the second suite of organic compounds were unavailable for use in the current study. Preliminary results, however, show that only a limited number of organic compounds were detected and that false positive detections are not a problem with the method. Of the 45 samples analyzed using HPLC in 1994, only 6 detections were reported in the Willamette River and Columbia River near Beaver Army Terminal. These six detections represent five organic compounds: dicamba, 2,4-D, diuron, 1-naphthol, and carbaryl.

Atrazine, a triazine herbicide and the most frequently detected organic compound in the lower Columbia River Basin, was detected in 23 of 45 samples (fig. 33). The herbicides metolachlor and simazine, the next most frequently detected organic compounds, were detected in 17 and 16 of 45 samples, respectively. The largest concentrations of atrazine, metolachlor, and simazine were measured in the Willamette River at Portland. Atrazine concentrations in the Willamette River, for example, ranged from 0.01 to 0.18 µg/L, and the median concentration (0.033 µg/L) was more than 10 times the median concentrations found at the four main-stem sites (table 36). The atrazine metabolite, deethylatrazine, was detected in 9 of 45 determinations, and 8 of the 9 detections were in the Willamette River and Multnomah Channel. None of the atrazine concentrations measured in the lower Columbia River Basin, however, exceeded the EPA's lifetime health advisory level of 3 µg/L. Additionally, none of the organic compounds measured in the lower Columbia River Basin in 1994 exceededthe EPA's ambient water-quality criteria or drinking-water guidelines (table 49, at back of report).

Table 33. Number of historical determinations and uncensored data values for organic compounds, lower Columbia River Basin, Oregon and Washington, 1965-93

[All compounds listed are in filtered water unless otherwise stated; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; STORET, U.S. Environmental Protection Agency’s STOrage and RETrieval system; 2, 4-D, (2,4- dichlorophenoxy) acetic acid; 2,4-DB, 4-(2,4-dichlorophenoxy)butyric acid; DCPA, 3’,4’-dichloropropionanilide; DDE, dichlorodiphenyldichloroethylene; EPTC, S-ethyl dipropyl thiocarbamate; HCH, hexachlorocyclohexane; MCPA, (4-chloro-2-methylphenoxy) acetic acid; MCPB, 4-(4-chloro-2-methylphenoxy) butyric acid; 2,4,5-T, (2,4,5-trichlorophenoxy) acetic acid; --, not applicable or not available]

STORET code	Compound name	Chemical Abstracts Services registry number	Number of historical determinations	Number of uncensored data values
49315	Acifluorfen	50594-66-6	231	0
46342	Alachlor	15972-60-8	303	20
49312	Aldicarb	116-06-3	228	0
49313	Aldicarb sulfone	1646-88-4	228	0
49314	Aldicarb sulfoxide	--	228	0
39632	Atrazine	1912-24-9	309	252
39630	Atrazine, unfiltered	1912-24-9	21	9
82686	Azinphos-methyl	86-50-0	284	5
82673	Benfluralin	1861-40-1	288	2
38711	Bentazon	25057-89-0	231	7
04029	Bromacil	314-40-9	247	5
49311	Bromoxynil	1689-84-5	231	2
04028	Butylate	2008-41-5	288	0
49310, 82680	Carbaryl	63-25-2	516	72
49309	Carbofuran	1563-66-2	228	19
49306	Chlorothalonil	1897-45-6	228	0
38933	Chlorpyrifos	2921-88-2	296	94
49305	Clopyralid	1702-17-6	231	0
04041	Cyanazine	21725-46-2	303	1
39732	2,4-D	94-75-7	251	24
39730	2,4-D, unfiltered	94-75-7	62	39
49304	Dacthal	1861-32-1	231	0
38746	2,4-DB	94-82-6	231	0
82682	DCPA	1861-32-1	288	93
34653	p,p’-DDE	72-55-9	288	13
04040	Deethylatrazine	6190-65-4	303	137
39572	Diazinon	333-41-5	298	159
38442	Dicamba	1918-00-9	231	3
49303	Dichlobenil	1194-65-6	228	4
49302	Dichlorprop	120-36-5	231	0
39381	Dieldrin	60-57-1	297	8
82660	2,6-Diethylaniline	91-66-7	288	0
82662	Dimethoate	60-51-5	234	5
49301	Dinoseb	88-85-7	231	8
82677	Disulfoton	298-04-4	288	0
49300	Diuron	330-54-1	228	103
82668	EPTC	759-94-4	288	115
49298	Esfenvalerate	66230-04-4	228	0
82663	Ethalfluralin	55283-68-6	288	0
82672	Ethoprop	13194-48-4	288	77
39762	Fenoprop (silvex)	93-72-1	250	0
49297	Fenuron	101-42-8	228	0
38811	Fluometuron	2164-17-2	228	0
04095	Fonofos	944-22-9	295	68
34253	alpha-HCH	319-84-6	288	0
39341	gamma-HCH (lindane)	58-89-9	297	23

Table 33. Number of historical determinations and uncensored data values for organic compounds, lower Columbia River Basin, Oregon and Washington, 1965-93—Continued

[All compounds listed are in filtered water unless otherwise stated; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; STORET, U.S. Environmental Protection Agency’s STOrage and RETrieval system; 2, 4-D, (2,4- dichlorophenoxy) acetic acid; 2,4-DB, 4-(2,4-dichlorophenoxy)butyric acid; DCPA, 3’,4’-dichloropropionanilide; DDE, dichlorodiphenyldichloroethylene; EPTC, S-ethyl dipropyl thiocarbamate; HCH, hexachlorocyclohexane; MCPA, (4-chloro-2-methylphenoxy) acetic acid; MCPB, 4-(4-chloro-2-methylphenoxy) butyric acid; 2,4,5-T, (2,4,5-trichlorophenoxy) acetic acid; --, not applicable or not available]

STORET code	Compound name	Chemical Abstracts Services registry number	Number of historical determinations	Number of uncensored data values
49308	3-Hydroxycarbofuran	--	228	0
38478,82666	Linuron	330-55-2	576	1
39532	Malathion	121-75-5	297	27
38482	MCPA	94-74-6	231	2
38487	MCPB	94-81-5	231	0
38501	Methiocarb	2032-65-7	228	2
49296	Methomyl	16752-77-5	228	0
82667	Methyl parathion	298-00-0	288	0
39415	Metolachlor	51218-45-2	303	215
82630	Metribuzin	21087-64-9	303	60
82671	Molinate	2212-67-1	288	0
49295	1-Naphthol	--	228	1
82684	Napropamide	15299-99-7	288	104
49294	Neburon	555-37-3	228	0
49293	Norflurazon	27314-13-2	228	0
49292	Oryzalin	19044-88-3	228	3
38866	Oxamyl	23135-22-0	228	1
39542	Parathion	56-38-2	297	0
82669	Pebulate	1114-71-2	288	1
82683	Pendimethalin	40487-42-1	288	12
82687	cis-Permethrin	52645-53-1	288	2
82664	Phorate	298-02-2	288	0
49291	Picloram	1918-02-1	231	0
04037	Prometon	1610-18-0	303	56
82676	Pronamide	23950-58-5	289	35
04024	Propachlor	1918-16-7	288	11
82679	Propanil	709-98-8	288	5
82685	Propargite	2312-35-8	288	3
49236	Propham	122-42-9	228	0
38538	Propoxur	114-26-1	226	0
04035	Simazine	122-34-9	309	220
39742	2,4,5-T	93-76-5	252	2
39740	2,4,5-T, unfiltered	93-76-5	59	17
82670	Tebuthiuron	34014-18-1	288	42
82665	Terbacil	5902-51-2	284	59
82675	Terbufos	13071-79-9	288	0
82681	Thiobencarb	28249-77-6	288	0
79747	Total organic halide	--	92	76
82678	Triallate	2303-17-5	288	7
49235	Triclopyr	55335-06-3	231	16
82661	Trifluralin	1582-09-8	288	42

Table 34. Concentrations of organic compounds detected in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[Only detectable concentrations are listed in this table; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; E, estimated value]

Site name	Date	Concentration	
Alachlor			
Willamette River at Portland, Oregon	12-02-1994	0.002	E
Atrazine			
Columbia River at Warrendale, Oregon	08-10-1994	.002	
Columbia River at Warrendale, Oregon	11-08-1994	.006	E
Columbia River, river mile 102, downstream of Hayden Island, Oregon	03-22-1994	.003	
Columbia River, river mile 102, downstream of Hayden Island, Oregon	07-25-1994	.003	
Columbia River, river mile 102, downstream of Hayden Island, Oregon	12-05-1994	.003	E
Columbia River near Columbia City, Oregon	07-26-1994	.004	
Columbia River near Columbia City, Oregon	11-09-1994	.020	
Columbia River at Beaver Army Terminal near Quincy, Oregon	04-14-1994	.032	
Columbia River at Beaver Army Terminal near Quincy, Oregon	08-11-1994	.004	
Willamette River at Portland, Oregon	02-25-1994	.160	
Willamette River at Portland, Oregon	03-14-1994	.037	
Willamette River at Portland, Oregon	04-11-1994	.170	
Willamette River at Portland, Oregon	05-10-1994	.020	
Willamette River at Portland, Oregon	06-14-1994	.012	
Willamette River at Portland, Oregon	08-08-1994	.010	
Willamette River at Portland, Oregon	09-13-1994	.013	E
Willamette River at Portland, Oregon	10-29-1994	.029	
Willamette River at Portland, Oregon	11-03-1994	.130	
Willamette River at Portland, Oregon	12-02-1994	.180	
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.011	
Multnomah Channel near mouth, at St. Helens, Oregon	08-09-1994	.008	
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.160	
Lewis River at Woodland, Washington	06-29-1994	.003	
Carbaryl			
Willamette River at Portland, Oregon	02-25-1994	.017	
Willamette River at Portland, Oregon	10-29-1994	.006	E
Carbofuran			
Willamette River at Portland, Oregon	10-29-1994	.180	E
Willamette River at Portland, Oregon	11-03-1994	.088	E
Chlorpyrifos			
Willamette River at Portland, Oregon	12-02-1994	.006	
Lewis River at Woodland, Washington	07-19-1994	.010	

Table 34. Concentrations of organic compounds detected in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Only detectable concentrations are listed in this table; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; E, estimated value]

Site name	Date	Concentration	
Dacthal; Chlorthal-dimethyl (DCPA)			
Columbia River at Warrendale, Oregon	06-15-1994	0.001	
Columbia River at Warrendale, Oregon	11-08-1994	.003	E
Columbia River, river mile 102, downstream of Hayden Island, Oregon	12-05-1994	.001	E
Columbia River near Columbia City, Oregon	11-09-1994	.003	E
Columbia River at Beaver Army Terminal near Quincy, Oregon	08-11-1994	.002	
Willamette River at Portland, Oregon	10-29-1994	.004	
Willamette River at Portland, Oregon	12-02-1994	.001	E
Deethylatrazine			
Columbia River at Beaver Army Terminal near Quincy, Oregon	04-14-1994	.003	
Willamette River at Portland, Oregon	02-25-1994	.026	
Willamette River at Portland, Oregon	04-11-1994	.010	
Willamette River at Portland, Oregon	05-10-1994	.005	
Willamette River at Portland, Oregon	10-29-1994	.004	E
Willamette River at Portland, Oregon	11-03-1994	.004	E
Willamette River at Portland, Oregon	12-02-1994	.006	E
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.006	
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.009	E
Diazinon			
Willamette River at Portland, Oregon	05-10-1994	.006	
Willamette River at Portland, Oregon	06-14-1994	.009	
Willamette River at Portland, Oregon	08-08-1994	.007	
Willamette River at Portland, Oregon	09-13-1994	.008	E
Willamette River at Portland, Oregon	10-29-1994	.006	E
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.006	
Multnomah Channel near mouth, at St. Helens, Oregon	08-09-1994	.005	
Eptam (EPTC)			
Columbia River at Warrendale, Oregon	05-11-1994	.006	
Columbia River at Warrendale, Oregon	06-15-1994	.003	
Columbia River, river mile 102, downstream of Hayden Island, Oregon	03-22-1994	.002	
Columbia River, river mile 102, downstream of Hayden Island, Oregon	05-25-1994	.004	
Columbia River near Columbia City, Oregon	05-09-1994	.005	
Willamette River at Portland, Oregon	05-10-1994	.005	
Willamette River at Portland, Oregon	06-14-1994	.005	
Willamette River at Portland, Oregon	12-02-1994	.004	E
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.006	

Table 34. Concentrations of organic compounds detected in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Only detectable concentrations are listed in this table; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; E, estimated value]

Site name	Date	Concentration	
Ethoprop			
Willamette River at Portland, Oregon	10-29-1994	0.015	
Willamette River at Portland, Oregon	11-03-1994	.023	
Willamette River at Portland, Oregon	12-02-1994	.005	E
Fonofos			
Willamette River at Portland, Oregon	04-11-1994	.010	
Willamette River at Portland, Oregon	10-25-1994	.002	E
Willamette River at Portland, Oregon	11-03-1994	.005	E
Willamette River at Portland, Oregon	12-02-1994	.005	E
Metolachlor			
Columbia River at Warrendale, Oregon	11-08-1994	.004	E
Columbia River, river mile 102, downstream of Hayden Island, Oregon	12-05-1994	.002	E
Columbia River near Columbia City, Oregon	11-09-1994	.017	
Columbia River at Beaver Army Terminal near Quincy, Oregon	04-14-1994	.002	
Columbia River at Beaver Army Terminal near Quincy, Oregon	08-11-1994	.003	
Willamette River at Portland, Oregon	02-25-1994	.016	
Willamette River at Portland, Oregon	03-14-1994	.006	
Willamette River at Portland, Oregon	04-11-1994	.008	
Willamette River at Portland, Oregon	05-10-1994	.005	
Willamette River at Portland, Oregon	06-14-1994	.004	
Willamette River at Portland, Oregon	09-13-1994	.003	E
Willamette River at Portland, Oregon	10-29-1994	.049	
Willamette River at Portland, Oregon	11-03-1994	.110	
Willamette River at Portland, Oregon	12-02-1994	.048	
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.004	
Multnomah Channel near mouth, at St. Helens, Oregon	10-26-1994	.008	E
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.044	
Metribuzin			
Willamette River at Portland, Oregon	02-25-1994	.029	
Willamette River at Portland, Oregon	12-02-1994	.020	
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.021	
Napropamide			
Columbia River, river mile 102, downstream of Hayden Island, Oregon	12-05-1994	.007	E
Willamette River at Portland, Oregon	02-25-1994	.068	
Willamette River at Portland, Oregon	10-29-1994	.022	
Willamette River at Portland, Oregon	11-03-1994	.029	
Willamette River at Portland, Oregon	12-02-1994	.006	E

Table 34. Concentrations of organic compounds detected in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Only detectable concentrations are listed in this table; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; E, estimated value]

Site name	Date	Concentration	
Prometon			
Willamette River at Portland, Oregon	08-08-1994	0.003	
Pronamide			
Willamette River at Portland, Oregon	02-25-1994	.030	
Willamette River at Portland, Oregon	12-02-1994	.018	
Simazine			
Columbia River at Warrendale, Oregon	08-10-1994	.001	
Columbia River near Columbia City, Oregon	11-09-1994	.009	
Columbia River at Beaver Army Terminal near Quincy, Oregon	04-14-1994	.011	
Willamette River at Portland, Oregon	02-25-1994	.064	
Willamette River at Portland, Oregon	03-14-1994	.013	
Willamette River at Portland, Oregon	04-11-1994	.049	
Willamette River at Portland, Oregon	05-10-1994	.010	
Willamette River at Portland, Oregon	06-14-1994	.016	
Willamette River at Portland, Oregon	08-08-1994	.005	
Willamette River at Portland, Oregon	09-13-1994	.008	
Willamette River at Portland, Oregon	10-29-1994	.066	
Willamette River at Portland, Oregon	11-03-1994	.073	
Willamette River at Portland, Oregon	12-02-1994	.043	
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.019	
Multnomah Channel near mouth, at St. Helens, Oregon	08-09-1994	.004	
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.035	
Tebuthiuron			
Willamette River at Portland, Oregon	02-25-1994	.006	
Willamette River at Portland, Oregon	10-29-1994	.007	E
Willamette River at Portland, Oregon	12-02-1994	.003	E
Terbacil			
Willamette River at Portland, Oregon	02-25-1994	.032	
Willamette River at Portland, Oregon	04-11-1994	.080	
Willamette River at Portland, Oregon	10-29-1994	.017	E
Willamette River at Portland, Oregon	11-03-1994	.027	E
Willamette River at Portland, Oregon	12-02-1994	.010	E
Multnomah Channel near mouth, at St. Helens, Oregon	06-10-1994	.012	
Multnomah Channel near mouth, at St. Helens, Oregon	12-07-1994	.008	E
Triallate			
Willamette River at Portland, Oregon	02-25-1994	.004	
Willamette River at Portland, Oregon	12-02-1994	.008	E

Table 35. Chemical classifications for organic compounds analyzed, lower Columbia River Basin, Oregon and Washington, 1994

[--, no trade name; *, metabolite or pesticide no longer registered for use; see table 9 for Chemical Abstracts Services registry numbers]

Common Name	Trade name	Application	Class
acetochlor	Acenit; Elbacet; Harness; Mon-097	herbicide	chloroacetamide
alachlor	Lasso	herbicide	chloroacetamide
atrazine	AAtrex	herbicide	triazine
azinphos-methyl	Guthion	insecticide	organophosphate
benfluralin	Benefin; Balan; Bonalan	herbicide	dinitroaniline
butylate	Genate plus; Suntan +	herbicide	dinitroaniline
carbaryl	Sevin	insecticide	carbamate
carbofuran	Furandan	insecticide	carbamate
chlorpyrifos	Dursban	insecticide	organophosphate
cyanazine	--	herbicide	triazine
DCPA	Dacthal; Chlorthal-dimethyl	herbicide	organochlorine
4,4’-DDE	--	insecticide	organochlorine
deethylatrazine	--	*	metabolite
diazinon	--	insecticide	organophosphate
dieldrin	Panoram D-31	insecticide	organochlorine
2,6-diethylaniline	--	*	metabolite
disulfoton	--	insecticide	organophosphate
EPTC	Eptam	herbicide	carbamate
ethalfluralin	Sonalan	herbicide	dinitroaniline
ethoprop	Mocap; Ethoprophos	insecticide	organophosphate
fonofos	Dyfonate	insecticide	organophosphate
alpha-HCH	alpha-BHC	insecticide	organochlorine
gamma-HCH	Lindane	insecticide	organochlorine
linuron	Lorox; Linex	herbicide	phenyl urea
malathion	--	insecticide	organophosphate
metolachlor	Dual	herbicide	chloroacetamide
methyl parathion	Denncap-M	insecticide	organophosphate
metribuzin	Lexone; Sencor	herbicide	triazine
molinate	Ordram	herbicide	carbamate
napropamide	Devrinol	herbicide	chloroacetamide
parathion	--	insecticide	organophosphate
pebulate	Tillam	herbicide	carbamate
pendimethilan	Prowl; Stomp	herbicide	dinitroaniline
cis-permethrin	Pounce; Ambush	insecticide	permethrin
phorate	Thimet	insecticide	organophosphate
prometon	Pramitol	herbicide	triazine
pronamide	Kerb, Propyzamid	herbicide	chloroacetamide
propachlor	Ramrod	herbicide	chloroacetamide
propanil	Stampede	herbicide	chloroacetamide
propargite	Omite, Alkyl sulfite	insecticide	miscellaneous
simazine	Aquazine, Princep	herbicide	triazine
tebuthiuron	Spike	herbicide	phenyl urea
terbacil	Sinbar	herbicide	uracil
terbufos	Counter	insecticide	organophosphate
thiobencarb	Bolero	herbicide	carbamate
triallate	Avadex bw, Far-go	herbicide	carbamate
trifluralin	Treflan	herbicide	dinitroaniline

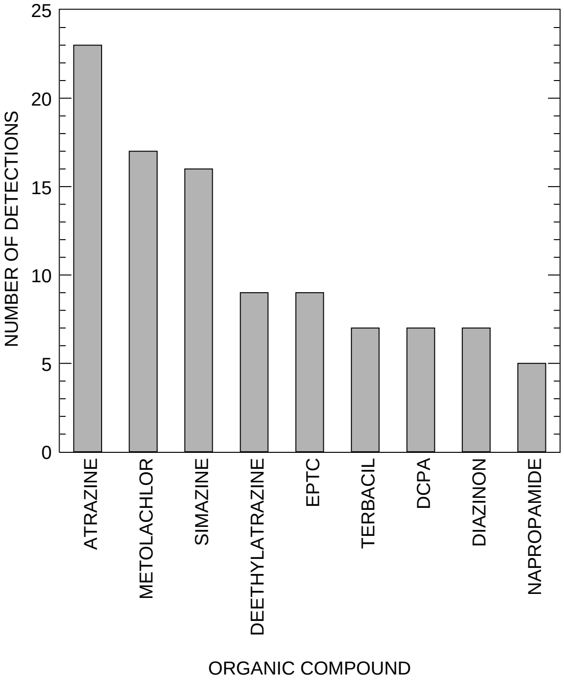

Figure 33. Frequently detected organic compounds, lower Columbia River Basin, Oregon and Washington, 1994. (Numbers are based on total of 45 samples.)

Atrazine, metolachlor, and simazine, were detected in 93, 86, and 93 percent, respectively, of the samples collected in the Willamette River and Multnomah Channel (fig. 34). Additionally, all of the frequently detected pesticides shown in figure 33—except for DCPA—were detected more often in the Willamette River and Multnomah Channel, than at the other main-stem and tributary sites in the lower Columbia River Basin. The high percentage of detections of agricultural organic compounds from the Willamette River Basin reflects the fact that most of the lower Columbia River Basin's agricultural land is in the Willamette Basin (table 2).

Although not detected as frequently as the before-mentioned organic compounds, EPTC (eptam[6]) was detected in the lower Columbia River Basin shortly after the spring-application period. It was detected consistently from March to June 1994 in concentrations ranging from 0.002 to 0.006 µg/L in the main stem at Warrendale, Hayden Island, and Columbia City, and in the Willamette River and Multnomah Channel tributaries. EPTC was introduced in the lower Columbia River Basin in the early 1960s and is used to treat a variety of crops, including beans, peas, sugar-beet root, clover, and strawberries. It was used through the time of this study (John Rinehold, Oregon State University, oral commun., 1994).

The Willamette River, which is a source of atrazine to the lower Columbia River, has higher atrazine concentrations during the spring and fall high-streamflow periods than during the summer low-streamflow period (fig. 35). High atrazine concentrations associated with spring runoff coincide with periods of application. Atrazine is used for preemergent-weed control in preparation for grain crops and nursery stock and is normally applied in March and April when soil moisture is high and before winter rains cease (Burrill and others, 1992). In the Willamette River Basin alone, 382,000 lbs of atrazine were applied in 1987; in contrast, only 4,500 lbs were applied in the Clatskanie River drainage (John Rinehold, Oregon State University, unpub. data, 1993). The higher atrazine concentrations measured in November and December coincide with high suspended-sediment concentrations. These higher atrazine concentrations probably result from the presence of soil-sorbed atrazine that was flushed from freshly eroded agricultural soils that enter the stream during fall runoff.

Most likely, however, these higher concentrations during fall runoff were not transported in the suspended phase. Instead, equilibrium calculations show that atrazine in the Willamette River at Portland, during fall and winter runoff, is predominantly in the filtered-water (dissolved) phase. Using a suspended organic carbon-water sorption coefficient (K_{oc}) of 163 (Mercer and others, 1990), and data from the November 3, 1994 sampling in the Willamette River, the fraction of atrazine transported in the suspended form can be calculated from the following equations. The K_{oc} is related to the sorption coefficient (Kd) by:

$$K_{oc} = K_d / f_{oc} \tag{1}$$

where f_{oc} is the organic carbon fraction in the suspended sediment and K_d is defined as

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[6] EPTC, a selective carbamate herbicide that decomposes in 4 to 6 weeks, has been used as a preplant soil treatment to inhibit the growth of weed seedlings (Burrill and others, 1992).

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
				Alachlor				
Warrendale	4	<0.002	--	--	<0.002	--	--	<0.002
Hayden Island	4	<.002	--	--	<.002	--	--	<.002
Columbia City	4	<.002	--	--	<.002	--	--	<.002
Beaver	4	<.002	--	--	<.002	--	--	<.002
Willamette River	10	<.002	<.002	<.002	<.002	<.002	<.002	.002
Multnomah Channel	4	<.002	--	--	<.002	--	--	<.002
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	<.002	<.002	.002
				Atrazine				
Warrendale	4	<.001	--	--	.001	--	--	.006
Hayden Island	4	<.001	--	--	.003	--	--	.003
Columbia City	4	<.001	--	--	.002	--	--	.020
Beaver	4	<.001	--	--	.002	--	--	.032
Willamette River	10	.010	.010	.013	.033	.162	.179	.180
Multnomah Channel	4	<.001	--	--	.010	--	--	.160
Sandy River	3	<.001	--	--	<.001	--	--	<.001
Lewis River	4	<.001	--	--	<.001	--	--	.003
Kalama River	4	<.001	--	--	<.001	--	--	<.001
Cowlitz River	4	<.001	--	--	<.001	--	--	<.001
All sites	45	<.001	<.001	<.001	.002	.012	.142	.180
				Carbaryl				
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	<.003
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	<.003	.016	0.017
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Carbaryl—Continued								
Lewis River	4	<0.003	--	--	<0.003	--	--	<0.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<0.003	<0.003	<.003	<0.003	<0.003	.017
Carbofuran								
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	<.003
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	.023	.171	.180
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003
Lewis River	4	<.003	--	--	<.003	--	--	<.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<.003	<.003	<.003	<.003	<.003	.180
Chlorpyrifos								
Warrendale	4	<.004	--	--	<.004	--	--	<.004
Hayden Island	4	<.004	--	--	<.004	--	--	<.004
Columbia City	4	<.004	--	--	<.004	--	--	<.004
Beaver	4	<.004	--	--	<.004	--	--	<.004
Willamette River	10	<.004	<.004	<.004	<.004	<.004	.006	.006
Multnomah Channel	4	<.004	--	--	<.004	--	--	<.004
Sandy River	3	<.004	--	--	<.004	--	--	<.004
Lewis River	4	<.004	--	--	<.004	--	--	.010
Kalama River	4	<.004	--	--	<.004	--	--	<.004
Cowlitz River	4	<.004	--	--	<.004	--	--	<.004
All sites	45	<.004	<.004	<.004	<.004	<.004	<.004	.010
Dacthal; Chlorthal-dimethyl (DCPA)								
Warrendale	4	<.002	--	--	<.002	--	--	.003
Hayden Island	4	<.002	--	--	<.002	--	--	<.002
Columbia City	4	<.002	--	--	<.002	--	--	.003
Beaver	4	<.002	--	--	<.002	--	--	.002

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
			Dacthal; Chlorthal-dimethyl (DCPA)—Continued					
Willamette River	10	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	0.004
Multnomah Channel	4	<.002	--	--	<.002	--	--	<.002
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	<.002	<.002	.004
			Deethylatrazine					
Warrendale	4	<.002	--	--	<.002	--	--	<.002
Hayden Island	4	<.002	--	--	<.002	--	--	<.002
Columbia City	4	<.002	--	--	<.002	--	--	<.002
Beaver	4	<.002	--	--	<.002	--	--	.003
Willamette River	10	<.002	<.002	<.002	.004	.007	.024	.026
Multnomah Channel	4	<.002	--	--	.004	--	--	.009
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	<.002	.006	.026
			Diazinon					
Warrendale	4	<.002	--	--	<.002	--	--	<.002
Hayden Island	4	<.002	--	--	<.002	--	--	<.002
Columbia City	4	<.002	--	--	<.002	--	--	<.002
Beaver	4	<.002	--	--	<.002	--	--	<.002
Willamette River	10	<.002	<.002	<.002	.004	.007	.009	.009
Multnomah Channel	4	<.002	--	--	.003	--	--	.006
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	<.002	.006	.009
			Eptam (EPTC)					
Warrendale	4	<.002	--	--	.002	--	--	.006

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Eptam (EPTC)—Continued								
Hayden Island	4	<0.002	--	--	<0.002	--	--	0.004
Columbia City	4	<.002	--	--	<.002	--	--	.005
Beaver	4	<.002	--	--	<.002	--	--	<.002
Willamette River	10	<.002	<.002	<.002	<.002	0.004	0.005	.005
Multnomah Channel	4	<.002	--	--	<.002	--	--	.006
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	<.002	.005	.006
Ethoprop								
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	<.003
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	.008	.022	.023
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003
Lewis River	4	<.003	--	--	<.003	--	--	<.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<.003	<.003	<.003	<.003	<.003	.023
Fonofos								
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	<.003
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	.005	.010	.010
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003
Lewis River	4	<.003	--	--	<.003	--	--	<.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<.003	<.003	<.003	<.003	<.003	00.010

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Metolachlor								
Warrendale	4	<0.002	--	--	<0.002	--	--	0.004
Hayden Island	4	<.002	--	--	<.002	--	--	.002
Columbia City	4	<.002	--	--	<.002	--	--	.017
Beaver	4	<.002	--	--	<.002	--	--	.003
Willamette River	10	<.002	<0.002	0.004	.007	0.048	0.104	.110
Multnomah Channel	4	<.002	--	--	.006	--	--	.044
Sandy River	3	<.002	--	--	<.002	--	--	<.002
Lewis River	4	<.002	--	--	<.002	--	--	<.002
Kalama River	4	<.002	--	--	<.002	--	--	<.002
Cowlitz River	4	<.002	--	--	<.002	--	--	<.002
All sites	45	<.002	<.002	<.002	<.002	.004	.028	.110
Metribuzin								
Warrendale	4	<.004	--	--	<.004	--	--	<.004
Hayden Island	4	<.004	--	--	<.004	--	--	<.004
Columbia City	4	<.004	--	--	<.004	--	--	<.004
Beaver	4	<.004	--	--	<.004	--	--	<.004
Willamette River	10	<.004	<.004	<.004	<.004	.006	.028	.029
Multnomah Channel	4	<.004	--	--	<.004	--	--	.021
Sandy River	3	<.004	--	--	<.004	--	--	<.004
Lewis River	4	<.004	--	--	<.004	--	--	<.004
Kalama River	4	<.004	--	--	<.004	--	--	<.004
Cowlitz River	4	<.004	--	--	<.004	--	--	<.004
All sites	45	<.004	<.004	<.004	<.004	<.004	<.004	.029
Napropamide								
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	.007
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	.024	.064	.068
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Napropamide—Continued								
Lewis River	4	<0.003	--	--	<0.003	--	--	<0.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<0.003	<0.003	<.003	<0.003	0.006	.068
Prometon								
Warrendale	4	<.003	--	--	<.003	--	--	<.003
Hayden Island	4	<.003	--	--	<.003	--	--	<.003
Columbia City	4	<.003	--	--	<.003	--	--	<.003
Beaver	4	<.003	--	--	<.003	--	--	<.003
Willamette River	10	<.003	<.003	<.003	<.003	<.003	<.003	.003
Multnomah Channel	4	<.003	--	--	<.003	--	--	<.003
Sandy River	3	<.003	--	--	<.003	--	--	<.003
Lewis River	4	<.003	--	--	<.003	--	--	<.003
Kalama River	4	<.003	--	--	<.003	--	--	<.003
Cowlitz River	4	<.003	--	--	<.003	--	--	<.003
All sites	45	<.003	<.003	<.003	<.003	<.003	<.003	.003
Pronamide								
Warrendale	4	<.018	--	--	<.018	--	--	<.018
Hayden Island	4	<.018	--	--	<.018	--	--	<.018
Columbia City	4	<.018	--	--	<.018	--	--	<.018
Beaver	4	<.018	--	--	<.018	--	--	<.018
Willamette River	10	<.018	<.018	<.018	<.018	<.018	.029	.030
Multnomah Channel	4	<.018	--	--	<.018	--	--	<.018
Sandy River	3	<.018	--	--	<.018	--	--	<.018
Lewis River	4	<.018	--	--	<.018	--	--	<.018
Kalama River	4	<.018	--	--	<.018	--	--	<.018
Cowlitz River	4	<.018	--	--	<.018	--	--	<.018
All sites	45	<.018	<.018	<.018	<.018	<.018	<.018	.030
Simazine								
Warrendale	4	<.005	--	--	<.005	--	--	<.005
Hayden Island	4	<.005	--	--	<.005	--	--	<.005
Columbia City	4	<.005	--	--	<.005	--	--	.009

Table 36. Distribution of organic-compound concentrations in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; to avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one element concentration per month was statistically summarized; concentrations are reported in micrograms per liter; acetochlor, azinphos-methyl, benfluralin, butylate, cyanazine, 4,4’-DDE, dieldrin, 2,6-diethylaniline, dimethoate, disulfoton, ethalfluralin, alpha-HCH, gamma-HCH (lindane), linuron, malathion, methyl parathion, molinate, parathion, pebulate, pendimethalin, cis-permethrin, phorate, propachlor, propanil, propargite, tebuthiuron, terbufos, thiobencarb, and trifluralin are not included in this table, because no samples had concentrations greater than their corresponding method detection limit; see table 9 for Chemical Abstracts Services registry numbers and method detection limits; see table 7 for full site names; -- indicates fewer than 6 samples were collected, therefore the percentile was not calculated; <, less than]

Site name	Number of samples	Minimum value	Value at indicated percentile					Maximum value
			10	25	50	75	90	
Simazine—Continued								
Beaver	4	<0.005	--	--	<0.005	--	--	0.011
Willamette River	10	.005	0.005	0.010	.030	0.064	0.072	.0730
Multnomah Channel	4	<.005	--	--	.012	--	--	.035
Sandy River	3	<.005	--	--	<.005	--	--	<.005
Lewis River	4	<.005	--	--	<.005	--	--	<.005
Kalama River	4	<.005	--	--	<.005	--	--	<.005
Cowlitz River	4	<.005	--	--	<.005	--	--	<.005
All sites	45	<.005	<.005	<.005	<.005	.010	.045	.073
Terbacil								
Warrendale	4	<.007	--	--	<.007	--	--	<.007
Hayden Island	4	<.007	--	--	<.007	--	--	<.007
Columbia City	4	<.007	--	--	<.007	--	--	<.007
Beaver	4	<.007	--	--	<.007	--	--	<.007
Willamette River	10	<.007	<.007	<.007	<.007	.028	.075	.080
Multnomah Channel	4	<.007	--	--	<.007	--	--	.012
Sandy River	3	<.007	--	--	<.007	--	--	<.007
Lewis River	4	<.007	--	--	<.007	--	--	<.007
Kalama River	4	<.007	--	--	<.007	--	--	<.007
Cowlitz River	4	<.007	--	--	<.007	--	--	<.007
All sites	45	<.007	<.007	<.007	<.007	<.007	0.014	.080
Triallate								
Warrendale	4	<.001	--	--	<.001	--	--	<.001
Hayden Island	4	<.001	--	--	<.001	--	--	<.001
Columbia City	4	<.001	--	--	<.001	--	--	<.001
Beaver	4	<.001	--	--	<.001	--	--	<.001
Willamette River	10	<.001	<.001	<.001	<.001	<.001	.008	.008
Multnomah Channel	4	<.001	--	--	<.001	--	--	<.001
Sandy River	3	<.001	--	--	<.001	--	--	<.001
Lewis River	4	<.001	--	--	<.001	--	--	<.001
Kalama River	4	<.001	--	--	<.001	--	--	<.001
Cowlitz River	4	<.001	--	--	<.001	--	--	<.001
All sites	45	<.001	<.001	<.001	<.001	<.001	<.001	.008

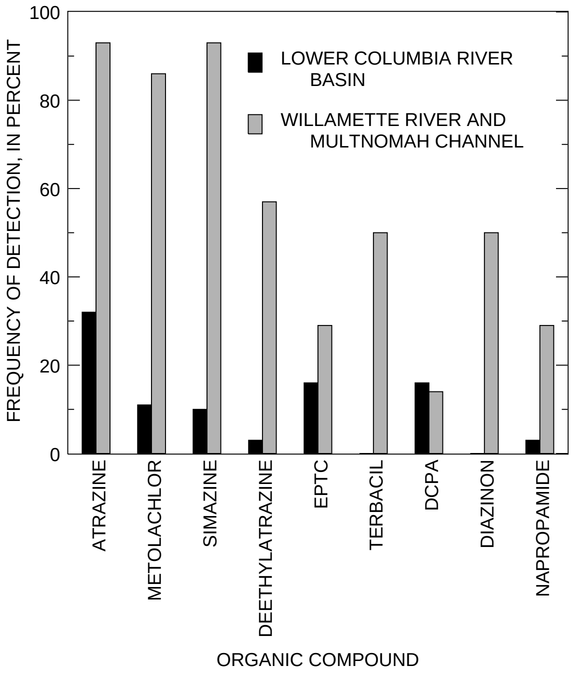

Figure 34. Frequency of detection for selected organic compounds in the lower Columbia River Basin, Oregon and Washington, 1994. (Lower Columbia River Basin = 31 samples and excludes the Willamette River at Portland and Multnomah Channel near mouth; Willamette River Basin = 14 samples and includes the Willamette River at Portland and Multnomah Channel near mouth)

$$Kd = Cs/\ Ce(2)$$

where Cs is the concentration of atrazine sorbed to a specific weight of suspended sediment in nanograms per gram (ng/g) and Ce is the concentration of atrazine dissolved in an equal weight of water in nanograms per milliliter (ng/mL). During the November 3, 1994 sampling in the Willamette River, the foc was 0.03, the concentration of dissolved atrazine was 0.130 ng/mL, and the concentration of suspended sediment was 0.081 g/L. Thus, given a Koc of 160 and a foc of 0.03,

$$Kd\ (mL/g) = 160 \times 0.03 = 4.8\ mL/g$$

When the Kd and the Willamette River's dissolved atrazine concentration are substituted into equation 2,

$$4.8\ mL/g = Ce\ ng/g\ /\ 0.130\ ng/mL$$

$$Ce = 0.63\ ng/g$$

the concentration of atrazine on suspended sediment was equal to 0.63 ng/g. The concentration of suspended sediment in the Willamette River was

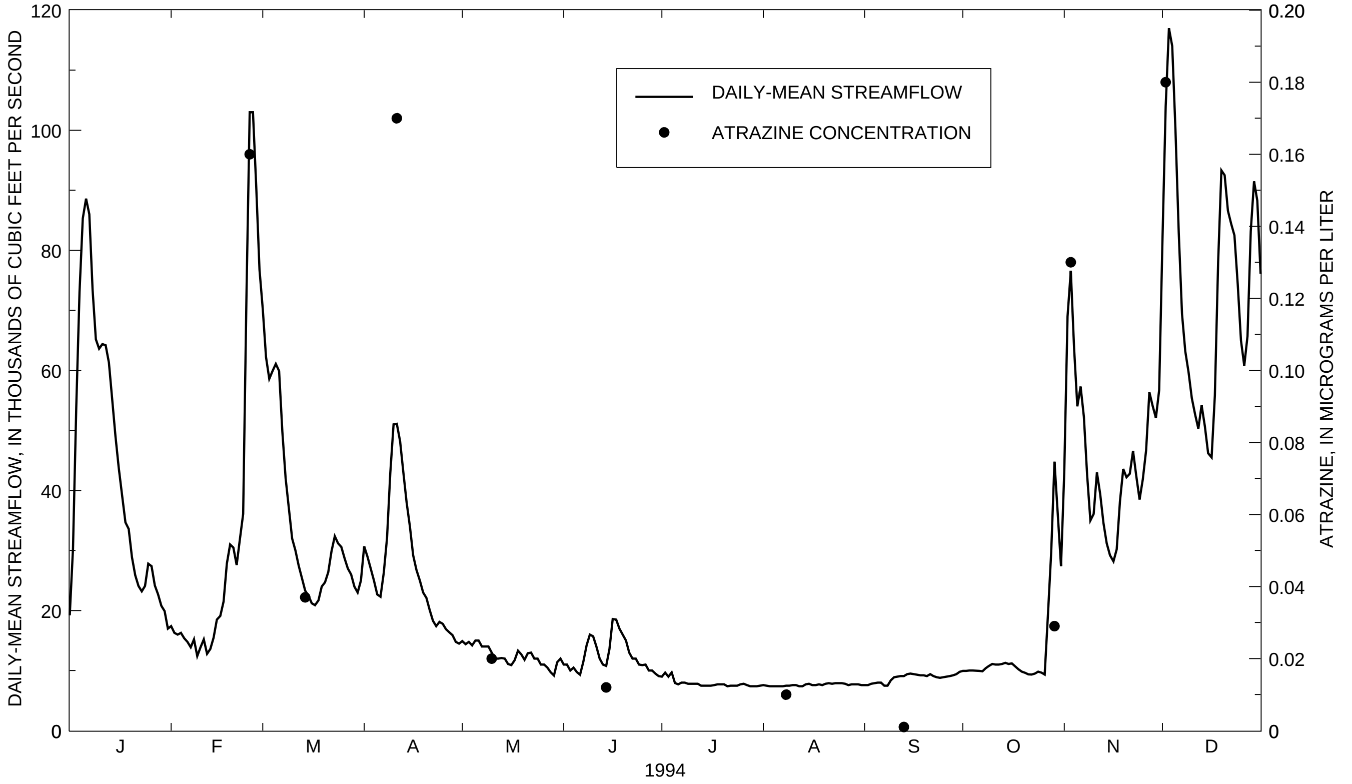

Figure 35. Relation between daily mean streamflow and atrazine concentrations in filtered water in the Willamette River at Portland, lower Columbia River Basin, Oregon, 1994. (The term "filtered water" is an operational definition referring to the chemical analysis of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter.)

0.081 g/L, thus 0.051 ng/L of atrazine was transported on suspended sediment and 0.130ng/mL was transported in the dissolved phase. On the basis of this calculation, only 0.04 percent of the total atrazine was transported in the suspended phase. Using data from the December 2, 1994 sampling in the Willamette River, only 0.05 percent of the total atrazine was transported in the suspended phase.

Although equilibrium calculations clearly demonstrate atrazine's affinity for the dissolved phase, the presence of freshly eroded agricultural soils in waterways may enhance dissolved atrazine concentrations. The work of Squillace and Thurman (1992) suggests that atrazine concentrations in agricultural soils are high (greater than 2 mg/g [micrograms per gram]) following atrazine application in spring, because the organic-carbon content of soil typically ranges from 1 to 5 percent and the soil moisture is less than 20 percent. Under these conditions, 95 percent of the atrazine is sorbed to soils. During intense rainfall, however, atrazine temporarily may be transported on suspended sediment from agricultural fields to waterways. When the suspended-sediment concentration of the sediment-water mixture from the agricultural field decreases to less than 50 g/L, atrazine desorbs (50 percent sorbed) to the filtered form (Squillace and Thurman, 1992).

Concentrations of atrazine in the Willamette River from November to December were as large as 0.180 mg/L and affected atrazine concentrations in the main stem and Multnomah Channel (fig. 36). The effect on the lower Columbia River Basin of the high atrazine concentrations from the Willamette River was seen in the Multnomah Channel (0.16 mg/L) and Columbia River near Columbia City (0.02 mg/L). An identical, but attenuated, atrazine pattern exists from August to September, a period of low streamflow in the Willamette River and Columbia River (fig. 36). During August and September, atrazine was also measurable in the Columbia River at Beaver Army Terminal. Seasonal variations in simazine and metolachlor concentrations in the Willamette River and Columbia City closely mirror those of atrazine.

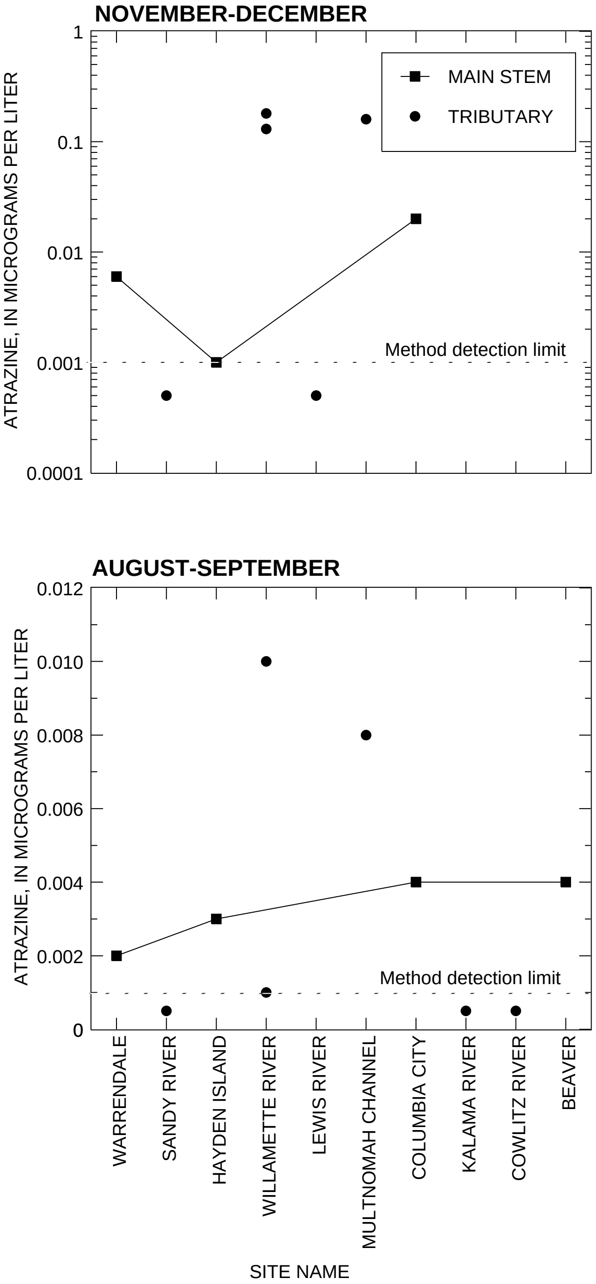

Figure 36. Atrazine concentrations in filtered water from November to December and from August to September, lower Columbia River Basin, Oregon and Washington, 1994

The significance of the Willamette River as a source of atrazine to the lower Columbia River is evident during periods of high streamflow in the Willamette River Basin. Between November 3rd and 9th, 1994, atrazine was measured from filtered-water samples in the Columbia River at Warrendale (estimated 6 ng/L [nanograms per liter]), Willamette River at Portland (130 ng/L), and Columbia River near Columbia City (20 ng/L). The average daily mean streamflow in the Willamette River for this7-day period (47,000 ft3/s) is high. On the basis of streamflow data for the period 1972–87 (Moffatt and others, 1990, p. 292), a streamflow of 47,000 ft3/s was equaled or exceeded only about 27 percent of the time. During the 7-day period of sampling, the atrazine load in the Willamette River (54 lbs/d) was nearly 14 times that at Warrendale (3.9 lbs/d), while the streamflow in the Willamette River (although large for the Willamette River) was less than one-half the average daily mean streamflow for thesame 7-day period at Warrendale (115,000 ft3/s). The significance of the Willamette River atrazine load was further confirmed downstream in the Columbia River near Columbia City where an instantaneous atrazine load of 25 lbs/d was measured on November 9. The smaller atrazine load at Columbia City is probably a result of decreasing Willamette River streamflows, which decreased from 76,600 ft^3/s on November 3 (the day the Willamette River was sampled) to only 43,000 ft^3/s on November 9 (the day Columbia City was sampled). Unquestionably, the Willamette River is the single largest source of atrazine to the lower Columbia River.

Fecal-Indicator 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, enterococcal, and fecal-streptococcal bacteria are indicators of fecal contamination in water. These bacteria are found in the gut of warm-blooded animals, but also may be associated with soils, vegetation, and insects. Thus, the occurrence of any of these bacteria does not conclusively indicate the presence of fecal contamination. Unless the source of the indicator bacteria has been determined by species identification to be nonfecal, the presence of an indicator bacterium indicates a potential health hazard.

Washington and Oregon standards for fecal-indicator bacteria are based on EPA criteria (U.S. Environmental Protection Agency, 1976, 1986b). Currently (1994), the Columbia River is categorized as a class A stream by the WDOE (State of Washington, 1992), where fecal-coliform concentrations shall not exceed a geometric-mean concentration (based on at least five samples per month) of 100 colonies per 100 mL of water, with not more than 10 percent of the samples exceeding 200 colonies per 100 mL. ODEQ’s standard for indicator bacteria states that fecal-coliform concentrations should not exceed a log-mean concentration of 200 colonies per 100 mL, with less than 10 percent of the samples exceeding 400 colonies per 100 mL (State of Oregon, 1994). Neither WDOE nor ODEQ had an enterococci standard in 1994. In 1992, Oregon had a geometric-mean enterococci standard of 31 colonies per 100 mL, with less than 61 colonies per 100 mL for 10 percent of the samples. Because the geometric- and log-mean values are used with at least five samples collected within 30 days, and because the current (1994) data set consists of monthly samples, the standard for Washington and Oregon of 200 and 400 fecal-coliform colonies, respectively, per 100 mL will apply. To aid in the screening of the data in this report, fresh waters regulated by Oregon with a concentration of 31 or more enterococci colonies per 100 mL or 200 or more fecal-coliform or fecal-streptococci colonies per 100 mL will be considered to be concentrations of concern (table 37). Fresh waters regulated by Washington with a concentration of 100 or more colonies of fecal-coliform or fecal-streptococci colonies per 100 mL will also be considered of concern. Multiple-indicator bacterial tests have been used because of the high variability (lack of precision) within any one test. When different indicator tests have similar results, users of the data have greater assurance that the magnitude of observed concentrations are real and reproducible.

Table 37. Indicator-bacteria standards and concentrations of concern for Oregon and Washington streams, lower Columbia River Basin, 1994

[Standards are the geometric or log mean of at least 5 samples collected within 1 month with not more than 10 percent of the samples exceeding two times the mean; since the data set for the lower Columbia River Basin includes only 1 sample per month, the higher values are used as the standard; values are reported in colonies per 100 milliliters of water; -- indicates not applicable]

	Standard	Concern		
State	Fecal coliform	Fecal coliform	Enterococci	Fecal streptococci
Oregon [a]	400	200	31 [b]	200
Washington [c]	200	100	--	100

[a] State of Oregon, 1994.

[b] Federal standard is 33 per 100 milliliters, U.S. Environmental Protection Agency, 1986b.

[c] State of Washington, 1992.

For more detail, see the “Quality Assurance” section at the end of this report.

Table 38 presents a statistical summary of the indicator-bacteria data collected for each site during the 1994 sampling period. Only one sample, from more than 200 indicator-bacteria tests, exceeded the Washington State standard; the Oregon State standard was not exceeded. This single exceedance, which was from the Cowlitz River, is consistent with the results of an indicator-bacteria study performed by the WDOE in 1992 of recreational areas in the Columbia River (Washington Department of Ecology, 1993). In the WDOE study, fecal-coliform concentrations in samples from near the mouth of the Cowlitz River and near the mouth of the Willamette River also were found to exceed the State standards. Table 38 also shows that there were several sites and times when indicator-bacteria concentrations were at the level of concern. This is particularly true of the Willamette River at Portland and Columbia River at Beaver Army Terminal sites, at which there were concentrations of concern in more than one fecal-indicator test. However, for most of the time and for most of the other sites there were no concentrations of concern.

Analysis of the indicator-bacteria data for seasonal variability showed that many of the samples deemed “concentrations of concern” were collected in September, with higher concentrations also occurring in the months of January, April, October, November, and December. It is possible that fall and winter storms were responsible for the higher concentrations during these months. However, a plot of streamflow versus bacteria count in the Columbia River did not reveal a significant relation. Very few high concentrations were observed during the months of June, July, and August. It is a positive sign, relative to human-health concerns, that during periods of high water-contact recreational activities, high bacteria counts were not observed.

To determine whether the patterns of indicator bacteria observed in 1994 were similar to concentrations over a longer time period, 1976–94 fecal-coliform data were analyzed from the USGS NASQAN sites at the Columbia River at Warrendale and Willamette River at Portland (fig. 37). The Columbia River at Warrendale has consistently had low concentrations of fecal-coliform bacteria with no significant seasonal

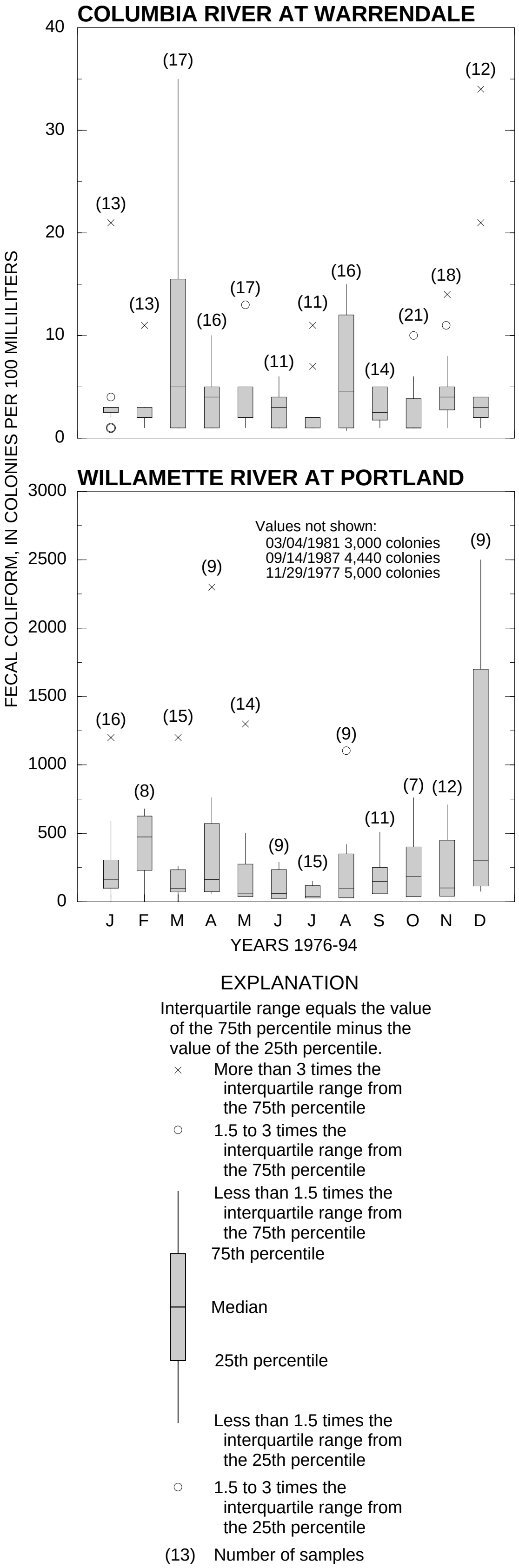

Figure 37. Distribution of fecal-coliform bacteria concentrations in the Columbia River at Warrendale and Willamette River at Portland, Oregon, 1976-94.

Table 38. Distribution of fecal-indicator bacteria concentrations, lower Columbia River Basin, 1994

[To avoid statistical bias that may be associated with constituents analyzed more than once at a site, only one concentration per month was statistically summarized; values are reported in colonies per 100 milliliters of water; see table 7 for full site names; USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; WDOE, Washington Department of Ecology; -- indicates fewer than 5 samples were collected, therefore the percentile was not calculated; a bold number indicates a concentration of concern; a bold number and shaded cell indicates a value that exceeds State standards; see table 37 for quantification of concentrations of concern and standards]

Site name	Agency	Number of samples	Minimum value	Value at indicated percentile			Maximum value
				25	50	75	
Fecal coliform							
Warrendale	USGS	11	1	1	2	3	5
Hayden Island	USGS	12	3	5	8	17	100
Columbia City	USGS	11	2	6	20	24	26
Beaver Army Terminal	USGS	11	3	5	11	32	**110**
Sandy River	ODEQ	10	2	4	8	33	130
Willamette River	USGS	11	1	13	80	130	140
Willamette River	ODEQ	8	4	11	19	106	170
Multnomah Channel	USGS	11	9	16	24	62	160
Lewis River	USGS	4	4	--	6	--	8
Lewis River	WDOE	10	2	5	11	29	100
Kalama River	USGS	4	12	--	21	--	30
Kalama River	WDOE	10	2	5	12	52	71
Cowlitz River	USGS	4	7	--	10	--	16
Cowlitz River	WDOE	10	4	11	22	55	**21,000**
Enterococci							
Warrendale	USGS	10	1	1	1	3	25
Hayden Island	USGS	12	<1	1	4	6	9
Columbia City	USGS	11	1	2	4	7	10
Beaver Army Terminal	USGS	11	1	3	4	25	**150**
Sandy River	USGS	4	4	--	6	--	**33**
Sandy River	ODEQ	10	5	5	5	22	**50**
Willamette River	USGS	12	6	16	26	71	**520**
Willamette River	ODEQ	8	5	5	10	14	**80**
Multnomah Channel	USGS	11	1	6	11	15	**42**
Lewis River	USGS	4	1	--	2	--	5
Kalama River	USGS	4	1	--	6	--	40
Cowlitz River	USGS	4	1	--	4	--	57
Fecal streptococci							
Warrendale	USGS	6	1	1	1	3	5
Beaver Army Terminal	USGS	6	2	7	34	**140**	**440**
Willamette River	USGS	9	14	17	42	130	**1,100**

variability. The Willamette River at Portland, however, had much higher, more variable concentrations, especially during fall and winter months, when storms are numerous. The likely explanation for the differences between these two sites is that the Columbia River site is not immediately below an urban area, whereas the Willamette River at Portland receives combined storm- and sanitary-sewer runoff during storms.

Radionuclides

Radionuclides in the lower Columbia River Basin were monitored by the Oregon Health Division from 1961 to 1993 (Oregon Health Division, Radiation Protection Services, 1994a, 1994b). No measured constituents exceeded any domestic or international standards during that period. However, concern about radionuclides does exist due to the Trojan nuclear power plant near Goble, Oregon, the Hanford Nuclear Reservation in eastern Washington, and fallout from nuclear testing and accidents worldwide.

Radionuclide activity in the Lower Columbia River, as measured at the Columbia River at Goble, Oregon (river mile 74), has declined dramatically since monitoring began there in 1962 (Oregon Health Division, 1994a, 1994b). Gross beta activity in surface waters at the Goble site has fallen from a maximum of 310 pCi/L (picocuries per liter) during the 1962 to 1967 period to a maximum of 4 pCi/L during the 1984 to 1993 period. In contrast, gross alpha activities in surface waters at the Goble site have remained constant, with a maximum of less than 2 pCi/L for 1968–72 and 2 pCi/L for 1984–93. No data are available for gross alpha at the Goble site for 1962–72.

Additionally, data indicate that radionuclide activities either declined or remained stable for streambed sediments and aquatic flora in the lower Columbia River. For example, Zn-65 activity in streambed sediments and *Cladophora* (an alga) declined from measured maximum activities of 100 and 340 pCi/gram, respectively, during 1962–67 to less than 0.1 and less than 0.2 pCi/gram, respectively, for 1978–83 (Oregon Health Division, 1994a, 1994b). Monitoring for Zn-65 activity in the lower Columbia River stopped in 1983. Those radionuclides measured during 1989–93 at Goble—K-40, Ra-226, Cs-137, Be-7, Th-232—generally had low maximum activities in streambed sediments and *Cladophora*. In streambed sediments, measured maximum activities were 17.0, 0.8, 0.2, < 1.0, and 0.8 pCi/gram, respectively. Similarly, in cladophora, measured maximum activities were 5.7, < 0.2, < 0.1, and 1.1 pCi/gram, respectively—Th-232 was not measured in *Cladophora*. Activities for K-40 were higher than other measured radionuclides, probably because it is naturally occurring. All measured activities were below standards established by international and domestic agencies for the Columbia River (Oregon Health Division, 1994a, 1994b).

QUALITY ASSURANCE

Quality-assurance data have been used, to the degree possible, in the Bi-State monitoring program to quantify accuracy, precision, presence of laboratory contamination, and analytical bias. Analytical bias is important to the Bi-State program because water-quality data were collected and analyzed by multiple agencies (ODEQ, WDOE, and USGS) and laboratories. Statistics generated from the quality-assurance data were used in the interpretation of Bi-State data and should be consulted by other users.

Examples of Quality-Assurance Data

The quality-assurance program for ambient monitoring involved various types of quality-assurance samples for constituents in filtered and unfiltered water and in suspended sediment. The types of quality assurance are as follows:

(A) SOURCE SOLUTION BLANK—Contaminant-free water (for example, distilled or deionized water) was shipped to the laboratory disguised as a routine sample. The source solution blank is a measure of contamination from sources other than sample collection and processing. For example, contaminants present in the atmosphere, on the interior of sample bottles, in preservatives, in the laboratory environment, and so on.

(B) FIELD EQUIPMENT BLANK—A volume of contaminant-free water is passed through all sampling and processing equipment that an ambient water sample would contact (for example, the sampler, sample splitter, pump, tubing, filter, filter holder, and sample bottle). The blank sample is then preserved and analyzed with the batch of actual samples. Field equipment blanks are used to show that (1) the equipment-cleaning protocol adequately removes contamination introduced from previous sampling, (2) the sampling and processing protocol does not result in contamination, and (3), the handling and transport of sampling equipment and supplies between sample collections do not introduce contamination.

(C) SPLIT SAMPLES—Large sample volumes of ambient water are divided into two or more equal volumes and sent to one or more laboratories. Split samples provide an estimate of precision within and between labs. These comparisons are especially important when multiple laboratories are used in a study. In the current study, samples were split using a 10-L churn splitter.

(D) STANDARD REFERENCE SAMPLES—Samples of a known chemical concentration (analyzed multiple times to determine a most probable value [median]and an F-pseudosigma value[7]) were disguised as routine samples and shipped to the laboratory. Reference samples do not come in contact with sampling or processing equipment. Results from standard reference samples are used to assess analytical accuracy.

(E) FIELD MATRIX SPIKES—A spike solution of known concentration is added to a split of ambient sample water and is processed and analyzed according to standard protocols. Samples may be sent to one lab or several laboratories. Field matrix spikes are used to assess analytical precision and recoveries of analytes from matrices of ambient water samples. Multiple split samples that have been spiked can be used to measure precision.

(F) SURROGATE SPIKES—Organic compounds that are expected to behave similarly to target analytes are spiked into each sample following filtration (to remove particulate matter) and prior to passing the sample through the solid phase extraction cartridge. Data from surrogate spikes are used to assess target analyte recovery and when aggregated over longer periods of time (months for example), can be used to assess long term analytical precision. Surrogate spike data are published in the USGS's water-data report (U.S. Geological Survey, 1995). Surrogate data should be interpreted with caution, however. Depending on conditions, surrogate recoveries may not be representative of all target analytes.

Use of Quality-Assurance Results to Interpret Environmental Data

The quality-assurance data have been organized and presented below to aid with the interpretation of the environmental data by quantifying accuracy, precision, bias, and contamination. To this end, the data have been organized into the following groups:

1. Field measurements;
2. Major ions;
3. Nutrients;
4. Indicator bacteria, chlorophyll *a*, suspended sediment, suspended solids, and organic carbon;
5. Filtered trace elements;
6. Suspended trace elements; and
7. Filtered organic compounds.

Although the quality-assurance data cover several constituent groups, data within each group were often few in number, which precluded a comprehensive analysis.

Table 39 lists quality-assurance data for field measurements of water temperature, specific conductance, pH, dissolved oxygen, and alkalinity. On the basis of limited quality assurance data, water temperature, specific conductance, and alkalinity values were similar for ODEQ and USGS measurements in the Sandy River. For the current study, water temperature, specific conductance, and alkalinity data were aggregated into a single data set for interpretation. Dissolved oxygen and pH measurements between agencies were not comparable, however. Because the number of quality-assurance samples was small, it is not possible to conclude that differences exist between agencies. Instead, additional joint quality-assurance samples need to be collected. If differences exist between agencies, field sampling protocols should be amended accordingly.

Quality-assurance data for major ions collected by the USGS are listed in table 40. Review of the split, standard-reference, and equipment-blank samples, respectively, show that precision, accuracy,

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[7] F-pseudosigma is equivalent to the standard deviation of traditional statistics when the data conform to a Gaussian distribution. Values greater than or less than the accepted value by 2 x F-pseudosigma, respectively, are considered lower- and upper-warning levels (Long and Farrar, 1995).

Table 39. Quality-assurance data for field measurements, lower Columbia River Basin, Oregon, 1994

[°C, degrees Celsius; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; USGS, U.S. Geological Survey; ODEQ, Oregon Department of Environmental Quality; $CaCO_3$, calcium carbonate]

Site name	Agency	Date	Time	Water temperature, in °C	Specific conductance, in µS/cm	pH, whole water field, in standard units	Dissolved oxygen, in mg/L	Alkalinity, field in mg/L as $CaCO_3$
Sandy River near Troutdale	USGS	08-15-1994	1105	20.0	70	7.9	9.7	21
Sandy River near Troutdale	ODEQ	08-15-1994	1025	19.0	72	7.5	9.0	20

and absence of extraneous contamination were acceptable.

Analyses of a limited number of blind standard reference samples for nutrients show that the USGS laboratory had acceptable accuracy for its nutrient determinations (table 41). The only nutrient species close to a warning level was phosphorus in unfiltered water, for which standard reference samples N-38 and N-40 had concentrations near the lower warning level. For example, the phosphorus concentration for standard reference sample N-38 (0.09 mg/L) was smaller than the most probable value by 0.03 mg/L, which slightly exceeds two times the F-pseudosigma value and is near the lower warning level. Analysis of the USGS depth- and width-integrated sample, split between the USGS and ODEQ laboratories, shows general agreement among nutrient species, and, likewise, no gross differences exist for the grab sample split between the USGS and ODEQ laboratories.

Laboratory precision associated with analyses of bacteria, chlorophyll *a*, and suspended sediment was assessed by splitting a depth- and width-integrated sample between the USGS and ODEQ laboratories (table 42). Indicator bacteria counts for the ODEQ data were somewhat variable and exceeded counts made from the USGS split. These differences indicate the inherent difficulty in making intersite and intrasite comparisons of bacteria data. Although a grab sample for bacteria was collected, in addition to the depth- and width-integrated sample, the data were too variable to assess differences in enumeration between sampling methods. The sample split for chlorophyll *a* had a lower concentration in the USGS split than in the ODEQ split; additionally, the ODEQ comparison for chlorophyll *a* collected by depth- and width-integrated versus grab-sampling techniques shows nearly identical concentrations between sampling methods. The differences in chlorophyll concentrations between laboratories may be indicative of variable precision; however, data are too few to make any definitive conclusion. The samples split between laboratories for comparison of the USGS suspended-sediment determination and the ODEQ suspended-solids determination had a suspended-sediment concentration in the USGS sample (8 mg/L) that was nearly three times higher than in the ODEQ split. Differences between laboratories may be indicative of the bias or discrimination inherent in grab sampling methods relative to obtaining representative quantities of coarse-grained suspended sediment. Ideally, however, tests for differences between sampling methods should be made during periods of high streamflow, when suspended sediment and coarse-grain sized sediment concentrations are high. Conversely, the similarity between the grab sample and the depth- and width-integrated sample, which were both analyzed using the ODEQ suspended-solids method, suggests that differences may exist between the suspended-sediment and suspended-solids method. Last, USGS precision for suspended and filtered-water organic-carbon determinations was acceptable.

Quality-assurance data for filtered-water trace elements for the USGS included one split sample on the Sandy River, one laboratory blank, five equipment blanks, and one blind standard-reference sample (table 43). All quality-assurance samples were sent to the USGS laboratory as "blind samples." There were acceptable levels of precision

Table 40. Quality-assurance data for major ions, lower Columbia River Basin, Oregon, 1994

[All values reported are from filtered-water samples; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; values are reported in milligrams per liter; silica is reported as SiO_2; TDS, total dissolved solids at 180 degrees Celsius; Sandy River, Sandy River near Troutdale, Oregon; <, less than; --, not applicable; SRM, Standard-Reference Material; MPV, Most-Probable Value; F-pseudosigma is equivalent to one standard deviation for a normal data set]

Sample description	Date	Time	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	TDS
Split samples											
Sandy River	07-07-1994	1005	4.1	1.5	3.2	0.40	1.7	4.0	<0.10	17	--
Sandy River	07-07-1994	1010	4.2	1.6	3.3	.50	1.8	4.1	<.10	17	--
Blind standard-reference sample											
SRM M-126	05-16-1994	1043	8.1	1.6	17	2.7	--	--	--	--	--
MPV	--	--	7.62	1.62	17.8	2.62	--	--	--	--	--
F-pseudosigma	--	--	.46	.078	.77	.178	--	--	--	--	--
Equipment-blank sample											
Equipment blank	12-08-1994	1112	<.10	<.10	<.10	<.10	--	--	--	--	<1

Table 41. Quality-assurance data for nutrients, lower Columbia River Basin, Oregon, 1994

[All values reported are from filtered-water samples, unless otherwise stated; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; values are reported in milligrams per liter; N, nitrogen; USGS, U.S. Geological Survey; <, less than; ODEQ, Oregon Department of Environmental Quality; --, not analyzed or not applicable; SRM, Standard-Reference Material; MPV, Most-Probable Value; F-pseudosigma is equivalent to one standard deviation of a normal data set]

Sample description	Date	Time	Ammonia	Ammonia plus organic N	Ammonia plus organic N, unfiltered	Nitrite	Nitrite plus nitrate	Phos-phorus	Phos-phorus, unfiltered	Orthophos-phate
Split samples between agencies										
Sandy River, USGS analysis of USGS integrated sample	08-15-1994	1105	<0.010	<0.20	<0.20	<0.010	0.074	0.020	0.020	0.007
Sandy River, ODEQ analysis of USGS integrated sample	08-15-1994	1020	--	--	--	.020	<.20	.020	.020	.006
Sandy River, USGS analysis of ODEQ grab sample	08-15-1994	1024	<.010	<.20	<.20	<.010	<.050	.010	.010	.010
Sandy River, ODEQ analysis of ODEQ grab sample	08-15-1994	1025	.040	--	<.20	--	.030	--	.030	.007
Blind standard-reference samples										
USGS analysis of SRM N-38	08-15-1994	1110	.070	<.20	<.20	.060	.200	.100	.090	.116
MPV for N-38	--	--	.087	--	.20	--	.210	--	.120	.120
F-pseudosigma for N-38	--	--	.017	--	.158	--	.018	--	.0126	.0141
USGS analysis of SRM N-40	08-31-1994	1047	<.010	<.20	.20	.030	.120	.050	.040	.051
MPV for N-40	--	--	.024	--	.118	--	.110	--	.060	.052
F-pseudosigma for N-40	--	--	.027	--	.098	--	.012	--	.010	.005
USGS split samples										
Sandy River	07-07-1994	1005	.010	<.20	< .20	<.010	<.050	<.010	<.010	.003
Sandy River	07-07-1994	1010	.010	<.20	<.20	<.010	<.050	<.010	.010	.004

Table 42. Quality-assurance data for fecal-indicator bacteria, chlorophyll *a*, suspended sediment, suspended solids, and organic carbon, lower Columbia River Basin, Oregon, 1994

[cols/100mL, colonies per 100 milliliters of water; mg/L, milligrams per liter; the term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; Sandy River, Sandy River near Troutdale, Oregon; USGS, U.S. Geological Survey; K, nonideal bacteria count; --, not analyzed or not applicable; ODEQ, Oregon Department of Environmental Quality]

Sample description	Date	Time	Fecal coliform, in cols/ 100mL	Enterococci, in cols/ 100mL	Chlorophyll *a*, in mg/L	Suspended sediment, in mg/L	Suspended solids, in mg/L	Filtered organic carbon, in mg/L	Suspended organic carbon, in mg/L
Split samples between agencies									
Sandy River, USGS analysis of USGS integrated sample	08-15-1994	1105	K 4	K 4	1.0	8	--	--	--
Sandy River, ODEQ analysis of USGS integrated sample	08-15-1994	1020	11	45	3.0	--	3	--	--
Sandy River, ODEQ analysis of ODEQ grab sample	08-15-1994	1025	17	10	3.2	--	3	--	--
USGS split samples									
Sandy River	07-07-1994	1005	--	--	--	--	--	0.9	0.3
Sandy River	07-07-1994	1010	--	--	--	--	--	.8	.3

Table 43. Quality-assurance data for filtered-water trace elements, lower Columbia River Basin, Oregon, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; values are reported in micrograms per liter; Sandy River, Sandy River near Troutdale, Oregon; <, less than; --, not analyzed or not applicable; SRM, Standard-Reference Material; MPV, Most-Probable Value; F-pseudosigma is equivalent to one standard deviation for a normal data set]

Sample description	Date	Time	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese
Split samples												
Sandy River	07-07-1994	1005	<1	2	<1	<1	<1	<1	<1	44	<1	3
Sandy River	07-07-1994	1010	<1	2	<1	<1	<1	<1	<1	43	<1	3
Blank samples												
Laboratory blank	01-20-1994	1130	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Equipment blank	02-16-1994	0927	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Equipment blank	04-20-1994	1021	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Equipment blank	05-11-1994	0947	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Equipment blank	06-29-1994	1033	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Equipment blank	08-10-1994	1027	<1	<1	<1	<1	<1	<1	<1	--	<1	<1
Blind standard-reference sample												
SRM T-125	05-16-1994	1048	10	17	16	7	4	9	17	--	8	16
MPV	--	--	10.2	16.9	15.0	7.2	3.99	9.45	17.4	--	8.11	18.0
F-pseudosigma	--	--	1.54	1.67	1.19	.75	.71	.78	2.08	--	1.22	1.22

Table 43. Quality-assurance data for filtered-water trace elements, lower Columbia River Basin, Oregon, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; values are reported in micrograms per liter; Sandy River, Sandy River near Troutdale, Oregon; <, less than; --, not analyzed or not applicable; SRM, Standard-Reference Material; MPV, Most-Probable Value; F-pseudosigma is equivalent to one standard deviation for a normal data set

Sample description	Date	Time	Molybdenum	Nickel	Silver	Zinc	Antimony	Aluminum	Selenium	Uranium	Mercury
Split samples											
Sandy River	07-07-1994	1005	<1	<1	<1	2	<1	10	<1	<1	<0.1
Sandy River,	07-07-1994	1010	<1	<1	<1	<1	<1	10	<1	<1	<.1
Blank samples											
Laboratory blank	01-20-1994	1130	<1	<1	<1	<1	<1	<1	<1	<1	--
Equipment blank	02-16-1994	0927	<1	<1	<1	<1	<1	3	<1	<1	--
Equipment blank	04-20-1994	1021	<1	<1	<1	<1	<1	2	<1	<1	--
Equipment blank	05-11-1994	0947	<1	<1	<1	<1	<1	<1	<1	<1	--
Equipment blank	06-29-1994	1033	<1	<1	<1	1	<1	<1	<1	<1	<.1
Equipment blank	08-10-1994	1027	<1	1	<1	8	<1	<1	<1	<1	<.1
Blind standard-reference sample											
SRM T-125	05-16-1994	1048	19	10	4	4	6	20	9	--	--
MPV	--	--	20.1	11.2	3.83	5.95	6.24	24	9.78	--	--
F-pseudosigma	--	--	1.78	1.04	.60	4.01	1.30	8.56	1.85	--	--

and accuracy for all constituents—trace elements were within two times the F-pseudosigma value. Equipment blanks were generally acceptable; however, small amounts of aluminum and nickel were detected infrequently. A higher single occurrence for zinc (8 µg/L) was measured on August 8, 1994, and may be indicative of contamination during sample processing and (or) analysis. The sample was rerun and the high zinc confirmed. Ambient waters analyzed during the month of August, however, had a maximum zinc concentration of only 2 µg/L. Consequently, the source of the anomalous zinc concentration is unclear. The anomaly is of little significance to the interpretation of current (1994) ambient zinc data owing to the absence of high zinc concentrations in ambient waters sampled during August 1994. High zinc values for ambient waters might have suggested a more pervasive zinc contamination problem. Overall, the infrequent occurrence of contamination in USGS blanks suggests that the parts-per-billion protocol (Horowitz and others, 1994) currently being used by the USGS is working well.

Quality-assurance data for suspended trace elements included a blind standard-reference sample and two split samples from the Willamette River at Portland (table 44). Comparison of the USGS results with the most-probable value given by Govindaraju (1994) showed accuracy to be within 25 percent, except for titanium, arsenic, molybdenum, selenium, yttrium, and ytterbium. The precision was also shown to be within 25 percent, except for arsenic, cadmium, copper, molybdenum, and thallium. Except for the constituents listed above, the results show precision and accuracy to be good for making comparisons between sites and times. Contamination is generally not expected to be a problem with suspended trace elements, because concentrations are measured in parts per million (µg/g).

A specific quality-assurance program was designed to assess accuracy, precision, and contamination associated with field collection and laboratory analysis of organic compounds. Accuracy was assessed by using field matrix spikes. Precision was assessed by using ambient river-water splits and field matrix spikes. Contamination was assessed by using organic-free water for field-equipment blanks. All four field-equipment blank samples were less than the method detection limit for all analytes. Laboratory surrogate recovery results are published with the corresponding analytical data in the U.S. Geological Survey Water Resources Data Reports for Oregon for the 1994 WY (U.S. Geological Survey, 1995). Laboratory surrogate recoveries provide an indication of the recovery of the target organic compounds.

Statistical summaries for field matrix spike recoveries show that median recoveries ranged from as low as 20 percent for cis-Permethrin to as high as 130 percent for methyl parathion and terbufos (table 45). Calculations for the seven field matrix spikes were made by subtracting the environmental or ambient organic compound concentration (background) from the spiked environmental sample matrix. The theoretical spike concentration was calculated by determining the mass of the organic compound added to the environmental sample and dividing by the volume of the spiked sample. Recovery was subsequently calculated by dividing the background corrected spike concentration by the theoretical spiked concentration, and the minimum, median, and maximum recoveries, in percent, are shown in table 45. When the environmental concentration was less than the method detection limit, its concentration was assumed to be zero for computation purposes. This was the case in about 85 percent of the calculations.

River-water samples were collected and split to make two replicate samples at each of four sites. Replicate results are listed in table 45 as the difference between the analytical-replicate results and the mean of the two values (rounded to the nearest even nanograms per liter). When one of the two concentrations was below the method detection limit, both measured values were reported.

CONSIDERATIONS FOR FUTURE DATA-COLLECTION ACTIVITIES

The goals of the Bi-State ambient-monitoring program were to define existing water-quality conditions, characterize water-quality problems according to magnitude and type, and provide water-quality information to support pollution prevention, abatement, and resource-management programs. Additionally, ambient-monitoring programs can provide data for evaluating compliance, effectiveness of pollution-prevention programs, and

Table 44. Quality-assurance data for suspended trace element samples, lower Columbia River Basin, Oregon, 1994

[All values are reported in micrograms per gram, except aluminum, calcium, iron, magnesium, phosphorus, potassium, sodium, and titanium which are in percent; Willamette River, Willamette River at Portland, Oregon; SRM, Standard-Reference Material; --, not analyzed or not applicable; MPV, Most-Probable Value]

Sample description	Date	Time	Aluminum	Calcium	Iron	Magnesium	Phosphorus	Potassium	Sodium	Titanium	Antimony	Arsenic	Barium
Split samples													
Willamette River	04-11-1994	1000	8.2	1.5	5.8	1.1	0.16	0.96	0.94	0.78	0.60	6.9	470
Willamette River	04-11-1994	1005	8.3	1.5	5.9	1.1	.15	.96	.98	.77	.50	5.8	480
Willamette River	11-03-1994	0956	8.8	1.9	6.1	1.1	.15	.94	1.20	.76	1.10	8.0	500
Willamette River	11-03-1994	1001	8.8	1.9	5.8	1.1	.16	.97	1.2	.76	.90	5.0	480
Blind standard-reference sample													
SRM GSD-4	06-30-1994	1200	8.2	5.5	4.0	.6	.05	1.8	.22	.37	1.8	16	440
MPV	--	--	8.29	5.38	4.13	.63	.048	1.85	.223	.534	1.84	19.7	470

Sample description	Date	Time	Beryllium	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver
Split samples													
Willamette River	04-11-1994	1000	<2.0	0.30	80	66	15	1,500	1.50	1.00	36	0.60	0.70
Willamette River	04-11-1994	1005	<2.0	<2.00	86	68	17	1,500	1.70	.60	37	.49	.30
Willamette River	11-03-1994	0956	3.0	.30	72	62	33	1,900	.11	.90	38	.40	.33
Willamette River	11-03-1994	1001	3.0	.21	74	86	28	1,900	.11	.60	37	.40	.31
Blind standard-reference sample													
SRM GSD-4	06-30-1994	1200	2	<2	87	36	27	830	.05	.50	42	.2	.1
MPV	--	--	2.4	.19	81	37.3	30.4	850	.044	.86	40	.28	.084

Table 44. Quality-assurance data for suspended trace element samples, lower Columbia River Basin, Oregon, 1994—Continued

[All values are reported in micrograms per gram, except aluminum, calcium, iron, magnesium, phosphorus, potassium, sodium, and titanium which are in percent; Willamette River, Willamette River at Portland, Oregon; SRM, Standard-Reference Material; --, not analyzed or not applicable; MPV, Most-Probable Value]

Sample description	Date	Time	Vanadium	Zinc	Bismuth	Cobalt	Europium	Gallium	Holmium	Lanthanum	Neodymium	Niobium	Scandium
Split samples													
Willamette River	04-11-1994	1000	180	130	<20	27	<3.0	20	<7.0	30	28	17	23
Willamette River	04-11-1994	1005	180	130	<20	25	<4.0	20	<8.0	26	27	16	23
Willamette River	11-03-1994	0956	170	120	<20	28	<4.0	14	<8.0	24	23	10	23
Willamette River	11-03-1994	1001	170	140	<20	29	<4.0	17	<8.0	26	24	11	22
Blind standard-reference sample													
SRM GSD-4	06-30-1994	1200	120	100	<20	20	<4	19	<8	35	26	15	15
MPV	--	--	118	101	.64	18	1.3	20.5	1.07	40	32	18	15.4

Sample description	Date	Time	Strontium	Tantalum	Thorium	Tin	Uranium	Yttrium	Ytterbium	Lithium	Cerium	Gold	Thallium
Split samples													
Willamette River	04-11-1994	1000	210	<70	8.0	<8.0	1.9	29	3.0	29	55	<10	0.30
Willamette River	04-11-1994	1005	210	<80	6.7	<10.0	1.8	27	3.0	29	52	<20	.40
Willamette River	11-03-1994	0956	260	<80	5.6	<10.0	2.1	30	3.0	28	46	<20	.39
Willamette River	11-03-1994	1001	250	<80	4.7	<10.0	1.9	28	3.0	28	45	<20	.35
Blind standard-reference sample													
SRM GSD-4	06-30-1994	1200	140	<80	16.6	<10	2.1	17	<2	53	69	<20	1.2
MPV	--	--	142	1.36	14.6	4.0	2.6	26	2.9	51	78	--	1.2

Table 45. Quality-assurance data for organic compounds in filtered water, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; a spike mixture was added to all seven field matrix spike samples to increase river-water compound concentrations by 100 ng/L (nanograms per liter); MDL, method-detection limit; n, number of samples; Min, minimum; Max, maximum; Difference, the difference in concentrations determined for the split sample; Mean, the mean concentration determined for the split sample; see table 9 for Chemical Abstract Services Registry number for each compound; *, both concentrations were found to be below the MDL; #, values were not calculated because one concentration was found to be below and the other above the MDL; no quality-assurance data exist for acetochlor because it was added into the analytical schedule after the project had started]

Compound	MDL, in ng/L	Field matrix spike recoveries, in percent (n, 7)			Split sample concentrations, in ng/L							
					1		2		3		4	
		Min	Median	Max	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean
Alachlor	2	97	120	140	*	*	*	*	*	*	*	*
Atrazine	1	97	110	180	1	12	1	46	*	*	2	2
Azinphos-methyl	1	54	130	250	*	*	*	*	*	*	*	*
Benfluralin	2	62	90	100	*	*	*	*	*	*	*	*
Butylate	2	92	100	120	*	*	2	6	*	*	*	*
Carbaryl	3	93	160	170	*	*	*	*	*	*	*	*
Carbofuran	3	76	130	140	58	56	*	*	*	*	*	*
Chlorpyrifos	4	90	120	130	2	16	*	*	*	*	*	*
Cyanazine	4	86	100	150	*	*	*	*	*	*	*	*
DCPA (Dacthal)	2	99	120	130	#[a]	#	*	*	*	*	*	*
4,4’-DDE	6	66	70	77	*	*	*	*	1	2	*	*
Deethylatrazine	2	30	40	110	6	21	*	*	5	8	*	*
Diazinon	2	80	100	110	1	26	1	6	1	8	*	*
Dieldrin	1	82	100	120	*	*	*	*	1	16	*	*
2,6-Diethylaniline	3	78	90	110	*	*	*	*	*	*	*	*
Disulfoton	17	56	130	230	*	*	*	*	*	*	*	*
EPTC	2	90	108	120	2	19	*	*	*	*	*	*
Ethalfluralin	4	75	100	130	*	*	*	*	*	*	*	*
Ethoprop	3	93	120	140	*	*	*	*	*	*	*	*
Fonofos	3	85	100	120	2	4	*	*	*	*	*	*
alpha-HCH	2	94	120	130	*	*	*	*	*	*	*	*
gamma-HCH (lindane)	4	86	110	130	4	92	*	*	#[b]	#	*	*
Linuron	2	54	90	160	*	*	*	*	*	*	*	*
Malathion	5	90	110	150	*	*	*	*	*	*	*	*
Methyl parathion	6	80	130	140	*	*	*	*	*	*	*	*
Metolachlor	2	100	120	130	10	31	2	72	0	190	0	3

Table 45. Quality-assurance data for organic compounds in filtered water, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.70-micrometer filter; a spike mixture was added to all seven field matrix spike samples to increase river-water compound concentrations by 100 ng/L (nanograms per liter); MDL, method-detection limit; n, number of samples; Min, minimum; Max, maximum; Difference, the difference in concentrations determined for the split sample; Mean, the mean concentration determined for the split sample; see table 9 for Chemical Abstract Services Registry number for each compound; *, both concentrations were found to be below the MDL; #, values were not calculated because one concentration was found to be below and the other above the MDL; no quality-assurance data exist for acetochlor because it was added into the analytical schedule after the project had started]

Compound	MDL, in ng/L	Field matrix spike recoveries, in percent (n, 7)			Split sample concentrations, in ng/L							
					1		2		3		4	
		Min	Median	Max	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean
Metribuzin	4	82	110	130	*	*	*	*	*	*	*	*
Molinate	4	97	103	120	*	*	*	*	*	*	*	*
Napropamide	3	84	101	140	1	10	*	*	2	98	*	*
Parathion	4	85	130	140	*	*	*	*	*	*	*	*
Pebulate	4	93	100	120	*	*	*	*	*	*	*	*
Pendimethalin	4	67	100	120	*	*	*	*	*	*	*	*
cis-Permethrin	5	10	20	20	*	*	*	*	*	*	*	*
Phorate	2	64	90	140	*	*	*	*	*	*	*	*
Prometon	18	100	110	110	*	*	*	*	1	10	*	*
Pronamide	3	87	100	120	*	*	*	*	*	*	*	*
Propachlor	7	86	120	130	*	*	*	*	*	*	*	*
Propanil	4	110	120	130	*	*	*	*	*	*	*	*
Propargite	13	33	110	140	*	*	*	*	*	*	*	*
Simazine	5	50	101	120	0	1,300	*	*	7	82	*	*
Tebuthiuron	10	<10	88	100	*	*	*	*	*	*	*	*
Terbacil	7	76	110	140	*	*	1	20	3	12	*	*
Terbufos	13	77	130	160	*	*	*	*	*	*	*	*
Thiobencarb	2	100	120	130	*	*	*	*	*	*	*	*
Triallate	1	91	100	120	*	*	*	*	*	*	*	*
Trifluralin	2	66	90	110	*	*	*	*	*	*	*	*

[a] For DCPA (Dacthal) split 1, the concentrations determined were <2 and 2 ng/L.

[b] For Lindane split 3, the concentrations determined were <4 and 5 ng/L.

detection of water-quality trends over time. From the water-resource manager's perspective, ambient monitoring can provide quantitative information that can be used to form the basis for water-quality management decisions that will sustain acceptable levels of water quality. Where water-quality concerns exist, however, ambient monitoring can provide information for evaluating management options, initiating corrective actions, and evaluating effectiveness of actions.

Before considering future data-collection activities, it would be beneficial to summarize and present the relevant technical information gathered by the Bi-State committee to water-resource managers. If all basic water-quality data were stored in one database that is accessible at all levels, including Federal, State, local, Tribal, university, and the general public, the data could be compiled and utilized more efficiently. The data contained in the technical-information summary can be used by water-resource managers to identify water-quality problems and issues affecting beneficial uses in the lower Columbia River Basin. Once water-quality problems and issues have been defined, the following conceptual framework will provide a basis for designing and refining water-quality monitoring programs:

- Develop conceptual models of processes causing water-quality problems. Address specifically processes of input, transport and interaction among media (dissolved, suspended, and aquatic biota)
- Verify conceptual models with existing data; where data are inadequate, supplement ongoing data-collection activities.
- Determine the validity of conceptual models using a mass-balance approach. The conceptual model is verified if loads between main-stem sites balance. If loads fail to balance, however, then unaccounted-for loads (sources) remain and, depending on the magnitude of the unaccounted-for load, the conceptual model goes through further iterations until mass balance is achieved.
- Once mass balance is achieved, design monitoring programs addressing constituents of concern. The monitoring programs should provide more quantitative measures to verify conceptual models, which were refined earlier on the basis of existing water-quality data. Ultimately, monitoring programs can be developed that effectively target and provide data necessary to reduce constituent loadings that previously had resulted in water-quality concerns.

In addition to the conceptual framework presented above, immediate consideration should be given to the following:

- Initiate coordinated interagency quality-assurance/quality-control programs designed to evaluate accuracy, precision, bias, and contamination issues for constituents of concern. Additionally, on the basis of interagency comparisons of various field measurements (for example, pH and dissolved oxygen—described in the "Quality Assurance" section), immediate consideration should be given to resolving instrument calibration and (or) measurement techniques that may result in discrepancies between analyzing agencies.
- Supplement the Bi-State database with ancillary data. To increase the utility of the Bi-State database, add ancillary data that are pertinent to water-quality concerns. Ancillary data should include land and water-use information, precipitation quantity and quality, point and nonpoint source water-quality data, and fertilizer and pesticide quantities associated with agricultural activities.
- Continue the collection of monthly suspended sediment data from the Cowlitz River at Kelso. These data and USGS continuous streamflow data from the Cowlitz River at Castle Rock could be used to estimate monthly and annual mean suspended-sediment loads. On the basis of sparse data collected in September 1994, the Cowlitz River accounted for more than 20 percent of the suspended-sediment load in the Columbia River at Beaver Army Terminal. Consequently, better definition of the timing and magnitude of Cowlitz River suspended-sediment loads may provide useful information to water-quality managers as dredging needs are assessed and

the efficiency of sediment-retention structures is evaluated.

- Synoptically sample selected sites in the lower Columbia River Basin during low streamflows in late summer and again, in late fall or early spring, during periods of storm runoff in the Willamette River Basin. Because sampling dates during the current study were sometimes separated by days and weeks, mass-balance calculations were hampered for periods of storm runoff and were semiqualitative during periods of low streamflow.
- Supplement the Bi-State database with ongoing water-quality measurements made by other agencies. For example, measurements made by the U.S. Army Corps of Engineers for total dissolved gas, dissolved oxygen, water temperature, and barometric pressure in the lower main stem, in addition to pertinent data collected by the National Biological Service, U.S. Fish and Wildlife Service, and National Marine Fisheries Service could be incorporated in the database. Water-quality data from the USGS's NASQAN program at the Columbia River near Beaver Army Terminal and Willamette River at Portland should also be included in the Bi-State database.

As part of the USGS's NASQAN sampling network in the lower Columbia River Basin in 1995, water-quality samples will be collected from the Columbia River at Beaver Army Terminal and the Willamette River at Portland. Each site will be sampled monthly, in addition to six event-based samplings. Data collected as part of the NASQAN program will compliment many of the data collected in the current Bi-State monitoring program.

SUMMARY

Historically, water-quality studies in the lower Columbia River have focused on specific river reaches; many of these studies lack the continuity necessary to assess water quality in a river-basin framework. The Bi-State study has addressed this data gap by initiating an ambient-monitoring program that will assess temporal variations in constituent concentrations and loads in 1994. The purpose of this report is to describe the water-quality conditions in the lower Columbia River and major tributaries, by interpreting data collected historically and in 1994.

The Columbia River Basin has a drainage area of 259,000 square miles. Its drainage basin crosses seven northwestern States and one Canadian Province. The lower Columbia River Basin, which is the focus of this study, includes the subbasins draining into the Columbia River below Bonneville Dam, the largest of which is the Willamette River.

The lower Columbia River Basin receives mean annual precipitation ranging from 37 inches at Portland, Oregon, to 113 inches at Cougar, Washington. Streamflows in tributaries of the lower Columbia River are generally highest during the winter, but Columbia River streamflows are highest during the spring snowmelt season. The basin is 74 percent forest land and 17 percent agricultural land. Most of the agricultural land lies in the Willamette River Basin, which accounts for 87 percent of the irrigation withdrawals and 55 percent of the industrial withdrawals in the lower Columbia River Basin. On the basis of National Pollutant Discharge Elimination System permits, 102 municipal and industrial sites discharge into the lower Columbia River and the first 16 river miles of its tributaries. More than one-half of these are sewage-treatment plants, chemical manufacture facilities, or wood products industries.

The U.S. Geological Survey (USGS), Washington Department of Ecology, and Oregon Department of Environmental Quality collected water-quality data at 10 sites in the lower Columbia River Basin from January to December of 1994. Additionally, water-quality data spanning more than 50 years and more than 200 parameters were collated for interpretation in this report. Loads of suspended sediment, total dissolved solids, unfiltered-water phosphorus and filtered-water nitrite plus nitrate and ammonia were calculated by regressing constituent concentrations against streamflow and time. Monotonic-time trends were determined for water temperature, suspended sediment, unfiltered phosphorus, specific conductance, and total dissolved solids. Nutrient, major-ion, trace-element, and organic-compound concentrations were screened against U.S. Environmental Protection Agency (EPA) and State guidelines. Physical and microbiological measurements also were screened against State guidelines.

On the basis of an analysis of historical water-temperature data, percentile distributions of daily mean water temperatures were generally uniform among sites in the main stem of the lower Columbia River. An earlier USGS study notes that the principal water-temperature increases were measured well upstream of the lower Columbia River, in an area between Grand Coulee Dam and McNary Dam. Historical data also show that the temperature gradient is small between the Willamette River and the main stem of the Columbia River. Both historical and current data show that the highest water temperatures in the lower Columbia River Basin are during August. In the Columbia River at Bradwood, 75 percent of the daily mean water temperatures exceeded 20°C, a "special condition" criterion for the State of Washington. In 1994, 15 percent of the instantaneous measurements of water temperature exceeded 20°C in the lower Columbia River. The special condition criterion was exceeded consistently at the four main-stem sites during July and August —a period coinciding with season-high air temperatures and low streamflows.

Dissolved-oxygen concentrations vary in accordance with seasonal changes in water temperature. Aquatic life in the lower Columbia River Basin is not subjected to low dissolved-oxygen concentrations. Only the Sandy River at Troutdale had a dissolved-oxygen concentration below the Oregon State standard of 90 percent of saturation. Although concentrations of dissolved oxygen at the Willamette River and Multnomah Channel sites were lower than at other sites in the basin, they did not fall below the Oregon State standard of 5 mg/L. These decreases in concentration probably resulted from biochemical-oxygen demand. Comparison of dissolved-oxygen concentrations in the Willamette River from before 1958 to after 1972 showed a significant increase in dissolved-oxygen concentrations during the low-streamflow months of summer. Concentrations of dissolved oxygen and total dissolved gas were above saturation levels during high streamflows in the Willamette River and the lower Columbia River. The high concentrations of total dissolved gas in the Columbia River exceeded Oregon and Washington State standards of 110 percent of saturation and were caused by spilling water at the Columbia River dams.

Suspended-sediment and suspended-solid concentrations tend to increase with increased streamflow but were generally very low (less than 15 mg/L) during most of the year. Among sites, the Willamette River generally had higher concentrations. There were no detectable long-term trends in suspended sediment at the Willamette River and Columbia River at Warrendale sites. Suspended-sediment loads at the Beaver Army Terminal site in June and July of 1994 were larger than could be accounted for on the basis of loads measured upstream at the Warrendale and Willamette River sites. The difference in load between sites probably results from suspended sediment that is stored upstream of the Beaver site during low-streamflow conditions on the Columbia River and then resuspended during the high streamflows of the snowmelt season. Load calculations also showed that the Cowlitz River can be a source of sediment during high flows, whereas other tributaries do not appear to be significant sources.

Historical data and data for 1994 indicated that nutrients have relatively low concentrations in the lower Columbia River Basin. Historically, the largest 90th-percentile concentrations of unfiltered-water phosphorus and filtered-water nitrite plus nitrate and ammonia in the basin were in the Willamette River Basin. When 1994 median concentrations were ranked from largest to smallest for unfiltered-water phosphorus and filtered-water orthophosphate and nitrite plus nitrate, sampling sites followed the order:

Willamette River > Multnomah Channel > Columbia River sites downstream of Willamette River > Columbia River sites upstream of Willamette River > smaller tributaries.

Concentrations of unfiltered-water phosphorus in the Willamette River were largest during periods of winter storms from October to February 1994. Trend tests showed a significant ($\rho < 0.05$) downward trend for unfiltered-water phosphorus at the Columbia River at Warrendale from 1973 to 1994. Nutrient loads during 1994 in the Willamette River and Columbia River were comparable to those in the low-streamflow year of 1977, which is consistent with the low precipitation and streamflow in 1994. The Willamette River made a significant contribution to the loading of filtered-water nitrite plus nitrate and unfiltered-water phosphorus in the Columbia River. In May, the Willamette River contributed 25 percent of the measured nitrite-plus-nitrate load to the Columbia River, while contributing only 6 percent of the streamflow. In August, the Willamette River contributed 16 percent of the phosphorus load to the Columbia River, while contributing only 8 percent of the streamflow.

Median concentrations of most major ions in the lower Columbia River Basin in 1994 were similar to mean concentrations measured in river systems worldwide. In comparison to historical data, however, concentrations of major ions measured in 1994 were lower than historical measurements and reflect the limited dilution capacity of the main stem—a result of the low streamflows in 1994. On the basis of instantaneous measurements of specific conductance, median conductance values among main-stem sites were generally constant, ranging from 149 to 153 µS/cm. During the fall months, however, a specific-conductance gradient was measured among main-stem sites, decreasing by 37 µS/cm from Warrendale to Beaver Army Terminal, an effect of the lower specific conductance of water in the Willamette River and seasonally higher streamflows entering the main stem from the Willamette River. The median specific conductance in the Willamette River was 79 µS/cm, nearly one-half that of the main stem. The lower conductance waters of the Willamette River result from lower calcium, magnesium, and bicarbonate concentrations. Major-ion composition along the main stem remained relatively unchanged, with calcium and magnesium as the dominant cations and bicarbonate as the dominant anion.

Median concentrations of trace elements measured in 1994 were similar to background concentrations measured worldwide. The concentrations were also similar to historical concentrations, except for iron, which in 1994 had a median concentration (25 µg/L), about one-half that measured historically. This difference is the result of a disproportionately high number of sites sampled historically in the Willamette River Basin. Arsenic, a human carcinogen, was detected in 15 of 16 samples in the main stem, but was not detected in the tributary sites. All 15 arsenic detections had concentrations that exceeded EPA ambient water-quality criteria for the protection of human health and EPA human-health advisories for drinking water. Chromium was detected in all four main-stem sites, and most frequently, in the Columbia River at Hayden Island. None of the concentrations detected, however, exceeded water-quality criteria or guidelines.

Measurements of suspended trace-element concentrations (trace-element concentrations associated with the suspended-sediment fraction) showed that the suspended form is the dominant transport phase for aluminum, iron, and manganese, whereas the dissolved form is the dominant transport phase for arsenic, barium, chromium, and copper. Because seasonal variations in suspended trace-element concentrations are low, suspended trace-element loads are affected primarily by variations in suspended-sediment concentration. Consequently, winter storm-induced high streamflows have considerably greater loads than low streamflows, which are characteristic of summer and early fall. During periods of low streamflow, the Willamette River and Cowlitz River are the largest contributors of suspended trace-elements in the Basin. During the low-streamflow period, the Willamette River represents 60 percent of the suspended-silver load in the Columbia River at Warrendale, whereas only 10 percent of the streamflow is represented. On the basis of tributary loads during summer low-flow months, sources of suspended silver, nickel, aluminum, and antimony exist in the lower Columbia Basin and the sources of suspended zinc and arsenic exist outside of the lower basin.

Of the 47 organic compounds analyzed for this study, only 20 were detected. The Willamette River at Portland had the largest number of detections, and all 20 were detected at one time or another at that site. None of the organic compounds measured exceeded EPA’s ambient water-quality criteria or drinking-water guidelines. Atrazine, metolachlor, and simazine were the three most frequently detected organic compounds in the lower Columbia River Basin. These pesticides all come from agricultural sources. The largest concentrations of atrazine, metolachlor, and simazine were detected in the Willamette River, where they were detected in 85 to 90 percent of the samples collected. The high concentrations of atrazine in the Willamette River are associated with the spring application period and fall runoff and can be seen to affect atrazine concentrations in the main stem and Multnomah Channel. These seasonal variations are noticeable also with simazine and metolachlor. The Willamette River is unquestionably the single largest source of atrazine to the lower Columbia River.

Fecal-indicator bacteria measurements exceeded the Washington State standard for fecal coliform in one instance, in the Cowlitz River. Additionally, the Washington State standard was exceeded for several different fecal-indicator bacteria and in multiple samples in the Willamette River and Columbia River at Beaver Army Terminal. Other sites sampled generally had low concentrations. A review of historical data also showed consistently low concentrations in the Columbia River at Warrendale, with higher and more variable concentrations in the Willamette River. The source of bacteria in the Willamette River is likely local runoff from the Portland urban area.

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SUPPLEMENTAL DATA SECTION

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994

[Effluent discharge levels are reported in million gallons per day; STP, sewage-treatment plant; --, not applicable; *, value is based on average dry-weather design flow to facility; WTP, water-treatment plant; NA, data is not known or not shown on permit; #1 indicates outfall number; Stormwater, discharge is stormwater, therefore no discharge limits are in effect; avg, average; max, maximum; Industrial, permittee is classified as industrial and, therefore, has limits only on concentrations, not discharge; Misc, miscellaneous; UST, underground storage tank; PAH, polyaromatic hydrocarbons; Ref., references are:

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C = Debra Nesbit, Oregon Department of Environmental Quality, written commun., 1995,
D = Drew Gilken, Oregon Steel Mills, Inc., oral commun., 1995]

Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Astoria STP	A	461214/ 1234621	18	Columbia River	--	Domestic	4	*	
Camas STP	B	453444/ 1222317	121.2	Columbia River	--	Domestic	2.33	monthly average	
Camas WTP	B	453618/ 1222423	118.1	Lacamas Lake	NA	Domestic	.07	monthly average	
Castle Rock STP	B	461602/ 1225415	68	Cowlitz River	NA	Domestic	.4	monthly average	
Cathlamet STP	B	461220/ 1232315	NA	Columbia River	--	Domestic	.2	monthly average	
Cathlamet WTP	B	461313/ 1232110	NA	Columbia River	--	Domestic	.049	monthly average	
Clark Public Utilities District (La Center STP)	B	455137/ 1224007	87	East Fork of Lewis River	NA	Domestic	.125	monthly average	
Clatskanie STP	C	460718/ 1231252	47.8	Clatskanie River	1.1	Domestic	.50	*	
Cowlitz County Hall of Justice	B	460807/ 1225413	68	Cowlitz River	NA	Domestic	.4999	weekly maximum	
Cowlitz Water Pollution Control STP	B	460547/ 1225555	67	Columbia River	--	Domestic	10	*	
Fort Columbia State Park STP	B	461503/ 1235518	8	Columbia River	--	Domestic	.005	monthly average	
Gresham STP	A	453326/ 1222730	117.5	Columbia River	--	Domestic	10	*	
Ilwaco STP	B	461819/ 1240158	3	Columbia River/ Baker Bay	--	Domestic	.45	monthly average	
Ilwaco WTP	B	461853/ 1240211	NA	Black Lake	NA	Domestic	.045	monthly average	

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Effluent discharge levels are reported in million gallons per day; STP, sewage-treatment plant; --, not applicable; *, value is based on average dry-weather design flow to facility; WTP, water-treatment plant; NA, data is not known or not shown on permit; #1 indicates outfall number; Stormwater, discharge is stormwater, therefore no discharge limits are in effect; avg, average; max, maximum; Industrial, permittee is classified as industrial and, therefore, has limits only on concentrations, not discharge; Misc, miscellaneous; UST, underground storage tank; PAH, polyaromatic hydrocarbons; Ref., references are:

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Kalama STP	B	460032/ 1225042	75.5	Columbia River	--	Domestic	0.4	monthly average	
Kellogg Creek STP	C	462625/ 1223828	101.5	Willamette River	18.5	Domestic	10	*	
Longview STP	B	461049/ 1230045	56.4	Coal Creek Slough	NA	Domestic	2.7	monthly average	
Longview WTP	B	460856/ 1225447	68	Cowlitz River	NA	Domestic	.13	monthly average	
North Bonneville STP	B	453749/ 1215811	145	Columbia River	--	Domestic	.1225	monthly average	
Oak Lodge Sanitary District	C	452530/ 1223910	101.5	Willamette River	20.1	Domestic	4	*	
Portland STP (Columbia Boulevard)	C	453726/ 1224132	105.5	Columbia River	--	Domestic	#1:100 #2:100	* *	
Portland Tryon Creek STP	C	452500/ 1223945	101.5	Willamette River	19.0	Domestic	8.3	*	
Rainier STP	A	460537/ 1225642	67	Columbia River	--	Domestic	.5	*	
Ridgefield STP	B	474915/ 1224507	87.5	Lake River	NA	Domestic	.35	monthly average	
Riverwood Mobile Home Park	A	460403/ 1225349	70.6	Columbia River	--	Domestic	.013	*	
St. Helens STP	A	455116/ 1224714	86	Columbia River	--	Domestic	NA	--	halogenated organic compounds
Salmon Creek STP (Clark County)	B	454239/ 1224530	97.2	Columbia River	--	Domestic	3.1	monthly average	
Sauvie Island Moorage Company	C	453852/ 1224926	86.3	Multnomah Channel	19.0	Domestic	.0075	*	

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Effluent discharge levels are reported in million gallons per day; STP, sewage-treatment plant; --, not applicable; *, value is based on average dry-weather design flow to facility; WTP, water-treatment plant; NA, data is not known or not shown on permit; #1 indicates outfall number; Stormwater, discharge is stormwater, therefore no discharge limits are in effect; avg, average; max, maximum; Industrial, permittee is classified as industrial and, therefore, has limits only on concentrations, not discharge; Misc, miscellaneous; UST, underground storage tank; PAH, polyaromatic hydrocarbons; Ref., references are:

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Scappoose STP	C	454449/ 1225019	86.3	Multnomah Channel	10.5	Domestic	2.015	*	
Stella STP	B	461126/ 1230720	56.4	Columbia River	--	Domestic	0.0035	daily maximum	
Three D Corporation	C	460840/ 1234839	12	Youngs River	2.0	Domestic	.62[a]	*	
Troutdale STP	C	453244/ 1222308	120.5	Sandy River	2.3	Domestic	1.6	*	
U.S. Army Corps of Engineers	A	453840/ 1215631	146.1	Columbia River	--	Domestic	.2	*	
Vancouver-East STP	B	453645/ 1223700	110	Columbia River	--	Domestic	4	monthly average	
Vancouver-West STP	B	453810/ 1224145	105	Columbia River	--	Domestic	15.2	monthly average	
Warrenton STP	A	461000/ 1235517	7	Columbia River	--	Domestic	.45	*	
Washougal STP	B	453411/ 1222045	NA	Columbia River	--	Domestic	1.13	monthly average	
Woodbrook STP (Cowlitz County)	B	461249/ 1225050	68	Ostrander Creek	NA	Domestic	.09	monthly average	
Woodland STP	B	455904/ 1224410	87	Lewis River	NA	Domestic	.48	monthly average	
Ash Grove Cement Company	C	453707/ 1224656	101.5	Willamette River	3.0	Chemical	Stormwater	--	
Burlington Environmental	B	453423/ 1222008	123.3	Gibbons Creek	NA	Chemical	.003285 .010103	daily average daily maximum	
Chevron Chemical Company	A	455510/ 1224852	82	Columbia River	--	Chemical	25	daily maximum	

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Cytec Industries	B	460758/ 1225530	NA	Diking Improvement District #1	NA	Chemical	#1:0.082 .12 #2:0.53 1.7	daily average daily maximum daily average daily maximum	organics
E.F. Houghton and Company	B	460704/ 1225615	NA	Drain ditch #3	NA	Chemical	0.01	daily maximum	
Elf Atochem North America, Inc.	C	453415/ 1224430	101.5	Willamette River	7.4	Chemical	37.0	daily maximum	Cr, Cu, Ni, Pb, Zn
GATX Terminals	B	453809/ 1224238	104	Columbia River	--	Chemical	NA	--	total toxic organics
Hoechst-Celanes Corporation (Virginia Chemicals, Inc.)	B	455943/ 1225029	76	Columbia River	--	Chemical	1 1.5	daily average daily maximum	Zn
Kalama Chemical	B	460118/ 1225135	74	Columbia River	--	Chemical	.225	daily maximum	As, Co, Cr, Cu, Ni, Zn, organics
SEH America, Inc.	B	453906/ 1223324	87.6	Burnt Bridge Creek/ Vancouver STP	NA	Chemical	1.2 3.9	daily average daily maximum	total metals, total toxic organics, conductivity
Union Carbide (Washougal)	B	453419/ 1221953	123.3	Gibbons Creek/ Washougal WTP	NA	Chemical	.06 .085	daily averag daily maximum	As, F, total organics
Wacker Siltronic Corporation	C	453436/ 1224510	101.5	Willamette River	6.6	Chemical	.732[b]	daily maximum	Al, As, Cr^{+6}, F, P, Zn, total toxic organics
Allweather Wood Treaters	B	453416/ 1222007	123.3	Gibbons Creek	NA	Wood	NA	--	As, Cr, Cu
Astoria Plywood Company	A	461123/ 1234846	15	Columbia River	--	Wood	as low as practicable	--	Cd, Cr, Cu, Zn, phenols, creosote compounds
Boise Cascade St. Helens Veneer Mill	A	455051/ 1224807	86	Columbia River	--	Wood	.5	daily maximum	Cd, Cr, Cu, Zn, phenols, creosote compounds
Columbia Vista Corporation	B	453510/ 1222805	115.6	Columbia River	--	Wood	permit canceled	--	pentachlorophenol, total metals

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Effluent discharge levels are reported in million gallons per day; STP, sewage-treatment plant; --, not applicable; *, value is based on average dry-weather design flow to facility; WTP, water-treatment plant; NA, data is not known or not shown on permit; #1 indicates outfall number; Stormwater, discharge is stormwater, therefore no discharge limits are in effect; avg, average; max, maximum; Industrial, permittee is classified as industrial and, therefore, has limits only on concentrations, not discharge; Misc, miscellaneous; UST, underground storage tank; PAH, polyaromatic hydrocarbons; Ref., references are:

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Exterior Wood, Inc.	B	453500/ 1222100	123.3	Gibbons Creek	NA	Wood	NA	--	As, Cr, Cu
Fort Vancouver Plywood Company	B	453744/ 1224124	105.2	Columbia River	--	Wood	NA	--	
International Paper Company	B	460615/ 1225700	66.5	Columbia River	--	Wood	0.25	monthly average	
James River Sundial Chip Reloading Facility	A	453356/ 1222547	119	Columbia River	--	Wood	Industrial	--	Cd, Cr, Cu, Zn, phenols, creosote compounds
Linnton Plywood Association	C	453557/ 1224646	101.5	Willamette River	4.8	Wood	NA	--	
Pacific Wood Treating	B	454915/ 1224504	87.5	Lake River	NA	Wood	NA	--	As, Cr, Cu, aromatics, pentachlorophenol
Weyerhauser Company (Wood product)	B	460755/ 1225837	NA	Diking drainage ditch #3	NA	Wood	Industrial	--	Cd, Cr, Cu, Zn, phenols, creosote compounds
Ameron Pipe Products	C	453447/ 1223922	101.5	Willamette River	6.5	Misc	#1: no discharge[c] #2: 0.00005 #3: 0.5 #4: no discharge	-- daily maximum daily maximum --	
Fiberweb North America	B	453351/ 1221919	123.3	Gibbons Creek	NA	Misc	.0735	daily maximum	
Great Western Malting	B	453752/ 1224139	105.1	Columbia River	--	Misc	9.9	daily maximum	temperature
Holnam, Inc. (Ideal Basic Industries)	B	453737/ 1224111	105.5	Columbia River	--	Misc	.004999	daily maximum	
Lone Star Northwest, Inc. (City Center Plant)	C	453012/ 1223952	101.5	Willamette River	13.8	Misc	NA	--	

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Northwest Packing Company	B	453756/ 1224123	105.1	Columbia River	--	Misc	#1: 0.072 .015 #4:0.0115 .072	daily average daily maximum daily average daily maximum	temperature
Oregon Museum of Science and Industry	C	453036/ 1224000	101.5	Willamette River	13.5	Misc	.575	daily maximum	
Oregon Steel Mills, Inc.	D	453745/ 1224705	101.5	Willamette River	1.7	Misc	no discharge[d]	--	
Pendelton Woolen Mills	B	453427/ 1222104	122.8	Columbia River	NA	Misc	1 1.25	daily average daily maximum	total Cr, phenol, sulfide, dieldrin
Port of Portland Terminal 5 (Bulk storage)	C	453742/ 1224707	101.5	Willamette River	1.5	Misc	NA	--	
Astoria Seafood Company	A	461111/ 1235134	12	Columbia River	--	Seafood processing	NA	--	nutrients
Bioproducts, Inc.	A	461010/ 1235451	10.8	Columbia River	--	Seafood processing	.52	monthly average	nutrients
Chinook Packing Company	B	461618/ 1235648	6	Columbia River/ Baker Bay	--	Seafood processing	.7	daily maximum	nutrients
Jessie’s Ilwaco Fish Company, Inc.	B	461827/ 1240214	3	Columbia River/ Baker Bay	--	Seafood processing	.25	daily maximum	nutrients
Ocean Foods of Astoria	A	461051/ 1235134	12	Columbia River	--	Seafood processing	NA	--	nutrients
Pacific Coast Seafood Company	A	461000/ 1235426	11	Columbia River	--	Seafood processing	NA	--	nutrients
Point Adams Packing Company	A	461152/ 1235622	9	Columbia River	--	Seafood processing	NA	--	nutrients
Warrenton Deep Sea, Inc.	A	461024/ 1235443	7	Columbia River	--	Seafood processing	NA	--	nutrients

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Effluent discharge levels are reported in million gallons per day; STP, sewage-treatment plant; --, not applicable; *, value is based on average dry-weather design flow to facility; WTP, water-treatment plant; NA, data is not known or not shown on permit; #1 indicates outfall number; Stormwater, discharge is stormwater, therefore no discharge limits are in effect; avg, average; max, maximum; Industrial, permittee is classified as industrial and, therefore, has limits only on concentrations, not discharge; Misc, miscellaneous; UST, underground storage tank; PAH, polyaromatic hydrocarbons; Ref., references are:

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Boise Cascade--Vancouver	B	453736/ 1224045	106	Columbia River	--	Paper and pulp	Industrial	--	Cu, Ni, Pb, biocides, chlorinated organics
James River--Camas	B	453506/ 1222416	120.1	Columbia River	--	Paper and pulp	Industrial	--	Cu, Ni, Pb, biocides, chlorinated organics
James River II--Wauna Mill	A	460913/ 1232351	42	Columbia River	--	Paper and pulp	Industrial	--	Cu, Ni, Pb, biocides, chlorinated organics
Longview Fibre--Longview	B	460545/ 1225500	67.5	Columbia River	--	Paper and pulp	Industrial	--	Cu, Ni, Pb, biocides, chlorinated organics
Weyerhauser--Longview	B	460750/ 1225927	63.5	Columbia River	--	Paper and pulp	Industrial	--	Cu, Ni, Pb, biocides, chlorinated organics
ALCOA--Vancouver	B	453858/ 1224441	103	Columbia River	--	Aluminum	Industrial	--	phenolics, cyanide, Cr^{+6}, Al, Ni, Sb, Zn, total Cr, benzo(a)pyrene
Reynolds Metal[e]	B	461049/ 1231045	NA	Columbia River	--	Aluminum	NA	--	Fe
Reynolds Metal--Longview	B	460805/ 1230010	63	Columbia River	--	Aluminum	Industrial	--	Cd, Cu, F, Ni, Pb, Sb, Zn, cyanide
Reynolds Metal--Troutdale	A	453324/ 1222356	120	Columbia River	--	Aluminum	Industrial	--	Al, Cr, F, Ni, Sb, Zn, benzo(a)pyrene
Ilwaco Boat Hoist	B	461822/ 1220205	NA	Columbia River	--	Boat yard	.0144	daily maximum	As, Cu, Pb, Zn
Port of Ilwaco Boatyard and Marina	B	461820/ 1240230	NA	Columbia River	--	Boat yard	.0144	daily maximum	As, Cu, Pb, Zn
Port of Portland--Portland Shipyard	C	453400/ 1224314	101.5	Willamette River	6.5	Boat yard	#1:0.110 #2:0.101 #3:0.288	daily max daily max daily max	
Oregon Department of Fish and Wildlife (Prescott)	A	460230/ 1225304	73	Columbia River	--	Fish hatchery	NA	--	antibiotic chemicals

Table 46. Point-source locations and National Pollutant Discharge Elimination System permit levels of effluent discharge, lower Columbia River Basin, Oregon and Washington, 1994—Continued

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Point-source name	Ref.	Latitude/ longitude	Columbia river mile	Receiving water body	Tributary river mile	Source classification	Effluent discharge level	Time unit	Constituents of concern
Oregon Department of Fish and Wildlife (Wahkeena)	A	453434/ 1220756	134	Columbia River	--	Fish hatchery	NA	--	antibiotic chemicals
Vancouver Trout Hatchery	A	453459/ 1223237	113.5	Columbia River	--	Fish hatchery	4.05	daily average	antibiotic chemicals
Canonie Environmental Service Corp. (Gould Superfund site)	C	453432/ 1224451	101.5	Willamette River	7.0	Remediation	.007	daily maximum	Ag, Cr^{+6}, Cu, Hg, Ni, Pb, Zn
Union Oil Company of California--Willbridge Bulk Terminal	C	453420/ 1224408	101.5	Willamette River	5.7	Remediation	.144[f]	daily maximum	benzene, toluene, ethylbenzene, xylenes, total petroleum hydrocarbons
Western Station Corp. UST #606	B	454205/ 1224005	68	Salmon Creek	NA	Remediation	.003 .003	dail y average daily maximum	Pb, benzene
Chevron USA, Inc.--Willbridge Distribution Center	C	453357/ 1224415	101.5	Willamette River	7.9	Tank farm	NA	--	
Koppers Industry, Inc.	C	453438/ 1224532	101.5	Willamette River	6.5	Tank farm	.006[g]	daily maximum	toluene, phenols, metals, anthracene, PAHs, fluoranthene
Beaver Generating Plant	A	461026/ 1231031	54	Columbia River	--	Power generating	1.44	daily maximum	Al, B, Cu, Fe,
Trojan Nuclear Power Plant	A	460226/ 1225256	72.5	Columbia River	--	Power generating	64.3	daily maximum	Al, B, Cu, Fe

[a] Value is from renewal application dated 07/07/1992.

[b] Value is from renewal application dated 11/12/1991.

[c] No discharge unless discharge is greater that the recycler’s capacity of 0.07 mgd.

[d] No discharge unless discharge is greater than the recycler’s capacity. Permit states the limit is 5.76 mgd.

[e] Bicc Cable Corporation doing-business-as Cablec Utility Cable Company.

[f] Permittee has special permit for discharge of treated groundwater from petroleum hydrocarbon remediation system.

[g] Value is from permit expiring 07/31/1991.

Table 47. Summary of trace-element concentrations that exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994

[Only detectable concentrations were evaluated against water-quality guidelines; percentages were calculated using all measurements (censored and detected) for all sites sampled; µg/L, micrograms per liter; see table 7 for full site names; --, criteria do not exist to compare values to]

Site name	Total number of samples	Number of samples that exceed screening values					
		Ambient water-quality criteria				Drinking-water guidelines	
		Aquatic life		Human health			
		Acute	Chronic	Aquatic organisms and water	Aquatic organisms only	Regulation	Human-health advisory
Arsenic:							
Ambient water-quality criteria[a]:							
Aquatic life:							
Acute: 1-hour average 360 µg/L once in three years							
Chronic: 4-day average 190 µg/L once in three years							
Human health:							
Consumption of aquatic organisms and water: 0.18 µg/L							
Consumption of aquatic organisms only: 1.4 µg/L							
Note: Human-health guidelines are based on a slope factor (q_1^*) of 1.75 (milligrams per kilogram per day)$^{-1}$, a bioconcentration factor of 44 liters per kilogram, a lifetime risk of cancer equivalent to 1 in 100,000, a consumption rate of fish of 6.5 grams per day (about one six-ounce fillet per month--the national average), a consumption rate of water of 2 liters per day, a body weight of 70 kilograms (154 pounds), and a life expectancy of 70 years.							
Drinking-water guidelines[b]:							
Regulation: 50.0 µg/L (Maximum Contaminant Level)							
Human-health advisory: 0.2 µg/L Risk-specific dose							
Note: Human-health advisory is based on a slope factor (q_1^*) of 1.75 (milligrams per kilogram per day)$^{-1}$, a lifetime risk of cancer equivalent to 1 in 100,000, a consumption rate of water of 2 liters per day, a body weight of 70 kilograms (154 pounds), and a life expectancy of 70 years.							
Columbia River at Warrendale	4	0	0	4	0	0	4
Columbia River at Hayden Island	4	0	0	4	0	0	4
Multnomah Channel near mouth	4	0	0	1	0	0	1
Columbia River near Columbia City	4	0	0	4	0	0	4
Columbia River at Beaver Army Terminal	4	0	0	3	0	0	3
Percentage of samples that exceed screening values		0	0	38	0	0	38
Iron:							
Ambient water-quality criteria[1]:							
Aquatic life:							
Chronic: 1,000 µg/L							
Human health:							
Consumption of aquatic organisms and water: 300 µg/L							
Willamette River	25	--	0	1	--	--	--
Percentage of samples that exceed screening values		--	0	1	--	--	--

Table 47. Summary of trace-element concentrations that exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[Only detectable concentrations were evaluated against water-quality guidelines; percentages were calculated using all measurements (censored and detected) for all sites sampled; µg/L, micrograms per liter; see table 7 for full site names; --, criteria do not exist to compare values to]

Site name	Total number of samples	Number of samples that exceed screening values					
		Ambient water-quality criteria				Drinking-water guidelines	
		Aquatic life		Human health			
		Acute	Chronic	Aquatic organisms and water	Aquatic organisms only	Regulation	Human-health advisory
Mercury:							
Ambient water-quality criteria[1]:							
Aquatic life:							
Acute: 1-hour average 2.4 µg/L							
Chronic: 4-day average 0.012 µg/L (If exceeded, USEPA recommends that edible portions of fish be tested relative to FDA action levels.)							
Human health:							
Consumption of aquatic organisms and water: 0.14 µg/L							
Consumption of aquatic organisms only: 0.15 µg/L							
Note: Human-health guidelines are based on a reference dose (RfD) of 6 x 10^{-5} milligrams per kilogram per day, a bioconcentration factor of 5,500 liters per kilogram, a consumption rate of fish of 6.5 grams per day (about one six-ounce filet per month--the national average), a consumption rate of water of 2 liters per day, a body weight of 70 kilograms (154 pounds), and a life expectancy of 70 years.							
Drinking-water guidelines[2]:							
Regulation: 2 µg/L (Maximum Contaminant Level)							
Human-health advisory: 0.4 µg/L Lifetime-health advisory (relative-source contribution from drinking water is assumed to be 20 percent)							
Note: Human-health advisory is based on a reference dose (RfD) of 6 x 10^{-5} milligrams per kilogram per day, a consumption rate of water of 2 liters per day, a body weight of 70 kilograms (154 pounds), and a life expectancy of 70 years.							
Willamette River at Portland	5	0	1	1	1	0	1
Multnomah Channel near mouth	4	0	1	0	0	0	0
Columbia River at Beaver Army Terminal	4	1	1	1	1	1	1
Percentage of samples that exceed screening values		2	7	5	5	2	5

[a] U.S. Environmental Protection Agency (1995).

[b] U.S. Environmental Protection Agency (1994).

Table 48. Summary of physical and microbiological measurements that exceed screening values derived from ambient water-quality criteria, lower Columbia River Basin, Oregon and Washington, 1994

Site name	Total number of samples	Number of samples that exceed screening values
Dissolved oxygen: Oregon[a]: Columbia River and tributaries shall exceed 90-percent saturation (except for lower Willamette River and Multnomah Channel, where DO shall not be less than 5 milligrams per liter) Washington[b]: Columbia River shall exceed 90-percent saturation; tributaries shall not be less than 8 milligrams per liter		
Sandy River near Troutdale, Oregon	18	1
Percentage of samples that exceed screening value		6
Fecal coliform bacteria: Oregon[1]: Not to exceed 400 colonies per 100 milliliters of water Washington[2]: Not to exceed 200 colonies per 100 milliliters of water		
Cowlitz River at Kelso, Washington (Washington Department of Ecology sampling)	12	1
Percentage of samples that exceed screening value		8
pH: Oregon[1] and Washington[2]: Not to fall outside the range: 6.5 - 8.5		
Columbia River at river mile 102, downstream of Hayden Island, Oregon	14	2
Columbia River at Beaver Army Terminal near Quincy, Oregon	18	1
Percentage of samples that exceed screening value		9
Temperature: Washington[2]: Columbia River shall not exceed 20 degrees Celsius due to human activities		
Columbia River at Warrendale, Oregon	11	2
Columbia River at river mile 102, downstream of Hayden Island, Oregon	14	2
Columbia River near Columbia City, Oregon	12	2
Columbia River at Beaver Army Terminal near Quincy, Oregon	16	2
Percentage of samples that exceed screening value		15
Total dissolved gas: Oregon[1] and Washington[2]: Columbia River shall not exceed 110-percent saturation		
Columbia River at Warrendale, Oregon	3	1
Columbia River at river mile 102, downstream of Hayden Island, Oregon	3	1
Columbia River near Columbia City, Oregon	2	1
Columbia River at Beaver Army Terminal near Quincy, Oregon	6	1
Percentage of samples that exceed screening value		29

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[a] State of Oregon (1994).

[b] Washington State Administrative Code (1992).

Table 49. Summary of constituent concentrations in filtered water that did not exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.7-micrometer filter for organic compounds and 0.45-micrometer filter for inorganic constituents; for reference purposes, the aquatic-life guidelines listed below are based on a hardness of 50 milligrams per liter as calcium carbonate; the ambient hardness was used to calculate screening values for aquatic life in the evaluation of detected concentrations; screening values are based on a risk level of 10^{-5} where applicable; mg/L, milligrams per liter; MCL, maximum contaminant level; MCLG, maximum contaminant level goal; µg/L, micrograms per liter; RSD, risk-specific dose (carcinogen); see table 9 for Chemical Abstract Services registry numbers for organic compounds]

Constituent	Water-quality screening values	Total number of samples
Nutrients		
Ammonia	Ambient water-quality criterion[a,b]: Aquatic life: pH and temperature dependent	93
Nitrite	Drinking-water guideline[c]: Regulation: 1 mg/L (MCL and MCLG)	93
Nitrite plus nitrate	Drinking-water guideline[3]: Regulation: 10 mg/L (MCL and MCLG)	93
Major ions		
Fluoride	Drinking-water guideline[3]: Regulation: 400 µg/L (under review)	95
Trace elements		
Antimony	Ambient water-quality criteria[1]: Human health: Consumption of aquatic organisms and water: 140 µg/L Consumption of aquatic organisms only: 43,000 µg/L Drinking-water guidelines[1]: Regulation: 6 µg/L (MCL and MCLG) Human-health advisories: Child, long term: 10 µg/L Adult, lifetime: 3 µg/L	42
Barium	Ambient water-quality criterion[1]: Human health: Consumption of aquatic organisms and water: 20,000 µg/L Drinking-water guidelines[3]: Regulation: 2,000 ug/L (MCL) Human-health advisory: Adult, lifetime: 2,000 µg/L	50
Beryllium	Drinking-water guidelines[3]: Regulation: 4 µg/L (MCL and MCLG) Human-health advisory: Child, long term: 4,000 µg/L	42
Cadmium	Ambient water-quality criteria[1]: Aquatic life: Acute: 1.79 µg/L Chronic: 0.66 µg/L Drinking-water guideline[3]: Regulation: 5 µg/L (MCL and MCLG)	42
Chromium	Ambient water-quality criteria[1]: Aquatic life: Acute: 16 µg/L Chronic: 11 µg/L Drinking-water guideline[3]: Regulation: 100 µg/L (MCL and MCLG)	42

Table 49. Summary of constituent concentrations in filtered water that did not exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.7-micrometer filter for organic compounds and 0.45-micrometer filter for inorganic constituents; for reference purposes, the aquatic-life guidelines listed below are based on a hardness of 50 milligrams per liter as calcium carbonate; the ambient hardness was used to calculate screening values for aquatic life in the evaluation of detected concentrations; screening values are based on a risk level of 10^{-5} where applicable; mg/L, milligrams per liter; MCL, maximum contaminant level; MCLG, maximum contaminant level goal; µg/L, micrograms per liter; RSD, risk-specific dose (carcinogen); see table 9 for Chemical Abstract Services registry numbers for organic compounds]

Constituent	Water-quality screening values	Total number of samples
Trace elements–Continued		
Copper	Ambient water-quality criteria[1]: Aquatic life: Acute: 9.22 µg/L Chronic: 6.54 µg/L Human health Consumption of aquatic organisms and water: 1,3000 µg/L Drinking-water guideline[3]: Regulation: 1,300 µg/L (proposed MCL)	42
Lead	Ambient water-quality criteria[1]: Aquatic life: Acute: 33.78 µg/L Chronic: 1.32 µg/L Human health: Consumption of aquatic organisms and water: 50 µg/L	42
Molybdenum	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 10 µg/L Adult, lifetime: 40 µg/L	
Nickel	Ambient water-quality criteria[1]: Aquatic life: Acute: 789 µg/L Chronic: 87.71 µg/L Human health: Consumption of aquatic organisms and water: 610 µg/L Consumption of aquatic organisms only: 4,600 µg/L Drinking-water guidelines[3]: Regulation: 100 µg/L (MCL and MCLG) Human-health advisories: Child, long term: 500 µg/L Adult, lifetime: 100 µg/L	50
Selenium	Ambient water-quality criteria[1]: Aquatic life: Acute: 20 µg/L Chronic: 5 µg/L Drinking-water guideline[3]: Regulation: 50 µg/L (MCL)	50
Silver	Ambient water-quality criterion[1]: Aquatic life: Acute: 1.23 µg/L Drinking-water guidelines[3]: Human-health advisories (draft): Child, long term: 200 µg/L Adult, lifetime: 100 µg/L	50
Uranium	Drinking-water guideline[3]: Regulation (proposed): 20 µg/L (MCL)	43
Zinc	Ambient water-quality criteria[1]: Aquatic life: Acute: 65.04 µg/L Chronic: 58.91 µg/L	42

Table 49. Summary of constituent concentrations in filtered water that did not exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.7-micrometer filter for organic compounds and 0.45-micrometer filter for inorganic constituents; for reference purposes, the aquatic-life guidelines listed below are based on a hardness of 50 milligrams per liter as calcium carbonate; the ambient hardness was used to calculate screening values for aquatic life in the evaluation of detected concentrations; screening values are based on a risk level of 10^{-5} where applicable; mg/L, milligrams per liter; MCL, maximum contaminant level; MCLG, maximum contaminant level goal; µg/L, micrograms per liter; RSD, risk-specific dose (carcinogen); see table 9 for Chemical Abstract Services registry numbers for organic compounds]

Constituent	Water-quality screening values	Total number of samples
Organic compounds		
Alachlor	Drinking-water guidelines[3]: Regulation: 2 µg/L (MCL) Human-health advisory: 4 µg/L RSD	47
Atrazine	Drinking-water guidelines[3]: Regulation: 3 µg/L (MCL) Human-health advisories: Child, long term: 50 µg/L Adult, lifetime: 3 µg/L (under review)	47
Butylate	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 1,000 µg/L Adult, lifetime: 350 µg/L	47
Carbaryl	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 1,000 µg/L Adult, lifetime: 700 µg/L	47
Carbofuran	Drinking-water guidelines[3]: Regulation: 40 µg/L (MCL) Human-health advisories: Child, long term: 50 µg/L Adult, lifetime: 40 µg/L	47
Chlorpyrifos	Ambient water-quality criteria[1]: Aquatic life: Acute: 0.083 µg/L Chronic: 0.041µg/L Drinking-water guidelines[3]: Human-health advisories: Child, long term: 30 µg/L Adult, lifetime: 20 µg/L	47
Cyanazine	Drinking-water guidelines[3]: Regulation: 1 µg/L (tentative MCLG) Human-health advisories (draft): Child, long term: 20 µg/L Adult, lifetime:1 µg/L	47
DCPA	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 5,000 µg/L Adult, lifetime: 4,000 µg/L	47
Diazinon	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 5 µg/L Adult, lifetime: 0.6 µg/L	47
Dieldrin	Ambient water-quality criteria[1]: Aquatic life: Acute: 2.5 µg/L Chronic: 0.0019 µg/L	47

Table 49. Summary of constituent concentrations in filtered water that did not exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.7-micrometer filter for organic compounds and 0.45-micrometer filter for inorganic constituents; for reference purposes, the aquatic-life guidelines listed below are based on a hardness of 50 milligrams per liter as calcium carbonate; the ambient hardness was used to calculate screening values for aquatic life in the evaluation of detected concentrations; screening values are based on a risk level of 10^{-5} where applicable; mg/L, milligrams per liter; MCL, maximum contaminant level; MCLG, maximum contaminant level goal; µg/L, micrograms per liter; RSD, risk-specific dose (carcinogen); see table 9 for Chemical Abstract Services registry numbers for organic compounds]

Constituent	Water-quality screening values	Total number of samples
Organic compounds–Continued		
Dieldrin–Continued	Human health: Consumption of aquatic organisms and water: 0.0014 µg/L Consumption of aquatic organisms only: 0.0014 µg/L Drinking-water guidelines[3]: Human-health advisories: Child, long term: 0.5 µg/L RSD: 0.02 µg/L	
Disulfoton	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 3 µg/L Adult, lifetime: 0.3 µg/L	47
Fonofos	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 20 µg/L Adult, lifetime: 10 µg/L	47
alpha-HCH	Ambient water-quality criteria[1]: Human health: Consumption of aquatic organisms and water: 0.039 µg/L Consumption of aquatic organisms only: 0.13 µg/L	47
gamma-HCH (lindane)	Ambient water-quality criteria[1]: Aquatic life: Acute: 2 µg/L Chronic: 0.08 µg/L Human health: Consumption of aquatic organisms and water: 0.19 µg/L Consumption of aquatic organisms only: 0.63 µg/L Drinking-water guidelines3: Regulation: 0.2 µg/L (MCL and MCLG) Human-health advisories: Child, long term: 30 µg/L Adult, lifetime: 0.2 µg/L	47
Malathion	Ambient water-quality criterion[1]: Aquatic life: Chronic: 0.1 µg/L Drinking-water guidelines[3]: Human-health advisories: Child, long term: 200 µg/L Adult, lifetime: 200 µg/L	47
Methyl parathion	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 30 µg/L Adult, lifetime: 2 µg/L	47
Metolachlor	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 1,000 µg/L Adult, lifetime: 70 µg/L	47

Table 49. Summary of constituent concentrations in filtered water that did not exceed screening values derived from water-quality guidelines, lower Columbia River Basin, Oregon and Washington, 1994—Continued

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.7-micrometer filter for organic compounds and 0.45-micrometer filter for inorganic constituents; for reference purposes, the aquatic-life guidelines listed below are based on a hardness of 50 milligrams per liter as calcium carbonate; the ambient hardness was used to calculate screening values for aquatic life in the evaluation of detected concentrations; screening values are based on a risk level of 10^{-5} where applicable; mg/L, milligrams per liter; MCL, maximum contaminant level; MCLG, maximum contaminant level goal; µg/L, micrograms per liter; RSD, risk-specific dose (carcinogen); see table 9 for Chemical Abstract Services registry numbers for organic compounds]

Constituent	Water-quality screening values	Total number of samples
Organic compounds–Continued		
Metribuzin	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 300 µg/L Adult, lifetime: 200 µg/L	47
Parathion	Ambient water-quality criteria[1]: Aquatic life: Acute: 0.065 µg/L Chronic: 0.013 µg/L	47
Prometon	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 200 µg/L Adult, lifetime: 100 µg/L (under review)	47
Pronamide	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 800 µg/L Adult, lifetime: 50 µg/L	47
Propachlor	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 100 µg/L Adult, lifetime: 90 µg/L	47
Simazine	Drinking-water guidelines[3]: Regulation: 4 µg/L (MCL and MCLG) Human-health advisories: Child, long term: 70 µg/L Adult, lifetime: 4 µg/L	47
Tebuthiuron	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 700 µg/L Adult, lifetime: 500 µg/L	47
Terbacil	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 300 µg/L Adult, lifetime: 90 µg/L	47
Terbufos	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 1 µg/L Adult, lifetime: 0.9 µg/L	47
Trifluralin	Drinking-water guidelines[3]: Human-health advisories: Child, long term: 80 µg/L Adult, lifetime: 5 µg/L RSD: 50 µg/L	47

[a] U.S. Environmental Protection Agency, 1995.

[b] U.S. Environmental Protection Agency, 1976.

[c] U.S. Environmental Protection Agency, 1994b.

Table 50. Summary of trends in selected water-quality constituents, lower Columbia River Basin, Oregon, 1973-1995

[The term “filtered water” is an operational definition referring to the chemical analysis of that portion of a water-suspended sediment sample that passes through a nominal 0.45-micrometer filter; conversely, the term “unfiltered water” refers to the chemical analysis of a water sample that has not been filtered or centrifuged, nor in any way altered from the original matrix; trends are based on a quarterly season; Warrendale, Columbia River at Warrendale, Oregon; Willamette River, Willamette River at Portland, Oregon; *, not enough data for trend test to be performed]

Station number	Station name	Period of record	Number of observations	Non-flow adjusted				Flow adjusted	
				Probability level	Trend, units per year	Trend, percent of median per year	Median, units	Probability level	Trend, percent of median per year
Water temperature (in degrees Celsius)									
14128910	Warrendale	04/23/74-12/20/94	77	0.026	0.073	0.6	11.9	*	*
14211720	Willamette River	10/25/74-01/24/95	79	.000	.140	1.1	12.5	0.004	0.9
Suspended sediment concentration (in milligrams per liter)									
14128910	Warrendale	03/06/73-12/20/94	79	.105	-.143	-1.3	11.0	.731	-.2
14211720	Willamette River	10/25/74-12/02/94	79[a]	.119	-.118	-1.0	11.5	1.000	no trend
Ammonia in filtered water as nitrogen (in milligrams per liter)									
14128910	Warrendale	10/24/79-12/20/94	54	*	*	*	*	*	*
14211720	Willamette River	10/24/79-01/24/95	59	*	*	*	*	*	*
Nitrite plus nitrate in filtered water as nitrogen (in milligrams per liter)									
14128910	Warrendale	09/13/79-12/20/94	65	*	*	*	*	*	*
14211720	Willamette	09/17/79-01/24/95	59	*	*	*	*	*	*
Orthophosphate in filtered water as phosphorus (in milligrams per liter)									
14128910	Warrendale	10/15/81-12/20/94	47	*	*	*	*	*	*
14211720	Willamette River	10/16/81-01/24/95	51	*	*	*	*	*	*
Phosphorus in unfiltered water as phosphorus (in milligrams per liter)									
14128910	Warrendale	03/06/73-12/20/94	80[b]	.001	-.001	-2.8	.04	.015	-2.3
14211720	Willamette River	10/25/74-01/24/95	79	.749	no trend	no trend	.08	.817	.1
Specific conductance (in microsiemens per centimeter at 25 degrees Celsius)									
14128910	Warrendale	03/06/73-12/20/94	81	.019	-.74	-.5	160	.043	-.5
14211720	Willamette River	10/25/74-01/24/95	79	.141	.33	.5	72	.545	.1
Total dissolved solids (in milligrams per liter)									
14128910	Warrendale	03/06/73-12/20/94	80	.001	-.61	-.6	96	.001	-.8
14211720	Willamette River	10/25/74-01/24/95	77	.757	no trend	no trend	55	.926	-.0

[a] The number of observations for the non-flow-adjusted suspended-sediment trend was 112, based on a bimonthly season.

[b] A data anomaly of 0.55 milligrams per liter was removed from analysis.